Examination of pollutants emitted by vehicles in operation and of emission relevant components – In-service conformity

Berichte der
Bundesanstalt für Straßenwesen

Fahrzeugtechnik Heft F 105b

Examination of pollutants emitted by vehicles in operation and of emission relevant components – In-service conformity

by

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Impressum
**Bericht zum Forschungsprojekt FE 86.0066/2009:
Examination of pollutants emitted by vehicles in operation
and of emission relevant components – In-service conformity**

Fachbetreuung
Bernd Bugsel

Herausgeber
Bundesanstalt für Straßenwesen
Brüderstraße 53, D-51427 Bergisch Gladbach
Telefon: (0 22 04) 43 - 0
Telefax: (0 22 04) 43 - 674

Redaktion
Stabsstelle Presse und Öffentlichkeitsarbeit

Druck und Verlag
Fachverlag NW in der
Carl Schünemann Verlag GmbH
Zweite Schlachtpforte 7, D-28195 Bremen
Telefon: (04 21) 3 69 03 - 53
Telefax: (04 21) 3 69 03 - 48
www.schuenemann-verlag.de

ISSN 0943-9307
ISBN 978-3-95606-193-6

Bergisch Gladbach, Juli 2015

**This report is also published in German
(issue number: F105).
It is accessible at the electronic archive ELBA
under http://bast.opus.hbznrw.de**

Abstract – Kurzfassung

Examination of pollutants emitted by vehicles in operation and of emission relevant components – In-service conformity

Mobility plays an important role in the Federal Republic of Germany. Motorised private transport and, consequently, passenger vehicles are the crucial factor. Vehicles should be environmentally and socially compatible yet also economically efficient at the same time.

The crucial factor for pollution of the environment from road traffic is the exhaust emissions of the vehicles on the road. This is why, with the Directive 98/69/EC and the related introduction of exhaust emission standard Euro 3, the testing of the conformity of passenger and light commercial vehicles (in-service conformity check) was introduced. Vehicles already on the roads are to be examined again under type examination conditions (Type I Test) after a statistical selection process. In this way it is to be ensured that the systems and components relevant for the exhaust emissions of a vehicle will also function after several thousand kilometres. This is why the vehicles are checked again during in-service conformity check with respect to their limited pollution components. Due to the ever greater significance of CO_2-emissions, both the CO_2-emissions and the fuel consumption were included in this research project.

For the success of such a project the choice of vehicle is of critical importance. Since this is the only way it is possible to also obtain a representative result. Therefore, in addition to the selection criteria required by law, statistical and technical criteria are also considered. The vehicle owners were selected on a random basis. All test vehicles were checked with respect to their pollutant components in the emissions laboratory in accordance with their standard. By law the same testing conditions apply in an in-service conformity check as in the relevant type approval.

In this research project a total of 17 vehicle types were examined. Six types were equipped with positive-ignition engines and 11 types with compression ignition engines. Both groups were to each include vehicles of the limits Euro 4 and Euro 5. For vehicle types with positive-ignition engines, there was one type with the exhaust emission standard Euro 5. All others satisfied the exhaust emission standard Euro 4. For the vehicle types with compression ignition engines, 4 types satisfied exhaust emission standard Euro 5 and 7 types fulfilled exhaust emission standard Euro 4. Among the vehicle types with compression ignition and exhaust emission standard Euro 4, there were 4 types of category M1 and 3 types of category N1 of class III.

The aim of the research project is to examine the exhaust emissions in-service conformity of passenger and light commercial vehicles in operation to draw conclusions concerning the durability of engine components and systems for exhaust emission treatment.

Overall in this in-service conformity testing programme, we were able, in accordance with the statistical procedure, to assess all 17 of the vehicle types tested as “positive“. With the exception of one vehicle type, it was possible to conclude the random test for all vehicle types tested with the minimum random sample. This means that all 3 vehicles of one type in as-delivered condition complied with or fell below the respective limits for pollutant emissions according to the criteria of the statistical procedure. In the case of one vehicle type, where the random sample had to be enlarged, it was necessary to examine a total of 8 vehicles.

Furthermore, with all vehicle types the CO_2-emissions and fuel consumption (Type I Test) were determined to subsequently compare the measured CO_2-emissions with those of the manufacturers. Of the 17 vehicle types examined, eleven vehicle types complied with the relevant manufacturers’ values or fell below them. With six vehicle types, the CO_2-emissions were more than the permissible 4% above the manufacturer’s value during the Type I Test.

Untersuchung des Abgasverhaltens von in Betrieb befindlichen Fahrzeugen und emissionsrelevanten Bauteilen – Feldüberwachung

Mobilität spielt in der Bundesrepublik Deutschland eine wichtige Rolle. Dabei ist der motorisierte Individualverkehr und somit der Pkw-Verkehr die entscheidende Größe. Der Verkehr soll umweltgerecht, sozialverträglich aber auch gleichzeitig wirtschaftlich effizient sein.

Entscheidend für die Schadstoffbelastung der Umwelt durch den Straßenverkehr sind die Abgasemissionen der im Verkehr befindlichen Fahrzeuge. Daher wurde mit der Richtlinie 98/69/EG und der damit verbundenen Einführung der Abgasstufe Euro 3 erstmalig die Prüfung der Konformität von in Betrieb befindlichen Personenkraftwagen und leichten Nutzfahrzeugen (Feldüberwachung) eingeführt. Dabei sollen bereits im Verkehr befindliche Fahrzeuge nach einer statistischen Auswahl unter Typprüfbedingungen (Typ-I-Test) erneut untersucht werden. So soll gewährleistet werden, dass die abgasrelevanten Systeme und Bauteile eines Fahrzeuges auch noch nach mehreren tausend Kilometern funktionieren. Deshalb werden die Fahrzeuge bei der Feldüberwachung auf ihre limitierten Schadstoffkomponenten ein weiteres Mal überprüft. Aufgrund der immer größeren Bedeutung der CO_2-Emissionen wurden in diesem Forschungsvorhaben sowohl die CO_2-Emissionen als auch der Kraftstoffverbrauch mit erfasst.

Für den Erfolg eines solchen Projektes ist die Fahrzeugauswahl von entscheidender Bedeutung. Denn nur so ist es möglich auch ein repräsentatives Ergebnis zu erhalten. Deshalb wurden neben den gesetzlich vorgeschriebenen Auswahlkriterien auch statistische und technische Kriterien berücksichtigt. Dabei erfolgte die Auswahl der Fahrzeughalter nach dem Zufallsprinzip. Alle Prüffahrzeuge wurden im Abgaslabor, entsprechend ihrer Abgasnorm, auf ihre Schadstoffkomponenten überprüft. Gemäß der Gesetzgebung gelten bei einer Feldüberwachung die gleichen Prüfbedingungen wie bei der jeweiligen Typgenehmigung.

In diesem Forschungsvorhaben wurden insgesamt 17 Fahrzeugtypen untersucht. Wobei 6 Typen mit Fremdzündungsmotor und 11 Typen mit Selbstzündungsmotor ausgestattet waren. Beide Gruppen sollten jeweils Fahrzeuge der Grenzwertstufen Euro 4 und Euro 5 beinhalten. Bei den Fahrzeugtypen mit Fremdzündungsmotor war ein Typ mit der Abgasnorm Euro 5, alle anderen erfüllten die Abgasnorm Euro 4. Bei den Fahrzeugtypen mit Selbstzündungsmotor erfüllten 4 Typen die Abgasstufe Euro 5 und 7 Typen entsprachen der Abgasstufe Euro 4. Unter den Fahrzeugtypen mit Kompressionszündung und der Abgasnorm Euro 4 befanden sich 4 Typen der Klasse M1 und 3 Typen der Klasse N1 der Gruppe III.

Ziel des Forschungsvorhabens ist es, die Abgasemissionen von in Betrieb befindlichen Pkw und leichten Nutzfahrzeugen zu untersuchen, um so Rückschlüsse auf die Dauerhaltbarkeit von Motorkomponenten und Systemen zur Abgasnachbehandlung ziehen zu können.

Insgesamt konnten bei dieser Feldüberwachung, gemäß dem statistischen Verfahren, alle 17 geprüften Fahrzeugtypen mit „positiv“ bewertet werden. Mit Ausnahme eines Fahrzeugtyps, wurde bei allen untersuchten Fahrzeugtypen, die Stichprobe mit der Mindeststichprobengröße abgeschlossen. Das bedeutet, dass alle 3 Fahrzeuge eines Typs im Anlieferungszustand die jeweiligen Grenzwerte für Schadstoffemissionen gemäß den Kriterien des statistischen Verfahrens einhielten bzw. unterschritten. Nur bei einem Fahrzeugtyp war die Erhöhung der Stichprobe auf 8 Fahrzeuge erforderlich.

Weiterhin wurden bei allen Fahrzeugtypen die CO_2-Emissionen und der Kraftstoffverbrauch (Typ-I-Test) bestimmt, um anschließend die gemessenen CO_2-Emissionen mit denen der Hersteller vergleichen zu können. Von den 17 untersuchten Fahrzeugtypen hielten elf Fahrzeugtypen die jeweiligen Herstellerangaben ein oder unterschritten diese. Bei sechs Fahrzeugtypen lagen die CO_2-Emissionen um mehr als die bei der Typprüfung zulässigen 4 % über der Herstellerangabe.

Contents

Abbreviations

ADAC	General German Automobile Association
ASN	Supplementary Bodywork Code Number
AU	Periodic exhaust emissions test
CO	Carbon monoxide
CO_2	Carbon Dioxide
COC	Certificate of Conformity
COP	Conformity of Production
EUDC	Extra Urban Driving Cycle
Euro 4	Type approval test according to Directive 98/69/EC, more stringent requirements compared to EURO3 (including lower emission limits in the driving cycle, -7°C test for passenger cars with positive-ignition engine)
Euro 5, 6	Type approval test according to Regulation (EC) No. 715/2007 (Euro 5 and Euro 6), Official Journal of the European Union
HC	Hydrocarbons
HSN	Manufacturer Code Number
KBA	Federal Motor Transport Authority
Kfz	Motor Vehicle
NEDC	New European Driving Cycle
NMHC	Non-Methane Hydrocarbons
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NO_X	Nitrogen Oxides
OBD	On-Board Diagnosis
THC	Total Hydrocarbons
TSN	Type Code Number
TÜV NORD	TÜV NORD Mobilität GmbH & Co. KG
UBA	German Federal Environmental Agency
UDC	Urban Driving Cycle

Type reports

1 Fiat Fiat 500

2 Chevrolet Matiz

3 Dacia Sandero

4 Hyundai i10

5 Opel Zafira

6 Renault Twingo

7 Audi A4 (Avant)

8 BMW 118d

9 Opel Insignia

10 Volkswagen Golf

11 Citroen C4 Picasso

12 Mercedes Benz B 180 CDI

13 Peugeot 308 (HDI)

14 Toyota Auris (D-CAT)

15 Ford S-Max

16 Mercedes-Benz Viano CDI 2.2

17 Volkswagen Transporter/Caravelle

The type reports are accessible in the library of the BASt.

1 Introduction

Mobility plays an important role in the Federal Republic of Germany. Motorised private transport makes up approximately 80% of passenger traffic (Figure 1.1). If the total mileage of motor vehicles is taken as a starting point, passenger cars are the crucial factor. Motorcycles and mopeds play more of a secondary role.

The reasons for this are complex. Firstly, a high flexibility is demanded in commercial life and, secondly, many people wish to plan their leisure time as individually as possible. For most people, therefore, passenger cars are the number one means of transport, since the increased requirements are not sufficiently satisfied by local transport requirements. The total percentage distribution of the respective purposes of travel is shown in Figure 1-2 [1].

An important task of the EU Commission is to shape sustainable policy. Vehicles should be environmentally and socially compatible yet also economically efficient at the same time. Owing to the ever higher volume of passenger traffic, at the beginning of the 1970s legal provisions were developed and limits specified for pollutant emissions. To date these have been consistently updated and amended so that there has been a steady tightening of exhaust legislation with the aim of reducing pollutant emissions of passenger cars and contributing to air pollution control.

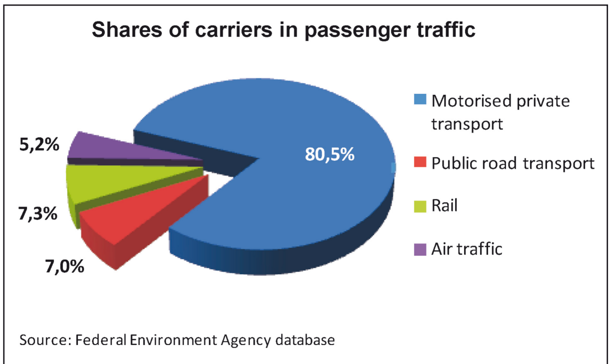


Fig. 1-1: Passenger traffic (2009)

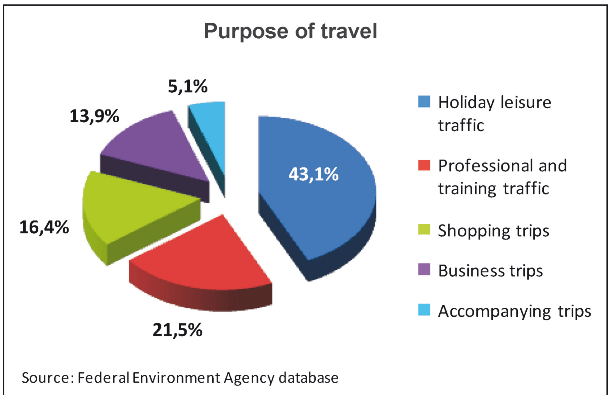


Fig. 1-2: Purpose of travel (2008)

The crucial factor for pollution of the environment from road traffic is the exhaust emissions of the vehicles in service. For this reason, with the Directive 98/69/EC and the related introduction of exhaust emission standard Euro 3, the testing of the in-service conformity of passenger cars and light-duty vehicles (in-service conformity testing) was introduced. Vehicles on the roads are to be examined under type approval Test conditions in the Type I Test after a statistical selection process.

It has been shown in many research projects that type-specific and design-related defects or inadequate maintenance regulations, which cause an impermissible increase of exhaust emissions in operation of the vehicle, can be identified by in-service conformity testing.

The research project FE 86.0066/2009 continues the series of the above-mentioned research projects. The aim of this in-service conformity testing is to determine the influence of the mileage and the vehicle´s age on the exhaust emissions behaviour of passenger cars and light-duty vehicles (17 with petrol and diesel engine of the exhaust emission standards Euro 4 and Euro 5). The examinations were conducted in close co-operation with the vehicle manufacturers. As a result, it has been made possible for the manufacturers in question to rectify any type-specific emissions-relevant defects that might occur on the vehicles on the roads (and possibly in series production). Moreover, the findings from the in-service conformity testing can be incorporated into future developments. Therefore in-service conformity testing can make an important contribution to detect impermissible increases in exhaust emissions of motor vehicles in service and is thus an important instrument for reducing environmental pollution caused by pollutant emissions from road traffic [2, 3, 4, 5].

2 Exhaust emissions of passenger cars and light-duty vehicles

Exhaust emissions are the result of combustion of fuels as occurs today in vehicles with combustion engines. Thereby, among other things, products are created that are classified as pollutants because of their toxic effect on the human organism. Some of these pollutants have been limited by law. These limits must be observed at the type approval test and in-service conformity testing. In addition to the procedures required by law, appropriate research projects for in-service conformity are also used. The manufacturer is formally requested, in the context of auditing, to submit the corresponding data and measuring results to the type approval authorities.

Although the CO_2 emissions are determined during the type approval test, they are not subject to any regulation within the type approval test. Nor are the CO_2 values determined during type approval further checked during the later in-service conformity testing. The CO_2 emissions and fuel consumption are, nevertheless, determined in the context of this project in order to investigate the correlation between the measured CO_2 emissions and the manufacturer's information in extent. The values given by the manufacturers must not exceed those measured during the type approval test (Type I Test) by more than 4% in the case of vehicles of category M or 6% in the case of vehicles of category N [3, 4].

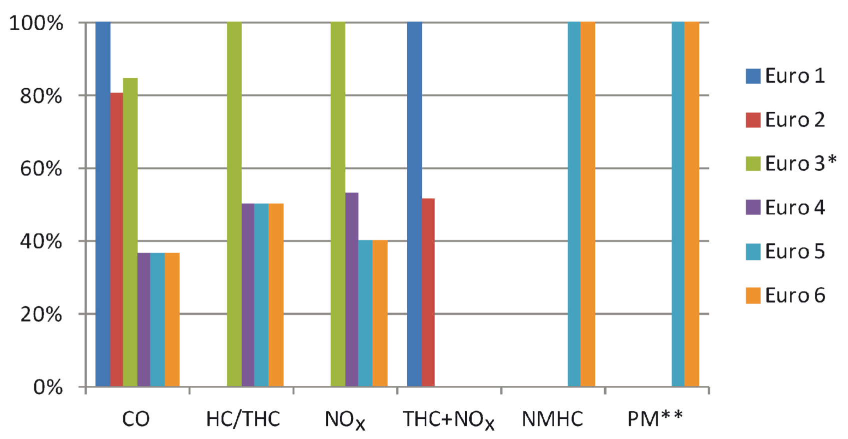
2.1 Development of the exhaust legislation

Since the existence of the Directive 70/220/EEC and the associated introduction of the exhaust emission standard (Euro 1) in 1992, it has been consistently further developed and the limits defined within have been increasingly tightened. All in all, for vehicles with petrol engine (Figure 2-1) and for vehicles with diesel engine (Figure 2-2), the following figures show the stepwise percentaged regulation of the pollutant emissions in the individual Euro standards. In the diagrams, for each of the pollutant components, the limits (or total limits) set at the time of implementation are set to 100%.

Limited pollutant components (e.g. NMHC-emissions for vehicles with petrol engine or the particle count (P) for vehicles with diesel engine), for which a limit (i.e. specifically with Euro 5/Euro 6) was not set until a later time, can be identified by a correspondingly smaller number of columns.

In summary, all limits of category M for the exhaust standards Euro 1 to Euro 6 are listed in the table 2-1.

With the Regulation (EC) No. 715/2007 dated 20 June 2007, the limit standards Euro 5 and Euro 6 were defined for passenger cars and light-duty vehicles. This Regulation particularly focuses on reducing particles (Euro 5), nitric oxide emissions (Euro 6) and an adjustment of the limits for vehicles with various drivetrain concepts.



* modified driving cycle
** PM only with petrol engine with direct injection

Fig. 2-1: Limit reductions for vehicles with positive-ignition engine of category M

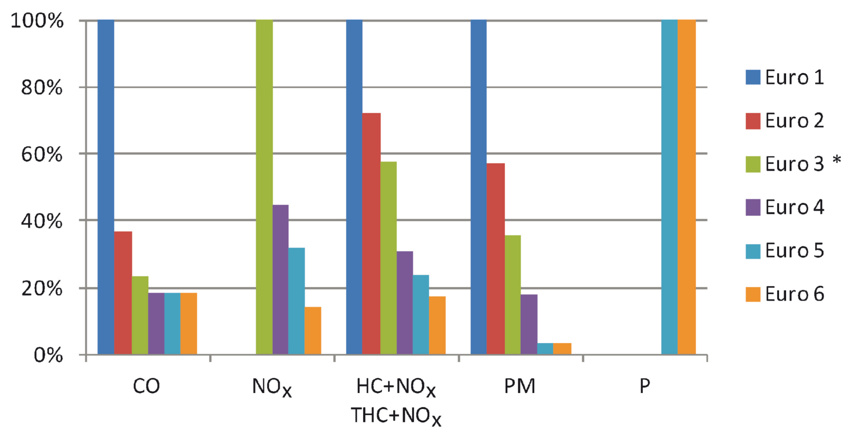
The constantly increasing requirements for air pollution control and facilities for exhaust gas treatment are becoming ever more elaborate and complex. For this reason a comprehensive package of measures was created to reduce pollution of the environment caused by motor vehicles.

For new vehicles and vehicle types, in addition to the specifications to be observed with respect to the pollutant limits at the time of the type approval test, conformity of production (COP) must also be demonstrated. The vehicle manufacturer is also obliged to guarantee the durability of exhaust gas relevant systems and components.

		Euro-Norm	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
		Year	1992	1996	2000	2005	2009	2014
		Directive/Regulation	91/441	94/12	98/69	98/69	715/2007	715/2007
		for new vehicle types from month/year	07/92	01/96	01/00	01/05	09/09	09/14
		for all vehicle types from month/year		01/97	01/01	01/06	01/11	01/15
	Pollutants		Limits					
Petrol	CO	[g/km]	2,72	2,2	2,3	1,0	1,0	1
	HC; THC	[g/km]	-	-	0,2	0,1	0,1	0,1
	NO_x	[g/km]	-	-	0,15	0,08	0,06	0,06
	$HC + NO_x$ $THC + NO_x$	[g/km]	0,97	0,5	-	-	-	-
	NMHC	[g/km]	-	-	-	-	0,068	0,068
	Mass of particulate matter	[mg/km]	-	-	-	-	5,0/4,5 *	5,0/4,5 *
	Number of particles	[#/km]	-	-	-	-	-	-
Diesel	CO	[g/km]	2,72	1,0	0,64	0,5	0,5	0,5
	HC; THC	[g/km]	-	-	-	-	-	-
	NO_x	[g/km]	-	-	0,56	0,25	0,18	0,08
	$HC + NO_x$ $THC + NO_x$	[g/km]	0,97	0,7	0,56	0,3	0,23	0,17
	NMHC	[g/km]	-	-	-	-	-	-
	Mass of particulate matter	[mg/km]	140	80	50	25	5,0/4,5	5,0/4,5
	Number of particles	[#/km]	-	-	-	-	$6,0 \times 10^{11}$	$6,0 \times 10^{11}$

* PM only with positive-ignition engine with direct injection

Tab. 2-1: Passenger car limits of the standards Euro 1 to Euro 6



* modified driving cycle

Fig. 2-2: Limit reductions for vehicles with compression ignition of category M

To ensure that the emissions level of the vehicles not only remains stable in new condition but also in everyday operation and that no impermissible increases in the pollutant emissions occur, in-service conformity testing was introduced as a further instrument of an overall concept for sustainable reduction of emissions of motor vehicles.

For the sake of completeness, reference is also made at this point to the instruments of monitoring by the On Board Diagnosis System (OBD system) and the periodic technical monitoring of all vehicles already in operation.

In this context the contribution of improved fuel qualities should not go unmentioned either. The progress achieved here benefits all vehicles and also supports the measures for reducing pollutant emissions.

For the above-mentioned instruments, the in-service conformity testing plays an important role. Unlike the OBD and the periodic exhaust emission test (AU), the in-service conformity is not the responsibility of the vehicle owner but the manufacturer. After issuance of the type approval, this is the only durability of exhaust components and the entire system. To this end vehicles already in use are selected on a random basis and then the exhaust emissions are measured on the chassis dynamometer at the exhaust emissions laboratory in the type test cycle (Type I Test). The precise procedure and the criteria for vehicle selection are explained in Section 3.

Table 2-2 shows various statutory measures for reducing exhaust emissions by motor vehicles.

As a result of all these measures, despite the increasing volume of traffic it was possible to achieve successes in air pollution control [2, 3, 4, 5, 6, 7, 8].

	New vehicles			**Vehicles on the roads**		
	Type Approval Test	**Durability Test**	**Conformity of Production**	**In-Service Conformity Testing**	**Periodic Exhaust Inspection**	**On Board Diagnosis**
Aim	Verification of compliance with statutory requirements by a vehicle type	Verification of compliance with statutory requirements by a vehicle type	Statistical verification of series production	Identification of type-specific or design-related defects or inadequate maintenance instructions	Identification of high-emitting vehicles, maintenance condition	Identification and display of malfunctions for immediate repair
Area of Responsibility	Vehicle manufacturer	Vehicle manufacturer	Vehicle manufacturer	Vehicle manufacturer	Vehicle owner	Vehicle owner
Vehicle Selection	Prototypes	Prototypes or series vehicles	Random sample from series production	Random sample of vehicle fleet in the field	All vehicles on the roads	All vehicles on the roads
Test Interval	One-off	One-off	Sporadically	Regularly	For first time after 3 years, then every 2 years	Permanently
Type of Test	Type test	Continuous operation or set deterioration factors	Type test	Type test	Short test	Real conditions according to application of manufacturer
Influence on Emissions Reduction	Technology used	Durability under laboratory conditions	Technology used and implementation in production	Technology used and implementation in the field	Maintenance condition	Durability and maintenance condition in real traffic
Legal basis	European Directives concerning measures against air pollution caused by emissions from motor vehicles 91/441/EEC, 94/12/EEC, 98/69/EC, 715/2007/EC			98/69/EG 715/2007/EG	96/96/EG, 1999/52/EG	98/69/EG 715/2007/EG

Tab. 2-2: Approaches for reducing exhaust emissions by motor vehicles

2.2 CO_2 emissions and fuel consumption

Although it was possible to substantially reduce the emissions of limited pollutants by means of many technical innovations, this was only successful to a limited extent with the carbon dioxide emissions. The above figure 2-3 illustrates that the nitrous oxide emissions were considerably reduced in the period from 1991 until 2009 (by 73.5%) for example. For carbon dioxide emissions, however, a substantially smaller reduction (18.1%) was achieved in the same period.

The considerable increase in vehicle weight and the increase in engine power are major reasons for this. If a VW Golf in 1991 weighed around 900 kg, today it weights over 1 300 kg. This is a weight increase of over 40%. The reasons for this are the increased safety requirements and the associated numerous assistance systems that contribute to passive and active driving safety. But numerous comfort facilities have also led to an increase in weight.

Although it is known that carbon dioxide is also responsible for the greenhouse effect and the climate-damaging effect, it is not classified as a pollutant since in normal concentration it does not have any toxic effects on the human organism. Transport in Germany contributes approximately 19% to the CO_2 emissions, whereby motor vehicle traffic alone adds up to 12%. This was one of the reasons why measures for reducing the CO_2 emissions of passenger cars and light-duty vehicles were taken in Europe with the Regulations (EC) no. 443/2009 and (EU) no. 510/2011. The Regulations envisage a gradual reduction of the average CO_2 emissions of new vehicles. So by the year 2020 the average CO_2 emission of the new passenger cars is to be gradually reduced to 95 g/km and the new light-duty vehicles to 147 g/km. In order to achieve the European climate protection objectives, these regulations are constantly reviewed and further developed.

Since the coming into effect of the Regulation (EC) Nr. 715/2007 the CO_2 and consumption values have been part of the type approval. In addition to tax classification of the vehicles this values also serve as consumer information. If the CO_2 and fuel consumption specifications are not complied with, consumers can make warranty claims against the manufacturer.

The fuel consumption is calculated from the carbon-bearing components CO_2, CO and HC. It must be observed that according to Directive 1999/100/EC or Regulation (EC) No. 715/2007 various fuels are allowed to be used. For this reason various factors must be taken into account when calculating the fuel consumption from the carbon-bearing exhaust components [1, 3, 4, 8, 9, 10].

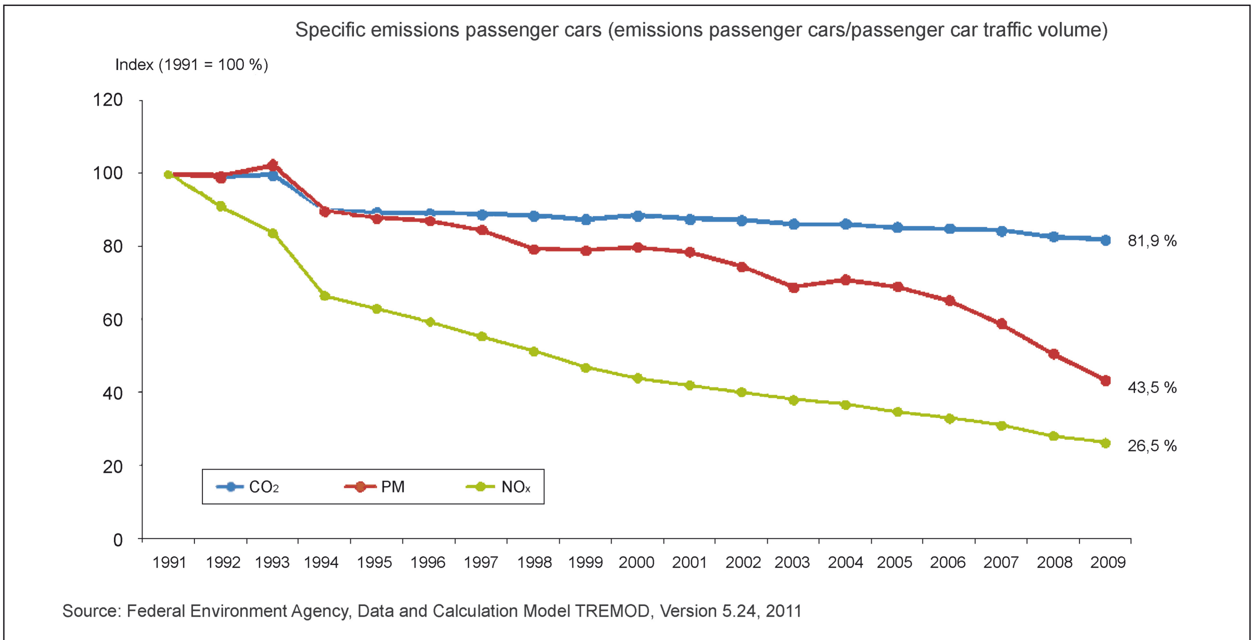


Fig. 2-3: Specific emissions passenger cars

2.3 New European Driving Cycle (NEDC)

The New European Driving Cycle (NEDC), also known as MVEG (Motor Vehicle Emissions Group), serves as a basis for determining the exhaust emissions.

It is mandatory for type approval in Europe and must therefore also be used for in-service conformity testing. The driving cycle is also described in the European Directive 98/69/EC or Regulation (EC) No. 715/2007. The NEDC consists of two partial cycles, an urban part (part one or urban driving cycle, UDC) and extra urban part (part two or extra urban driving cycle, EUDC), whereby the urban driving cycle comprises 4 basic urban driving cycles driven in succession. Overall, a distance of approximately 11 km is covered in 1180 seconds. Before the measurement can begin, the vehicle must be conditioned for at least 6 hours at a temperature of between 20°C and 30°C. The sampling starts immediately when the engine is started and ends after 1 180 seconds. Figure 2-4 shows the speed profile of the NEDC [3, 5, 6, 7, 8].

3 Project sequence

In addition to TÜV NORD leading the project, the general General German Automobile Association (ADAC) and the Federal Motor Transport Authority (KBA) were also involved. The vehicles owners of suitable vehicles are identified by the KBA. The measurements were taken in the exhaust emissions laboratories of TÜV NORD in Essen and Hanover and of the ADAC in Landsberg am Lech. All measurements were taken in accordance with the related Directive or Regulation [5].

3.1 Examination programme

The aim of the research project is to examine the exhaust gas emissions of passenger cars and light-duty vehicles in operation to draw conclusions concerning the durability of engine components and systems for exhaust gas treatment.

In this research project a total of 17 vehicle types were examined. Equipped with positive-ignition engines were 6 types and 11 types were with

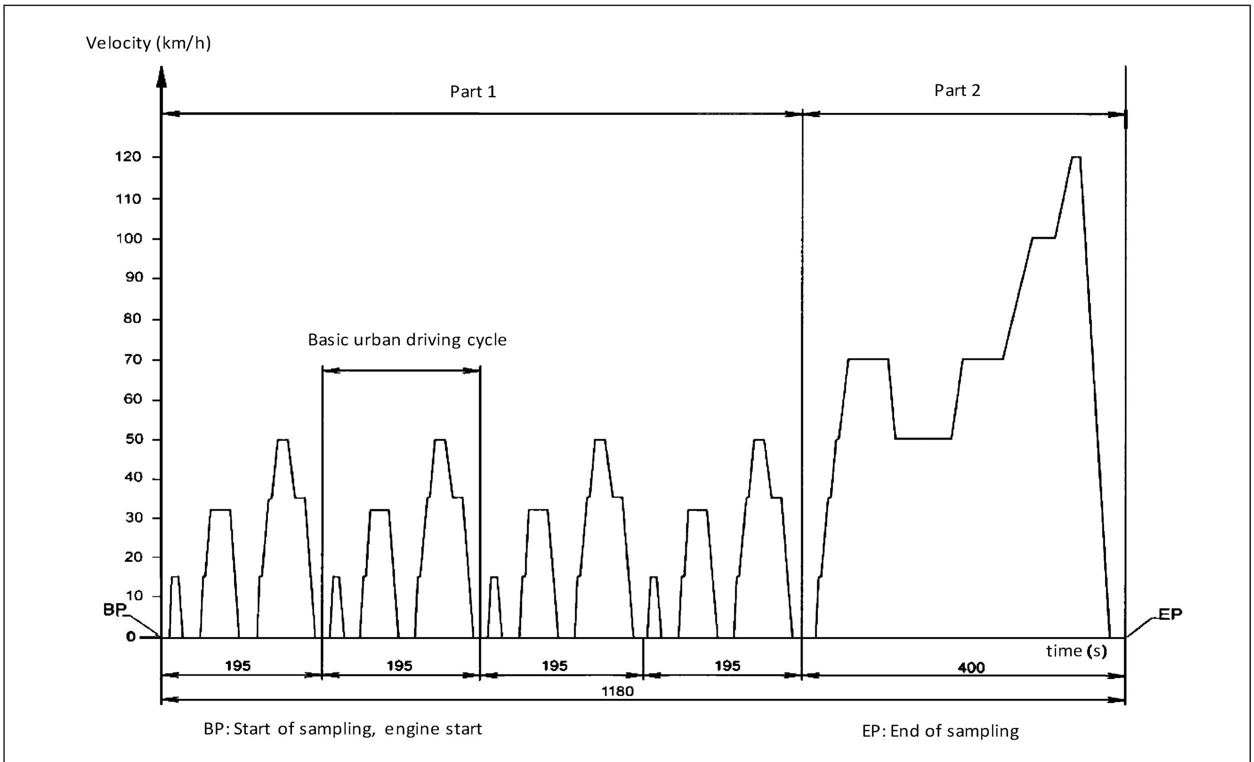


Fig. 2-4: Driving cycle of the NEDC [6]

compression ignition engines. Both groups were to each include vehicles of the limits Euro 4 and Euro 5. The vehicles with compression ignition included 3 light-duty vehicles of class III.

The distribution of the examined vehicle types over the vehicle categories M and N1/class III and the exhaust emission standards Euro 4 and Euro 5 is shown in table 3-1 divide into vehicles with petrol or diesel engines.

When determining emissions in the context of in-service conformity testing in accordance with the law, both the same driving cycle and the same test bench settings as for the type approval must be used. In other words inertia and resistance curve must correspond to those in the type approval test and all measurements are taken in the New European Driving Cycle (NEDC).

The vehicles were checked according to the classification of the exhaust type approval with respect to their limited pollutant components (carbon monoxide, hydrocarbons, nitrous gases and particulate mass). For the vehicles with positive-ignition motor, of the limit value stage Euro 5, the mass of non-methane hydrocarbons were also determined. In addition, the particle count was determined for vehicles with the exhaust emission standard Euro 5 and compression ignition engine. Here the exhaust emissions in the Type I Test were collected in separate bags and then analysed during phase 1 (urban part) and phase 2 (extra urban part) of the NEDC. The above-mentioned gaseous exhaust components were also continuously recorded at one-second intervals (modal measurement) during the entire duration of the cycle. These can be used later for analysis for anomalous vehicles which exceed the limits.

In this way, parts of the driving cycle or areas in the engine map in which high emission values occur can be specifically identified.

This facilitates the later description of the results and communication with respective manufacturers [5, 6, 7].

3.2 Vehicle selection

The vehicle selection is of great importance for a representative statement result and the success of the in-service conformity testing. The vehicle was selected in consultation with the customer. The 17 vehicle types examined in this project were selected in accordance with previously specified criteria. For the selection of the types to be examined, both statistical and technical criteria were considered. The data and statistics of the German motor vehicles licensing authority served as the basis for the selection of the vehicle types. The new licensing figures from the reference years 2008 and 2009 were of crucial importance. To avoid duplicated examinations and optimise the effectiveness of the research project, the vehicle selection and measuring results from other European in-service conformity testing programmes were considered.

3.2.1 Selection criteria in accordance with regulation or directive

The selection criteria taken as the basis for the examination of in-service conformity are described in the Directive 98/69/EC or the Regulation (EC) no. 715/2007 [3, 4, 5].

These criteria are:

- Between 15,000 and 100,000 km mileage for exhaust emission standard Euro 5 or between 15,000 and 80,000 km for exhaust emission standard Euro 4,
- Operating time between 6 months and 5 years,
- maintenance intervals performed properly and in accordance with manufacturer’s information with verification (maintenance book/service book),
- no indications of improper use or of any other changes with influence on the emissions behaviour

	Vehicle types with petrol engine		**Vehicle types with diesel engine**	
Exhaust emission standard	Euro 4	Euro 5	Euro 4	Euro 5
Vehicle category M	5	1	4	4
Vehicle category N1 class III	--	--	3	--

Tab. 3-1: Distribution of vehicle types

- OBD system: consider fault code and saved kilometres mileage; here only cars that were immediately repaired after a fault code was saved must be used,
- No major unauthorised repair on the engine or major repair on the vehicle,
- All components of the exhaust system must correspond to the type approval.

Because of the "car-scrap bonus" in 2009, new vehicles from the segments of mini, small cars and compact class had particularly high sales figures. For one vehicle type, vehicles with fewer than 15,000 km mileage were also selected for in-service conformity testing, since for this type a sufficient number of vehicles that met the criterion for the kilometres mileage could not be found. The vehicle type in question was the Hyundai i10, which, based on its high licensing figures in the year 2009, was a particularly suitable candidate for in-service conformity testing. The selection criteria were met for all other vehicle types.

3.2.2 Vehicle selection in accordance with licensing statistics

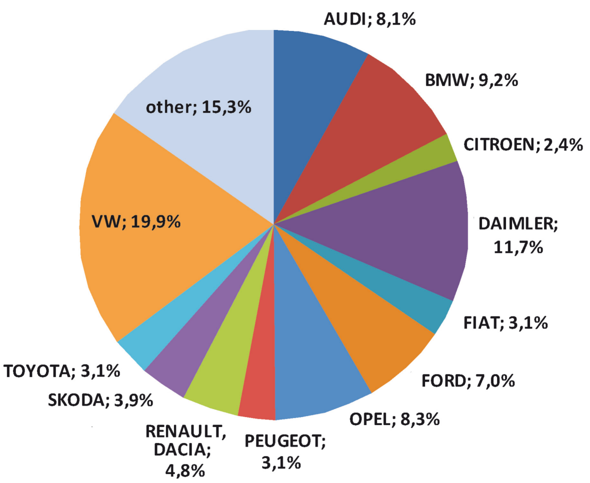
For this research project only vehicles with conventional petrol or diesel engines were selected, since approx. 99% of all newly licensed vehicles are sold with the energy converter petrol or diesel engine. Although alternative drives such as gas, hybrid and electrical vehicles are exhibiting high rates of increase in licensing statistics, in absolute terms only approximately 1% of all vehicles are equipped with alternative drives [11].

Although the share of new vehicles with diesel engines has slightly declined over the past couple of years, the total number of vehicles with diesel engines in Germany has nevertheless increased. These are also driven with an above-average frequency by high-mileage drivers and commuters. Therefore, 11 from a total of 17 vehicles with compression ignition were selected and 6 with positive ignition engine.

In addition to the number of new licenses, it was also planned to cover as broad a range of manufacturers as possible, whereby a representative cross-section of vehicle types licensed in the Federal Republic of Germany was also to be maintained. Vehicles from 14 different manufacturers were examined in the project, whereby the vehicles examined were first licensed in the years 2007, 2008, 2009, 2010. Figures 3-1 and 3-2 show the market share of the manufacturers of new vehicles licensed for the years 2008 and 2009 [11].

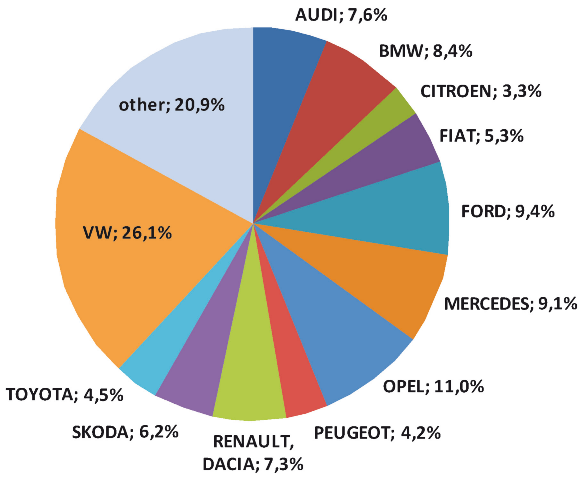
The vehicles are selected according to status of the emissions license via the supplementary bodywork code number (ASN) so that it can be ensured that all vehicles of a vehicle type were licensed according to the same exhaust emission limits.

When identifying the vehicle owners, regional key values were applied so that the vehicles were restricted to the areas of the locations of the TÜV



Source: database Federal Motor Transport Authority (KBA)

Fig. 3-1: Newly licensed passenger cars in Germany 2008



Source: database Federal Motor Transport Authority (KBA)

Fig. 3-2: Newly licensed passenger cars in Germany 2009

NORD research centres involved in Essen and Hanover and the ADAC in Landsberg am Lech. The vehicles owners were identified by using the inventory data of the German motor vehicles licensing authority. The specially adapted selection algorithms guaranteed that the vehicles owners were randomly selected [5].

With the help of the German motor vehicles licensing authority 300 vehicles owners for each vehicle type were identified and contacted in writing.

The vehicle owners who declared themselves willing to participate in the examination programme were initially surveyed by means of a questionnaire about important vehicle features such as mileage, maintenance condition, repairs performed and the series-production configuration of their vehicle. In this way it was possible in advance to clarify whether a vehicle was suitable for this project.

Table 3-2 provides an overview of the specific vehicle types selected within the framework of the research project.

3.3 Performing the examinations

Figure 3-3 shows the schedule of the examination programme. Once the vehicles were transferred to the respective exhaust emissions laboratories, the first reception test took place. The visual inspection ensured that the vehicles were in proper condition and all maintenance intervals had been observed. For the examined vehicles the fault recorder of the OBD system was also read and exhaust-relevant faults taken into account.

If no anomalies were detected here, the load adjustment of the test bench was effected in accordance with Directive 98/69/EC or Regulation (EC) no. 715/2007. The vehicles were also conditioned on the chassis dynamometer. According to the regulation, this is only specified for diesel vehicles but conditioning is nevertheless performed for all vehicles, since this approach has proved positive for the reliability of results in the past, i.e. within the framework of in-service conformity testing projects already carried out. After successful adaptation and subsequent conditioning of the vehicle, it was possible to start the actual emissions measurement.

No	Manufacturer	Trade Name	Type	Working Principle	Exhaust Emission standard	Engine Capacity	Engine Power	Engine Speed	EC Type Approval-No
1	FIAT	FIAT 500	312	Positive ignition	Euro 5	1 242 cm³	51 kW	5 500 min-1	e3*2001/116*0261*_
2	CHEVROLET	MATIZ	KLAK		Euro 4	796 cm³	38 kW	6 000 min-1	e4*2001/116*0092*_
3	DACIA	SANDERO 1.4	SD		Euro 4	1 390 cm³	55 kW	5 500 min-1	e2*2001/116*0314*_
4	HYUNDAI	i10	PA		Euro 4	1 086 cm³	49 kW	5 500 min-1	e1*2001/116*0131*_
5	OPEL	ZAFIRA	A-H/ Monocab		Euro 4	1 796 cm³	103 kW	6 300 min-1	e1*2001/116*0325*_
6	RENAULT	TWINGO	CN0D05		Euro 4	1 149 cm³	43 kW	5 250 min-1	e2*2001/116*0359*_
7	AUDI	A4 AVANT	B8	Compression ignition ng	Euro 5	1 968 cm³	105 kW	4 200 min-1	e1*2001/116*0430*_
8	BMW	118d	187		Euro 5	1 995 cm³	105 kW	4 000 min-1	e1*2001/116*0287*_
9	OPEL	Insignia	0G-A		Euro 5	1 956 cm³	118 kW	4 000 min-1	e1*2001/116*0475*_
10	VOLKSWAGEN	GOLF	1K		Euro 5	1 968 cm³	103 kW	4 200 min-1	e1*2001/116*0242*_
11	CITROEN	C4 Picasso	UA9HZ_		Euro 4	1 560 cm³	80 kW	4 000 min-1	e2*2001/116*0345*_
12	MERCEDES-BENZ	B 180 CDI	245		Euro 4	1 991 cm³	80 kW	4 200 min-1	e1*2001/116*0314*_
13	PEUGEOT	308 HDI	4*****		Euro 4	1 560 cm³	80 kW	4 000 min-1	e2*2001/116*0362*_
14	TOYOTA	AURIS D-CAT	E15UT(A)		Euro 4	1 998 cm³	93 KW	3 600 min-1	e11*2001/116*0305*_
15	FORD	S-MAX TDI	WA6		Euro 4 Gr.III	1 997 cm³	103 kW	4 000 min-1	e13*2001/116*0185*_
16	MERCEDES-BENZ	VIANO CDI 2.2	639		Euro 4 Gr.III	2 148 cm³	110 kW	3 800 min-1	e9*2001/116*0048*_
17	VOLKSWAGEN	TRANSPORTER/ CARAVELLE	7HC		Euro 4 Gr.III	1 896 cm³	75 kW	3 500 min-1	e1*2001/116*0220*_

Tab. 3-2: Vehicle type selection

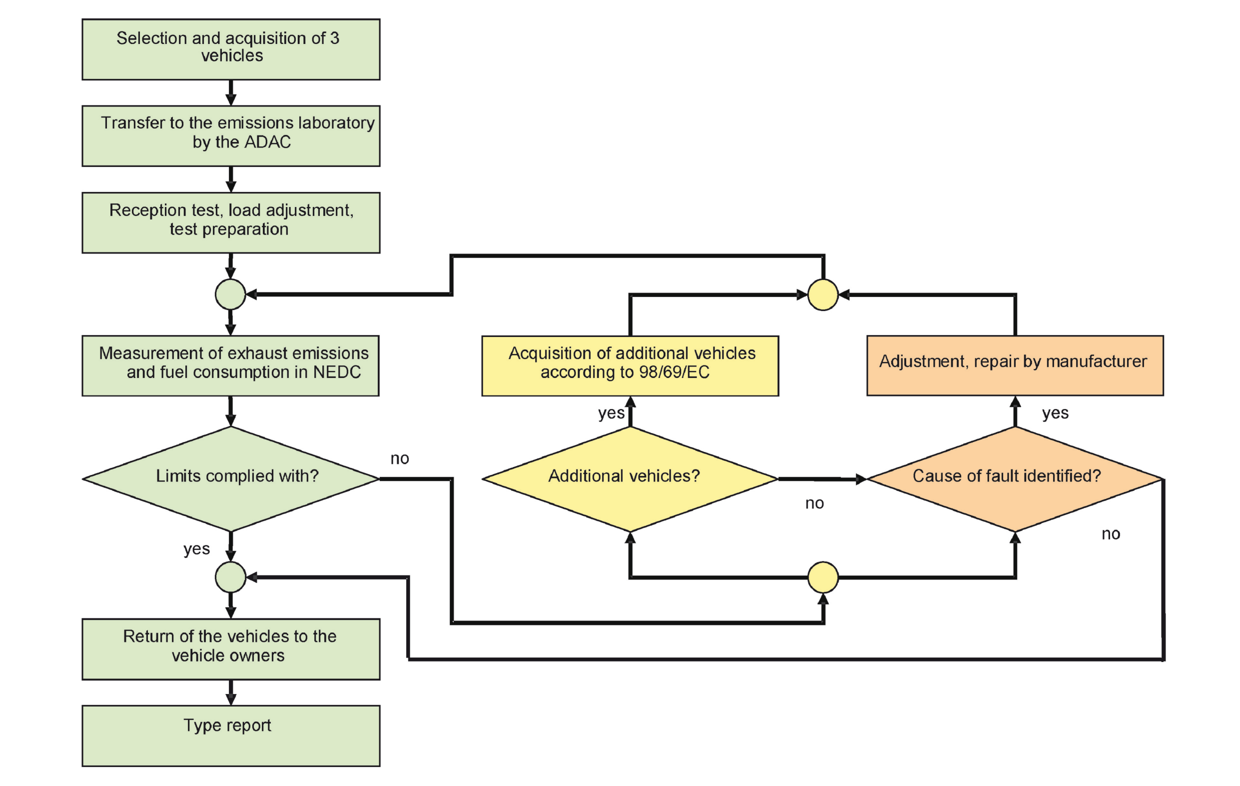


Fig. 3-3: In-service conformity testing programme sequence [6, 7]

According to the Directive, the measurements were taken in consultation with the manufacturer, also with the fuel already in the tank.

With one vehicle type, however, both conventional fuel and reference fuel were used in consultation with the manufacturer.

The identified emissions values of all vehicle types are given in the context of this project without inclusion of the respective deterioration factors (DF factors) and for periodically working regeneration systems without the corresponding Ki factors.

3.4 Evaluation of the random samples

In Figure 3-4 the procedure for evaluating a random sample during in-service conformity testing according to Directive 98/69/EC and Regulation (EC) No. 715/2007 is shown in a diagram. In the Directive, in cases where the limit is exceeded, measurements on up to 20 vehicles of a type are planned accordingly. In the evaluation of the measuring results, a distinction is made between the statistical procedure and the outlier procedure [2, 3, 5, 6, 7].

3.4.1 Outlier procedure

For high-emission vehicles the following procedure is specified:

If a certain exhaust emission value is exceeded in two vehicles of the same type due to a technical cause (for Euro 4 and Euro 5 vehicles 1.5 times the exhaust limit), a discussion should take place between the competent licensing authority and the vehicle manufacturer concerned to determine the cause of the fault and possible remedial measures.

If exhaust emission values of 2.5 times the exhaust emission limit or more are found in two vehicles (regardless of the licensing status of the vehicle type under examination) and this is due to a technical fault a recall action will be initiated by the competent licensing authority. As soon as two vehicles exhibit seriously elevated emissions (outliers) due to the same fault typical of the type, the random sample will be deemed to have a negative result and the examination will be aborted [5, 6, 7].

3.4.2 Statistical procedure

Table 3-3 shows the limits for the assessment of a random sample using the statistical procedure according to the Directive [5, 6, 7].

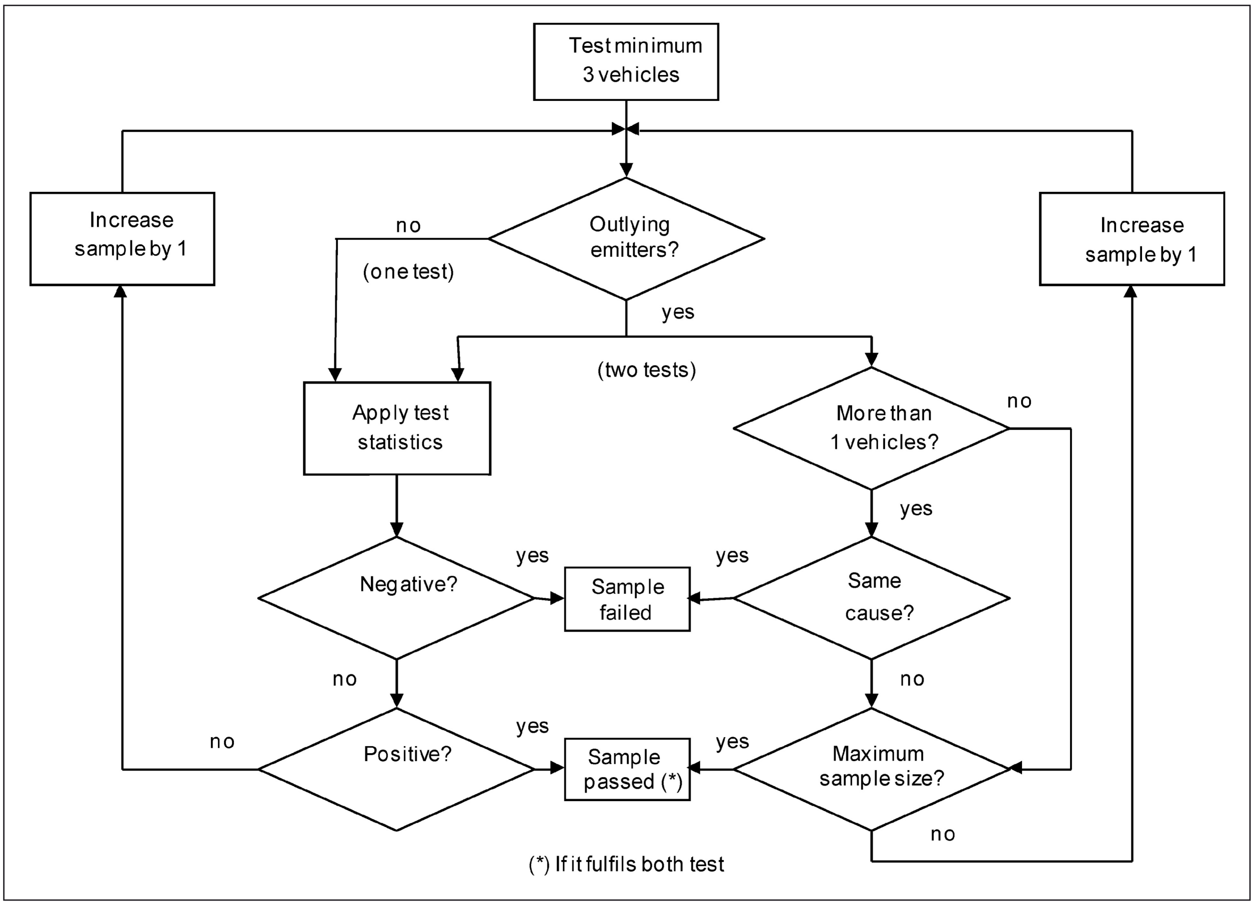


Fig. 3-4: Implementation of in-service conformity testing [6, 7]

Size of sample Number of vehicles tested	Number of anomalous vehicles (n)		
	Positive result	Additional tests	Negative result
3	0	0 < n	-
4	1	1 < n	-
5	1	1 < n < 5	5
6	2	2 < n < 6	6
7	2	2 < n < 6	6
8	3	3 < n < 7	7
9	4	4 < n < 8	8
10	4	4 < n < 8	8
11	5	5 < n < 9	9
12	5	5 < n < 9	9
13	6	6 < n < 10	10
14	6	6 < n < 11	11
15	7	7 < n < 11	11
16	8	8 < n < 12	12
17	8	8 < n < 12	12
18	9	9 < n < 13	13
19	9	9 < n < 13	13
20	11	-	12

Tab. 3-3: Assessment of a random sample using the statistical procedure

The assessment of the random sample using the statistical procedure is shown in Figure 3-5. If the size of the sample is 8 vehicles, for example, the requirements of the statistical procedure are deemed to have been met if a maximum of 3 vehicles exceed the limits. In such a case the examination is ended.

The requirements of the statistical procedure have not been fulfilled if at least 7 of the 8 vehicles do not comply with the limits. In such a case the examination ends with a negative result.

If, with 8 vehicles being examined, 4 to 6 vehicles exceed the limits an additional vehicle must be examined [5, 6, 7].

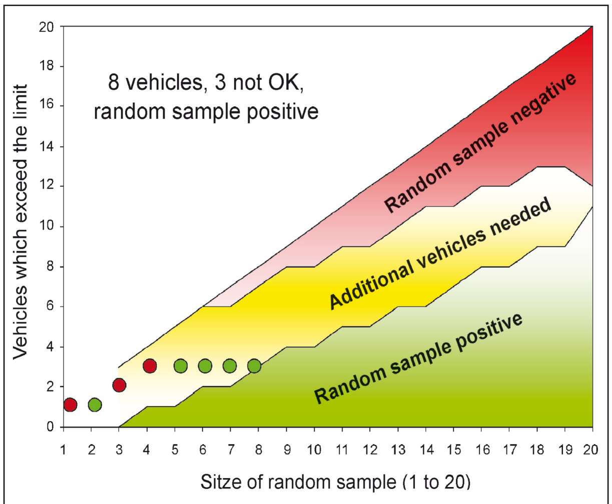


Fig. 3-5: Assessment of the random sample using the statistical procedure

4 Presentation of the results

In this chapter the exhaust emissions determined in the in-service conformity testing for the various vehicle types – at first are compiled in tabular form and after that the results – are presented graphically. With regard to the emissions of pollutants every vehicle type examined is first considered individually and then the corresponding pollution components for all the vehicle types examined are compared separately.

Evaluation of the CO_2 emissions and fuel consumption is dealt with in section 4.3.

Furthermore so-called “type reports“ are drawn up separately for all vehicle types examined within the framework of the project. In these the relevant vehicle data is shown as are the measuring results for the vehicles examined. The “type reports“ are attached as annex to the report.

4.1 Reception test

The reception test revealed that there were no evident anomalies in components relevant to exhaust emissions for any of the vehicles.

4.2 Pollutant emissions

4.2.1 Presentation of the results in tabular form

The tables 4-1 and 4-2 below give an overview of the measuring results. In the tables the average valuesfor the exhaust emissions and the respective

No	Manufacturer	Trade Name	Number of vehicles tested	Engine Capacity	∅ Mileage	Pollutant emissions in the NEDC			
				[cm³]	[km]	CO [mg/km]	THC [mg/km]	NMHC [mg/km]	NO_X [mg/km]
1	Fiat	Fiat 500	3	1 242	47 932	219,8	44,0	39,5	18,2
	Euro 5 limit for the vehicle category M					**1 000**	**100**	**68**	**60**
2	Chevrolet	Matiz	3	796	9 346	428	30	-	26
3	Dacia	Sandero	3	1 390	38 290	464	60,3	-	24,4
4	Hyundai	i10	3	1 086	10 445	415	31	-	18
5	Opel	Zafira	3	1 796	32 424	379	20	-	27
6	Renault	Twingo	3	1 149	23 879	190	40	-	17
	Euro 4 limit for the vehicle category M					**1 000**	**100**	**-**	**80**

Tab. 4-1: Average values for pollutant emissions of vehicle types with positive-ignition engine in the NEDC (Type I Test)

limits in the New European Driving Cycle are compiled for the vehicle types examined.

4.2.2 Presentation of the pollutant emissions for the types tested

The charts (Fig. 4-1 to 4-17) compare the emission values measured for the various vehicle types with the relevant exhaust emission limits. For this purpose the limits for the limited exhaust components were each applied 100%. The respective bar value shows the average value for all vehicles of one type measured. In addition the maximum and minimum values are shown in the chart. This means it is easy to identify how far the calculated average value is from the limit value and whether a vehicle has exceeded the limit. The results of the emission measurements are shown separately for each vehicle type examined in accordance with the order specified in table 4-1 and 4-2.

Passenger cars with positive-ignition engine

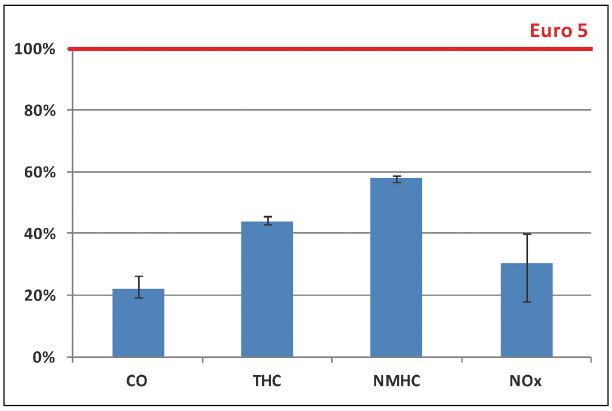


Fig. 4-1: Limited exhaust emissions, Fiat 500

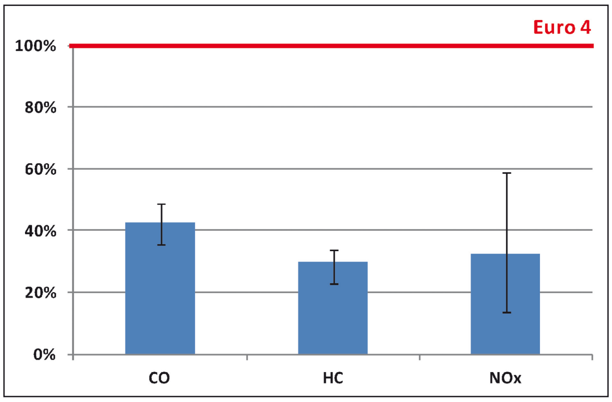


Fig. 4-2: Limited exhaust emissions, Chevrolet Matiz

No	Manufacturer	Trade Name	Number of vehicles tested	Engine Capacity [cm³]	∅ Mileage [km]	Pollutant emissions in the NEDC			
						CO [mg/km]	NO_X [mg/km]	THC+NO_X [mg/km]	PM [mg/km]
7	AUDI	A4 AVANT	3	1 968	32 958	146,9	126,5	151,1	0,49
8	BMW	118d	3	1 995	37 913	335,5	150,5	192,9	0,6
9	OPEL	Insignia	3	1 956	34 543	47,5	125,7	136,3	0,7
10	VOLKSWAGEN	GOLF	8	1 968	41 036	391,0	135,9	192,9	0,9
	Euro 5 limit for the vehicle category M					**500**	**180**	**230**	**5,0**
11	CITROEN	C4 Picasso	3	1 560	49 478	179	157	187	1,4
12	MERCEDES-BENZ	B 180 CDI	3	1 991	33 400	225	175	206	0,8
13	PEUGEOT	308 HDI	3	1 560	32 515	155	214	245	0,8
14	TOYOTA	AURIS D-CAT	3	1 998	42 031	341	190	218	5
	Euro 4 limit for the vehicle category M					**500**	**250**	**300**	**25**
15	FORD	S-MAX TDI	3	1 997	40 896	343	274	319	0,6
16	MERCEDES-BENZ	VIANO CDI 2.2	3	2 148	49 592	153	320	346	1,3
17	VOLKSWAGEN	TRANSPORTER/ CARAVELLE.	3	1 896	43 543	467	282	409	0,4
	Euro 4 limit for the vehicle category M					**740**	**390**	**460**	**60**

Tab. 4-2: Average values for pollutant emissions from vehicle types with compression-ignition engine in the NEDC (Type I Test)

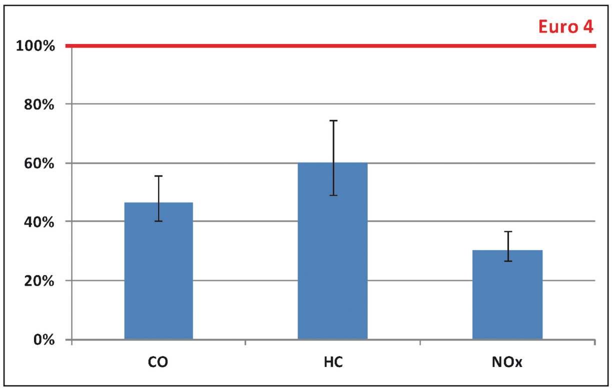


Fig. 4-3: Limited exhaust emissions, Dacia Sandero

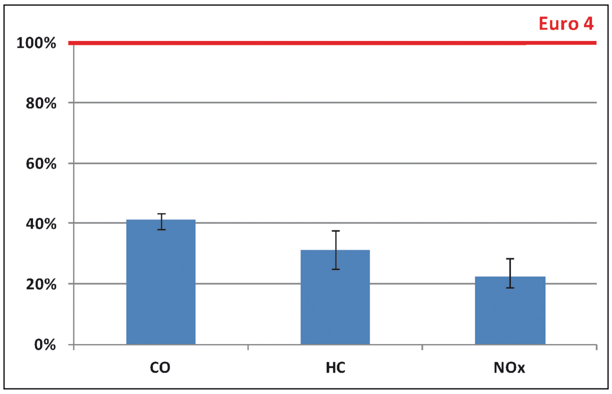


Fig. 4-4: Limited exhaust emissions, Hyundai i10

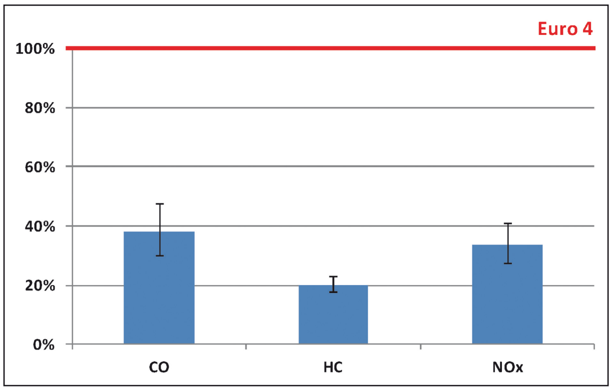


Fig. 4-5: Limited exhaust emissions, Opel Zafira

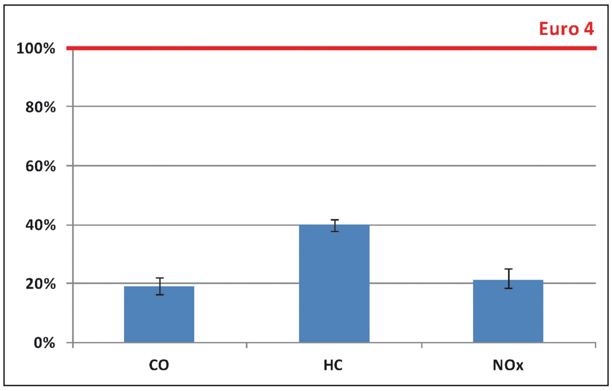


Fig. 4-6: Limited exhaust emissions, Renault Twingo

Passenger cars with compression-ignition engine

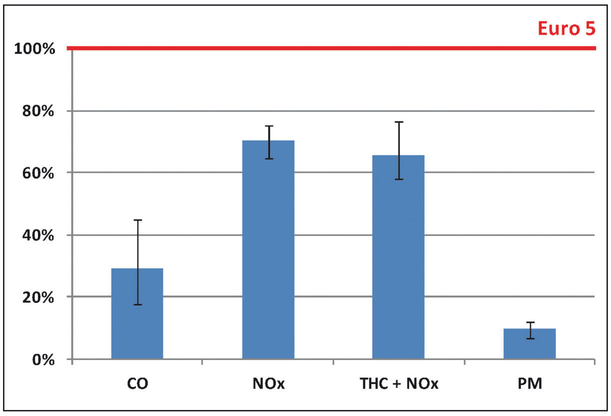


Fig. 4-7: Limited exhaust emissions, Audi A4

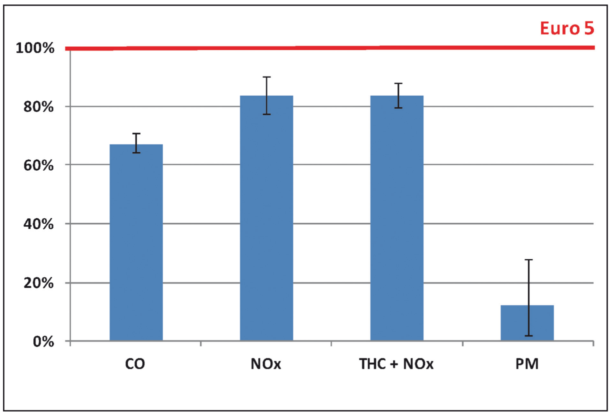


Fig. 4-8: Limited exhaust emissions, BMW 118

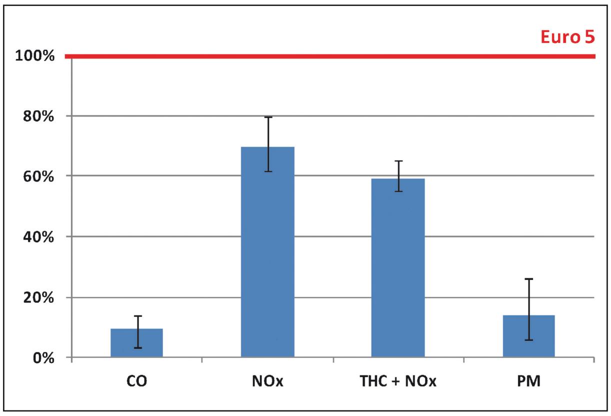


Fig. 4-9: Limited exhaust emissions, Opel Insignia

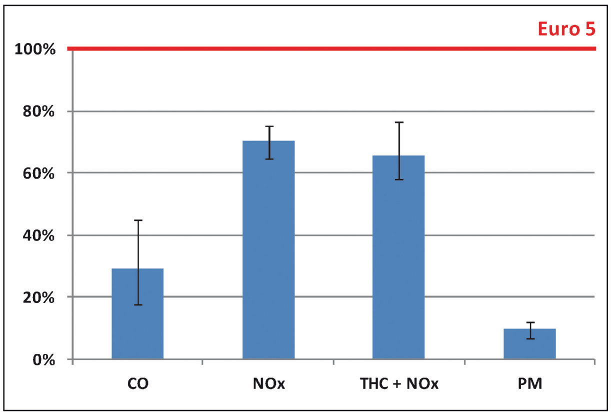


Fig. 4-10: Limited exhaust emissions, VW Golf

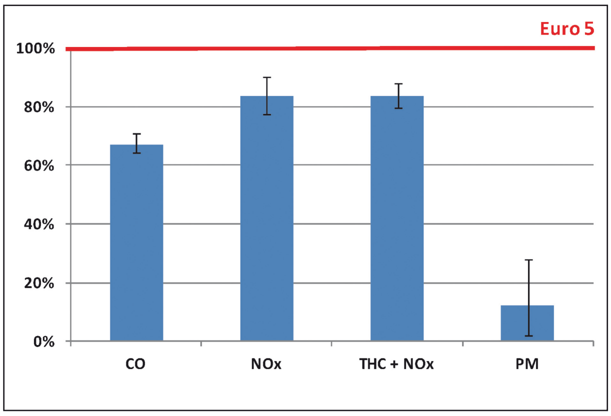


Fig. 4-11: Limited exhaust emissions, Citroen C4 Picasso

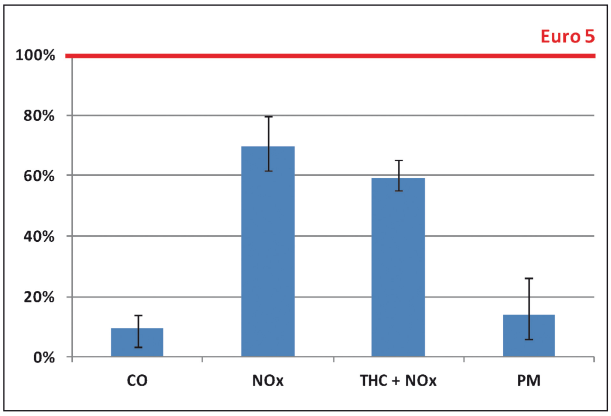


Fig. 4-12: Limited exhaust emissions, Mercedes-Benz B 180

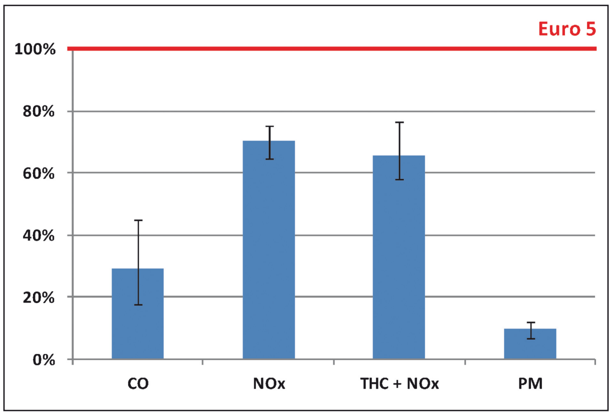


Fig. 4-13: Limited exhaust emissions, Peugeot 308

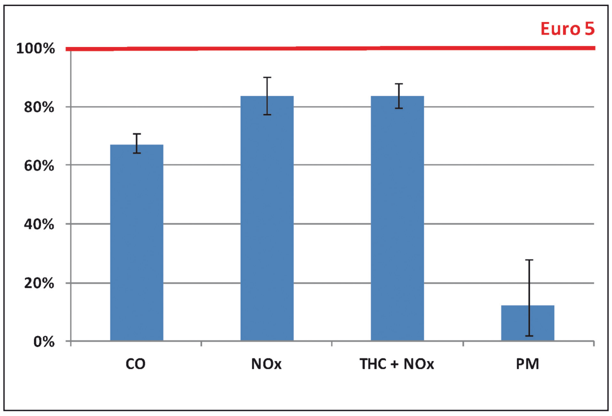


Fig. 4-14: Limited exhaust emissions, Toyota Auris

Light-duty vehicles of class III with compression-ignition engine

All vehicle types examined during this in-service conformity testing passed the random sample test in accordance with the statutory regulations and are therefore to be rated as “positive“.

For the exception of the vehicle type VW Golf, it was possible to conclude the random sample test with the minimum random sample size for all vehicle types examined. This means that all 3 vehicles of one type in as-delivered condition complied with or fell below the relevant limits for pollutant emissions according to the statistical procedure (see chapter 3.4.2).

With the vehicle type VW Golf it was necessary to examine 8 vehicles. In individual vehicles of this type elevated pollutant emissions were found. In the first measurements the CO emissions for vehicles 1 and 3 were substantially above the limit. In vehicle 2 the CO emissions were 99.9% of the limit. In view of this, the size of the random sample was initially increased by one vehicle. This vehicle

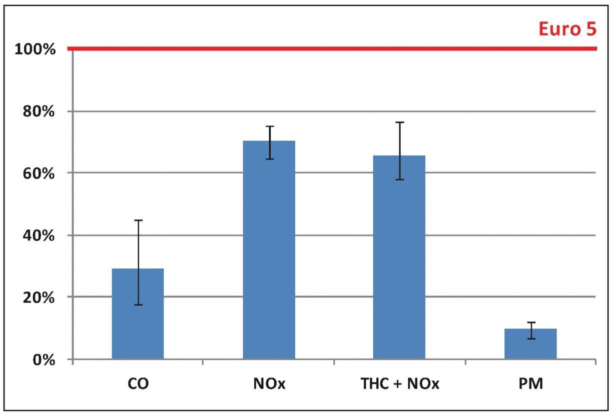


Fig. 4-15: Limited exhaust emissions, Ford S-Max

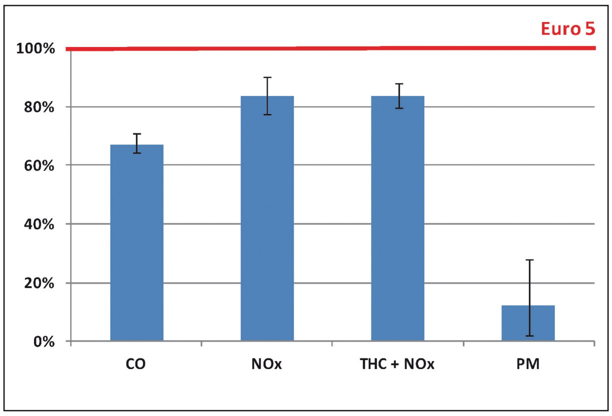


Fig. 4-16: Limited exhaust emissions, Mercedes-Benz Viano

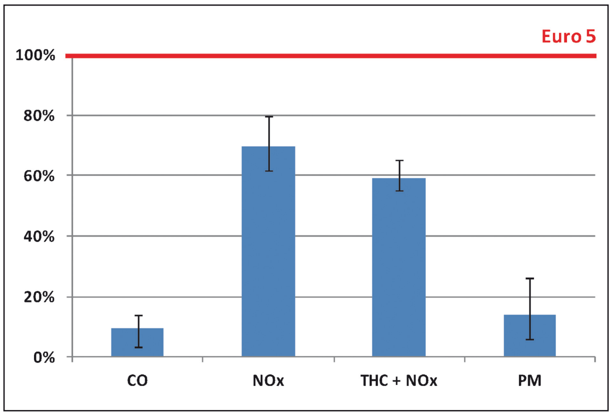


Fig. 4-17: Limited exhaust emissions, VW Transporter/ Caravelle

showed around 300 mg/km CO emissions and was therefore in the permitted range, but in this vehicle an elevated value was obtained for the exhaust components THC and NO_X. On the basis of these results the scope of the random sample was increased in accordance with the specifications of the Directive. The manufacturer Volkswagen AG was involved in measuring the additional vehicles and decided to conduct new measurements using a reference fuel. When reference fuel was used no anomalies were found in any of the additional vehicles and so with a random sample size of 8 vehicles with 3 anomalous vehicles the random sample was rated as “positive“.

The results of the emission measurements for the VW Golfs are shown in Figure 4-10. A detailed presentation of all relevant measurements obtained can be found in the corresponding type report (see annex).

4.2.3 Overview of the pollutant components

The exhaust emissions for each vehicle type examined were considered individually in chapter 4.2.2. Now the emissions of all Euro 4 and Euro 5 vehicle types will be shown next to one another in a general diagram. Each pollutant component is considered separately. Furthermore they are divided into vehicle types with positive-ignition engine and vehicle types with compression-ignition engine.

Presentation of the individual pollutant components for vehicle types with positive-ignition engine

Figure 4-18 shows the CO emissions. In none of the vehicle types were critical carbon monoxide emissions measured. All arithmetic averages are below 50% of the respective Euro 4 or Euro 5 limit.

For all the vehicle types examined the THC or HC values determined were way below the respective limit (Figure 4-19).

Since the introduction of the exhaust emission standard Euro 5, non-methane hydrocarbons also belong to the category of limited pollutants for vehicle types powered by petrol engines. In the context of the present project only one vehicle type with positive-ignition engine was examined which met the Euro 5 exhaust emission standard. The average of the NMHC values measured was approximately 60% of the limit (Figure 4-20).

Only very low values were also obtained for nitrogen oxides (Figure 4-21). With the introduction of the Euro 5 exhaust emission standard the NO_X limit was lowered from the previous 80 mg/km to 60 mg/km. But all the vehicle types examined which were of exhaust emission standard Euro 4 remained below the Euro 5 limit. For all vehicle types the respective averages for measurements were less than 30 mg/km. These values are way below the allowable limit.

Carbon monoxide

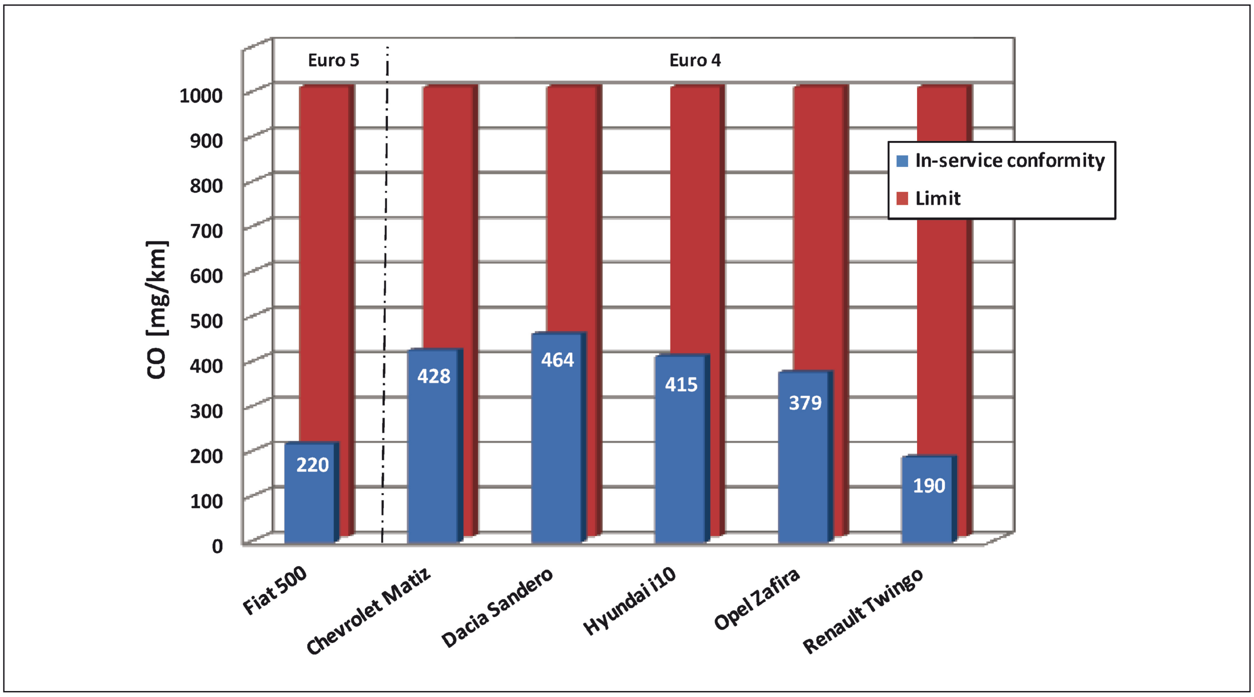


Fig. 4-18: CO emissions, vehicle types with positive-ignition engine

Hydrocarbon

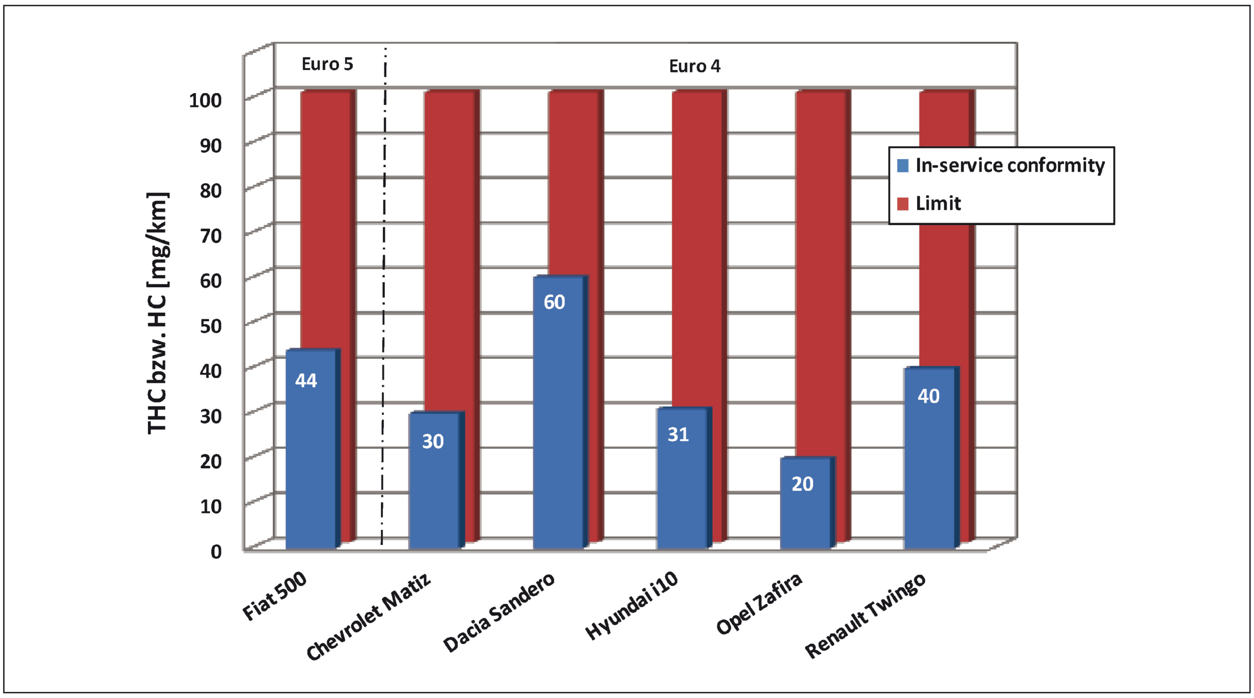


Fig. 4-19: THC emissions, vehicle types with positive-ignition engine

Non-methane hydrocarbons

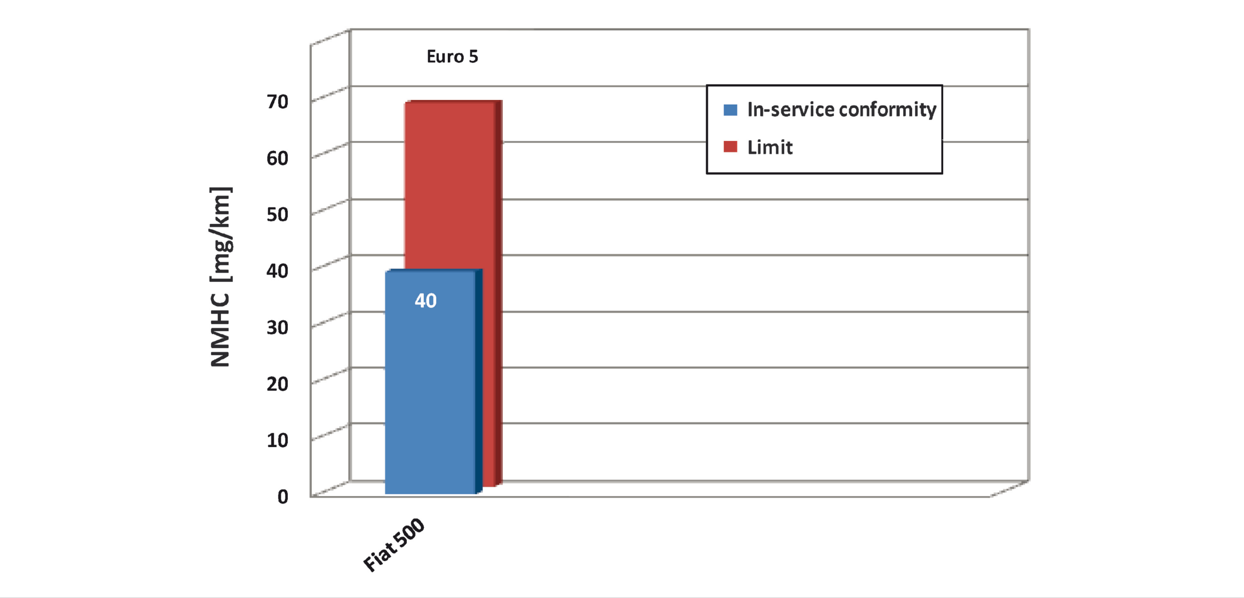


Fig. 4-20: Non-methane hydrocarbons emissions, vehicle types with positive-ignition engine

Nitrogen oxides

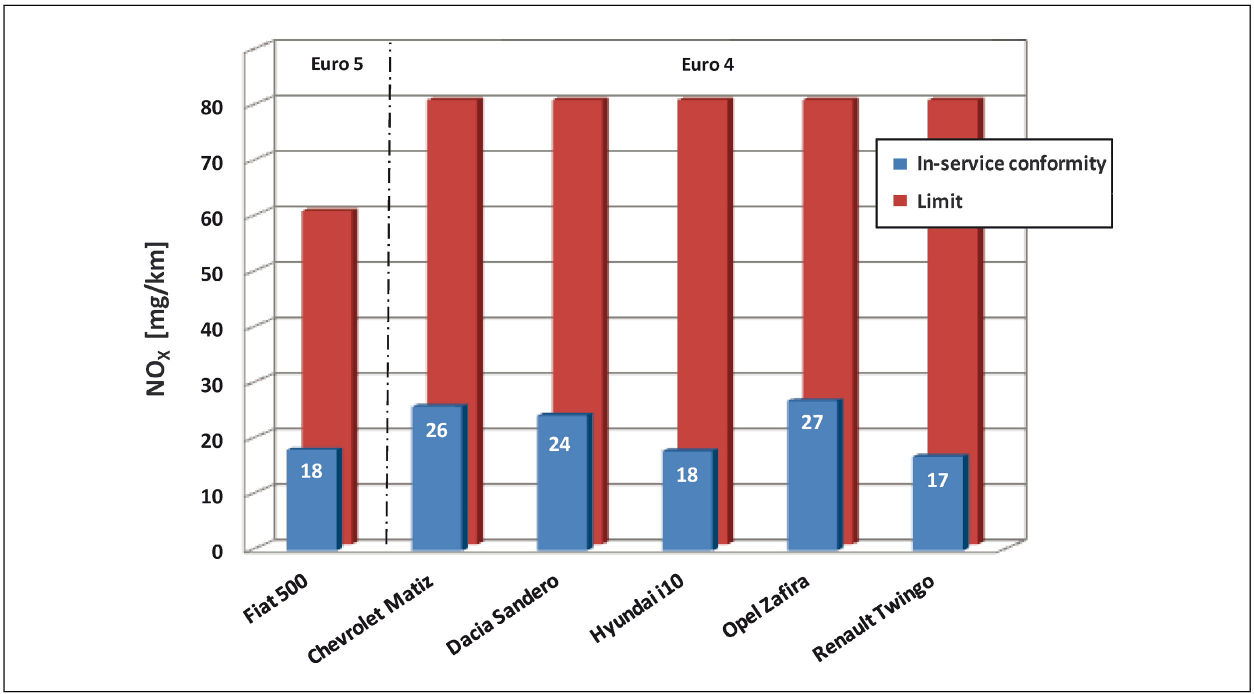


Fig. 4-21: NO_Xemissions, vehicle types with positive-ignition engine

Presentation of the individual pollutant components for vehicle types with positive-ignition engine

Vehicle types of various limit value stages were tested. These were passenger cars of the category M with the exhaust emission standards Euro 5 and Euro 4 and light-duty vehicles N1 class III of exhaust emission standard Euro 4.

In Figure 4-22 it can be seen that all vehicle types on average remain below the relevant CO limit. The type VW Golf, whose average came closest to the limit, exceeded the admissible limit in two of eight

Carbon monoxide

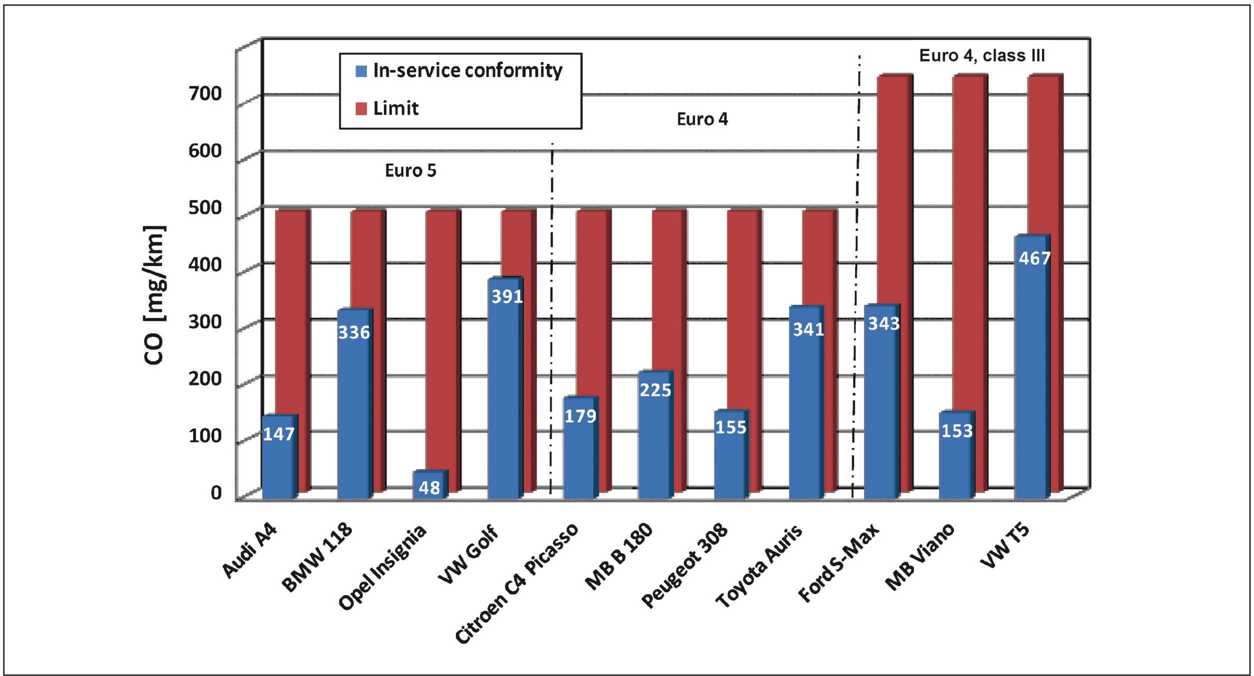


Fig. 4-22: CO emissions, vehicle types with compression-ignition engine

Nitrogen oxides

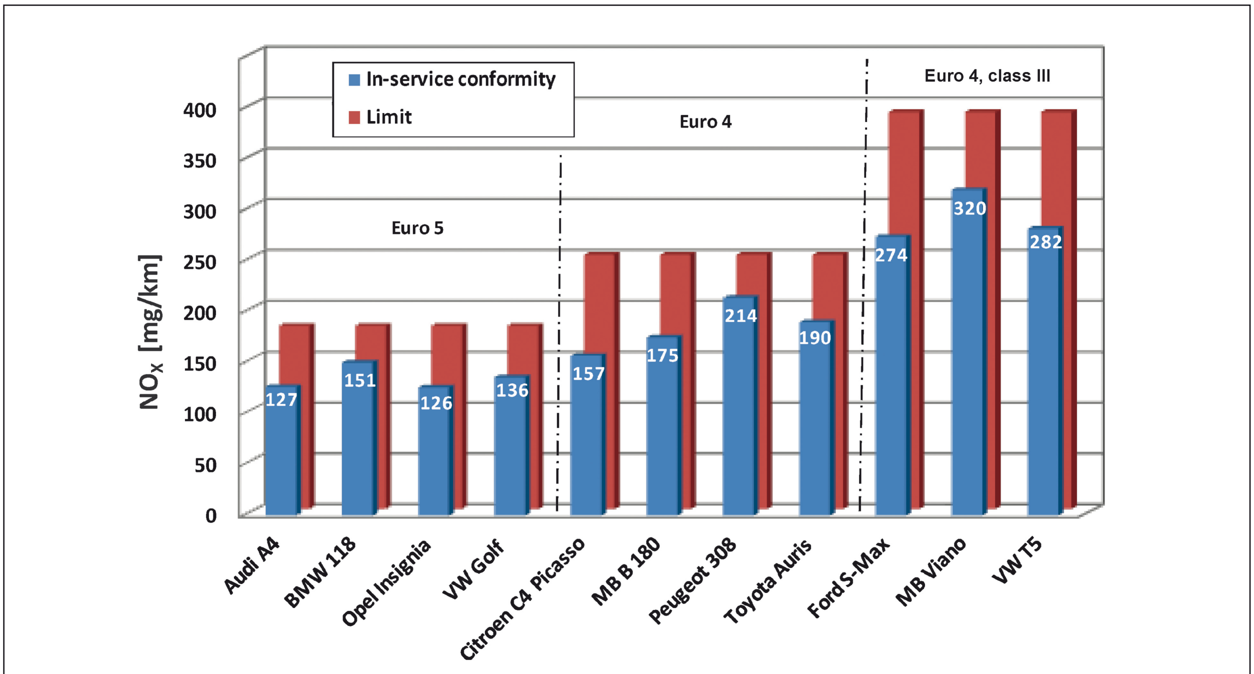


Fig. 4-23: NO_X emissions, vehicle types with compression-ignition engine

vehicles. With all the other vehicles the limit was not exceeded in any of the measurements conducted. The level of the deviation and the scatter of the measuring results for the type VW Golf are shown in Figure 4-10.

The exhaust emission standard Euro 5 exhibited in this series of tests the strictest limitation with only 180 mg/km. In all 3 categories the average NO_X value determined was about two thirds of the respective limit of the exhaust emissions standard. No vehicle exceeded the limit in the measurements.

Hydrocarbons and nitrogen oxides

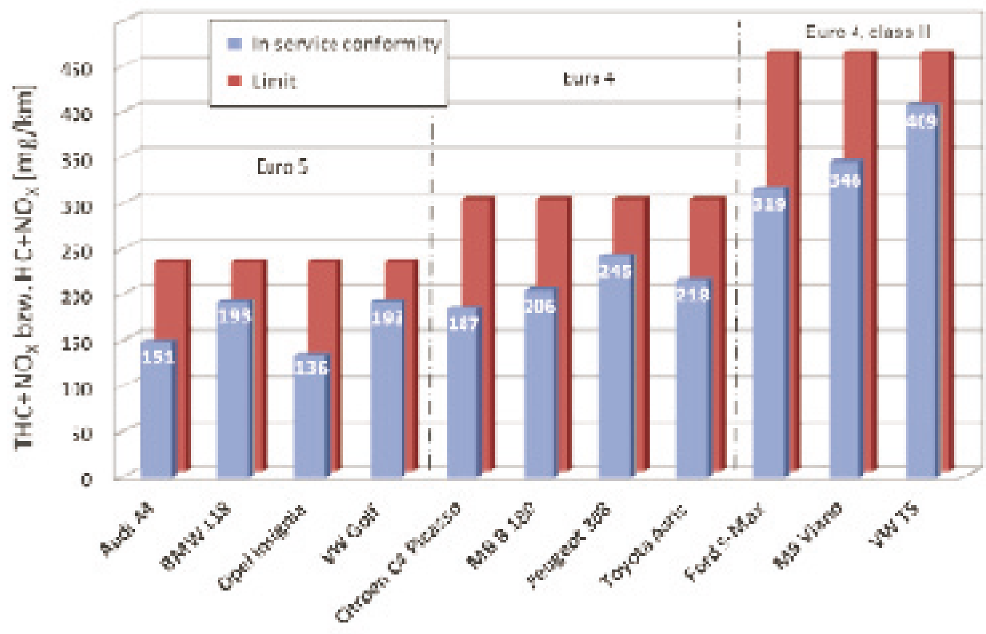


Fig. 4-24: THC + NO_x emissions, vehicle types with compression-ignition engine

Mass of particulate matter

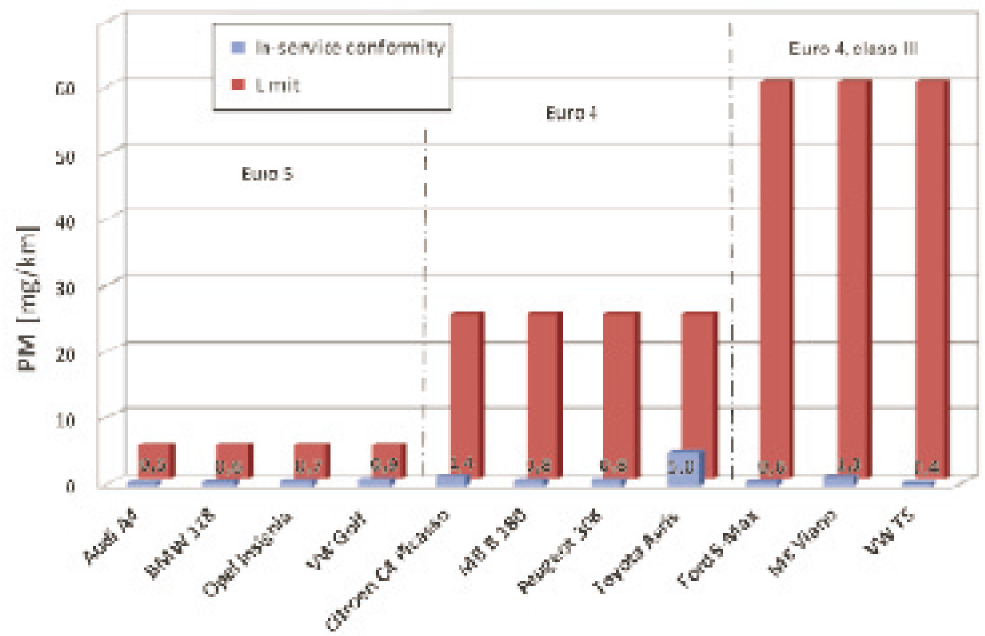


Fig. 4-25: Mass of particulate matter, vehicle types with compression-ignition engine

One vehicle of the type VW Golf, however, reached 177 mg/km and hence 99% of the limit (Figure 4-10).

The sum of hydrocarbons and nitrogen oxides (Figure 4-24) is only regulated for vehicles with compression-ignition engine. As for the nitrogenoxides, the limit of Euro 4 and Euro 5 has been tightened.

One vehicle of the type VW Golf reached a value of 240 mg/km in one measurement and therefore exceeded the permissible limit by 10 mg/km (Figure 4-10).

All other vehicles of the whole test series remained below the respective limit.

All diesel vehicles tested were equipped with soot particle filters and fell below the respective limit (Figure 4-25). It is worth mentioning in this context that even the vehicle types certified to exhaust emission standard Euro 4 complied with the substantially stricter Euro 5 specification.

4.3 CO_2 emissions and fuel consumption

According to Directive 1999/100/EC and Regulation (EC) No. 715/2007 the member states may not refuse to issue the EC type approval or operating permit with national validity for a vehicle type for reasons relating to the emissions of carbon dioxide (CO_2) and fuel consumption if the CO_2 emissions and the fuel consumption have been determined according to annex I of Directive 1999/100/EC or according to annex XII of Regulation (EC) No. 692/2008. These values are therefore part of the type approval. The CO_2 and consumption values serve as information for the consumer and since 1 July 2009 also the tax classification of vehicles in Germany. The type approval values must be given in a document which is to be handed over to the vehicle owner when he buys the vehicle (e.g. COC document or a certificate). If the CO_2 and consumption values exceed the limits to a major degree this may result in legal terms in warranty claims from the purchaser.

The fuel consumption is calculated from the CO_2 emissions measured in the type approval test in the “New European Driving Cycle“ and the other carbon-bearing emissions (CO and HC). In addition to the fuel consumption values the vehicle manufacturers must indicate the type approval values for the CO_2 emissions. In the type approval procedure no limit has to date been specified for the CO_2 emissions and the fuel consumption, but the value indicated by the manufacturer for a vehicle type (manufacturer's information) may not exceed the value determined in the type approval test by more than 4 % (category M) or 6% (category N) [2, 4, 8].

4.3.1 Presentation of CO_2 and fuel consumption results in tabular form

Table 4-3 below compares the averages of the CO_2 emissions and fuel consumption from the in-service conformity testing for the different vehicle types with the respective manufacturer's information. Furthermore the deviations in relation to the manufacturer's information are calculated and listed.

It should be noted here that, for the vehicle types where the calculated average was below the value indicated by the manufacturer, the percentage deviation is indicated by a minus sign. This therefore means that if the percentage figure is positive then the manufacturer's information is exceeded. If, on the other hand, the figure is negative it is below the manufacturer's information. All measurements, with the exception of those on some vehicles of the type VW Golf, were conducted using fuel commonly available on the market.

Table 4-3 shows that 11 of the total of 17 vehicle types complied with the respective manufacturer's information or fell below it. Four of these vehicle types fell substantially below the manufacturer's information with more than -4%. For 7 types the values determined for the CO_2 emissions roughly corresponded to the manufacturer's information (manufacturer's information -4% ≤ CO_2 value determined ≤ manufacturer's information +4%).

For 6 vehicle types the CO_2 emissions were more than the 4% above the manufacturer's information permitted in the type approval test. Among these 6 vehicle types there were 4 for which the CO_2 emission determined were more than 4% but less than 10% and for two vehicle types the CO_2 emissions determined were over 10%.

Vehicle types for which the average of the CO_2 emissions measured were more than 4% and for individual vehicle types more than 10% above the type approval value were classified as anomalous. The manufacturers of the vehicle types concerned were asked for a written explanation of the elevated CO_2 emissions. Where the manufacturers submitted their comments these were attached as an annex to the type reports.

No.	Manufacturer	Trade Name	Exhaust emission standard	Working principle	Manufacturer's information				In-service conformity testing				Deviation from manufacturer's information			
					Fuel consumption [l/100 km]			CO_2 [g/km]	Fuel consumption [l/100 km]			CO_2 [g/km]	Fuel consumption [%]			CO_2 [%]
					UDC	EUDC	NEDC	NEDC	UDC	EUDC	NEDC	NEDC	UDC	EUDC	NEDC	NEDC
1	FIAT	FIAT 500	Euro 5	positive ignition engine	6,4	4,3	5,1	**119**	7,6	4,5	5,6	**130,5**	18,7	4,7	10,5	**9,7**
2	CHEVROLET	MATIZ	Euro 4		6,6	4,1	5,1	**120**	6,7	4,3	5,2	**122,6**	1,6	3,2	2,0	**1,9**
3	DACIA	SANDERO 1.4	Euro 4		9,6	5,4	7,0	**165**	8,8	5,2	6,5	**154,2**	-8,7	-2,8	-7,1	**-6,5**
4	HYUNDAI	i10	Euro 4		6,2	4,3	5,0	**119**	6,8	4,7	5,5	**127,3**	10,2	8,5	9,3	**7,0**
5	OPEL	ZAFIRA	Euro 4		9,9	6,0	7,4	**177**	10,0	5,9	7,4	**175,6**	1,3	-1,7	0,0	**-0,8**
6	RENAULT	TWINGO	Euro 4		7,1	4,6	5,5	**130**	7,2	4,8	5,7	**135,2**	2,0	3,3	3,2	**4,0**
7	AUDI	A4 AVANT	Euro 5	compression-ignition engine	7,3	4,8	5,7	**151**	8,5	5,3	6,5	**170,5**	16,3	9,7	12,9	**12,9**
8	BMW	118d	Euro 5		5,4	4,0	4,5	**119**	6,3	4,3	5,0	**131,9**	16,1	7,5	11,1	**10,8**
9	OPEL	Insignia	Euro 5		9,3	5,3	6,8	**179**	9,4	5,2	6,7	**177,4**	1,5	-2,5	-1,4	**-0,9**
10	VOLKSWAGEN	GOLF	Euro 5		6,6	4,1	5,0	**132**	7,3	4,4	5,4	**142,3**	12,7	7,2	8,3	**7,7**
11	CITROEN	C4 Picasso	Euro 4		7,0	5,0	5,7	**150**	6,3	4,7	5,3	**139,5**	-9,6	-4,7	-7,0	**-7,0**
12	MERCEDES-BENZ	B 180 CDI	Euro 4		6,7	4,7	5,5	**144**	7,5	4,8	5,8	**152,3**	12,2	2,2	6,0	**6,1**
13	PEUGEOT	308 HDI	Euro 4		6,4	4,0	4,9	**129**	6,3	4,0	4,8	**126,7**	-2,6	-0,8	-2,0	**-1,8**
14	TOYOTA	AURIS D-CAT	Euro 4		7,2	4,9	5,7	**151**	7,1	4,9	5,7	**149,4**	-1,4	-0,7	0,0	**-1,1**
15	FORD	S-MAX TDI	Euro 4 Gruppe III		8,1	5,4	6,4	**169**	7,3	4,9	5,8	**152,6**	-9,9	-8,7	-9,4	**-9,7**
16	MERCEDES-BENZ	VIANO CDI 2.2	Euro 4 Gruppe.III		11,0	7,0	8,5	**226**	10,5	7,1	8,3	**220,3**	-4,8	1,2	-1,8	**-2,5**
17	VOLKSWAGEN	TRANSPORTER/ CARAVELLE	Euro 4 Gruppe III		9,6	7,0	7,9	**208**	9,0	6,4	7,3	**192,3**	-6,6	-8,6	-7,6	**-7,5**

Tab. 4-3: Averages for the CO_2 emissions measured in the New European Driving Cycle and the fuel consumption (Type I Test)

4.3.2 Presentation of CO_2 emissions

To provide a clearer overall view Figure 4-26 shows the vehicles broken down into the groups petrol engine and diesel engine and also arranged from left to right according to the exhaust emission standard (Euro 5, Euro 4 and Euro 4 class III). Above each pair of bars the deviation between the manufacturer's information and the average for the measurements conducted in the in-service conformity testing is given.

Vehicle types with petrol engine

The vehicle type with petrol engine and exhaust emission standard Euro 5 tested in this project emitted 9.7% more CO_2 than it was indicated by the manufacturer.

Of the 5 types examined with petrol engine and exhaust emissions standard Euro 4 only 1 type was measured as having an elevated carbon dioxide emission (7.0%). For all other vehicle types of exhaust emission standard Euro 4 the CO_2 emissions measured accorded with the values given by the manufacturer (-0.8% to 4.0%). According to the regulation the values indicated by the manufacturer may not exceed the CO_2 values determined in the type approval test by more than 4%. For one vehicle type the CO_2 values determined in the in-service conformity testing were even below those of the manufacturer (-6.5%).

Vehicle types with diesel engine

For the vehicle types with compression-ignition engine and the exhaust emission standard Euro 5, 3 of 4 vehicle types are conspicuous owing to their great deviations. Here the differences between the results from the in-service conformity testing and the manufacturer's information were between 7.7% and 12.9%. Only one vehicle type complied with the CO_2 emissions indicate by the manufacturer (-0.9%).

In the 4 vehicle types with exhaust emission standard Euro 4 and of vehicle category M the only case of an excessively high figure was 6.1%. All other vehicle types with exhaust emission standard Euro 4 exhibited a substantially lower CO_2 emission at -7.0% or corresponded approximately to the manufacturer's information (-1.8% and -1.1%).

The 3 vehicle types examined which had exhaust emission standard Euro4 and were of the vehicle category N1 class III all showed a positive result. In the case of 2 vehicle types a substantially lower CO_2 emission was even measured, namely -7.5% and -9.7%. A further type was measured as having a deviation of -2.5%.

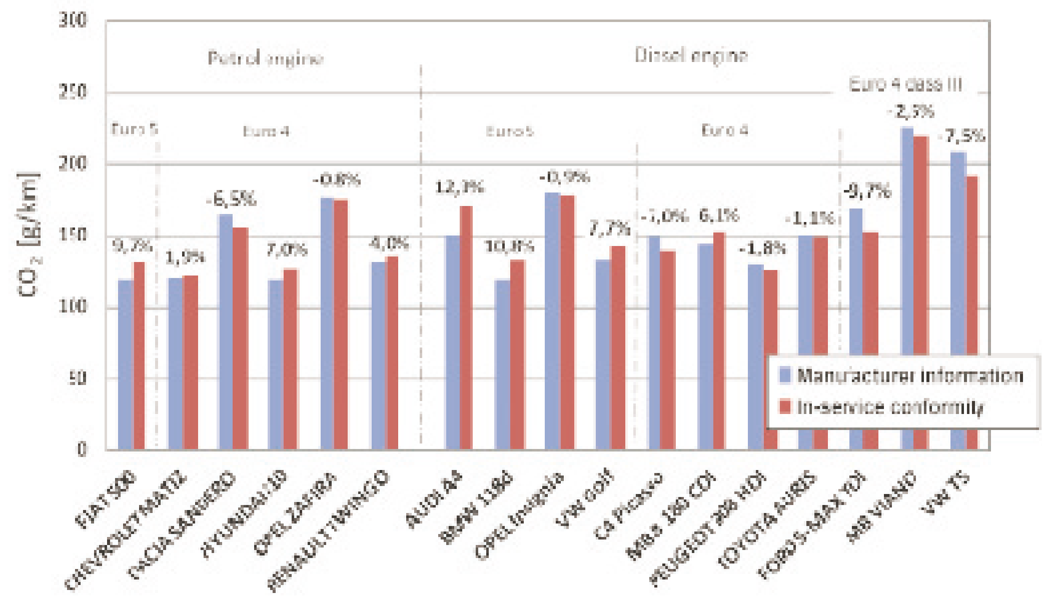


Fig. 4-26: Averages for the CO_2 emissions in the NEDC

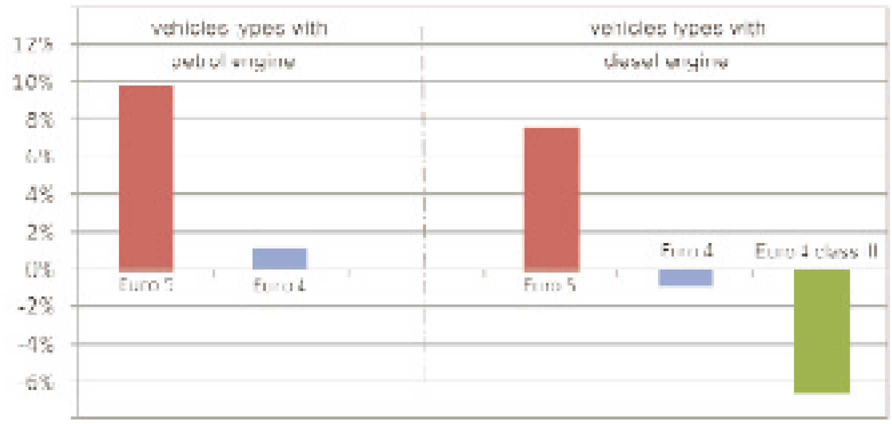


Fig. 4-27: Deviations in CO_2 emissions determined in the in-service conformity testing in relation to manufacturer's information

Figure 4-27 differentiates for the vehicle types examined between different vehicle categories (M1 and N1 class III), vehicle drive trains (petrol or diesel engine) and exhaust emission standards (Euro 4, Euro 5). For each cluster the average deviation of CO_2 measuring results from the in-service conformity testing is shown (related to the CO_2 values determined in the type approval test).

It is clear that for the CO_2 emissions from Euro 4 vehicles of category M there were little differences in relation to the manufacturer's information. In contrast to this result the CO_2 emissions for the types of passenger cars of category M with exhaust emission standard Euro 5 differed by 9.7% for vehicle types with petrol engine and 7.6% for vehicle types with diesel engine. So these results deviated substantially from the figures determined in the type approval procedure.

On the other hand special mention should be made of the measurements conducted on vehicle types with positive-ignition engine and with exhaust emission standard Euro 4 category N1 class III. Here the CO_2 values determined were on average -6.6% and so considerably below the manufacturer's information.

In view of the increasing significance of CO_2 emissions with respect to the planned excess emission charges for vehicle manufacturers, the parameters for the type approval test must be fixed in such a way that it is ensured that the measuring results are reproducible and realistic. These measures are necessary so that it is possible to check the CO_2 values for vehicles already in operation, as is already the case, for example, for pollutant emissions in the in-service conformity testing.

4.3.3 Presentation of fuel consumption

The following charts deal with the fuel consumption in the whole NEDC and in the individual phases (urban and extra urban).

Figure 4-28 shows the difference in fuel consumption between the manufacturer's information and the average of the measurements conducted in the NEDC. Since the fuel consumption is calculated from the carbon-bearing emissions and carbon dioxide accounts of the major portion of this, with respect to fuel consumption a similar picture is obtained to that for the CO_2 emissions (Figure 4-26). As can be seen in Figures 4-29 and 4-30, the greater deviations are evident in the urban part. They were between -10% and 19%. In the extra-urban part deviations of between -9% and 10% were determined. This result can be explained by the fact, for example, that the urban part proceeds more dynamically than the extra-urban part, where longer distances are covered at constant speed.

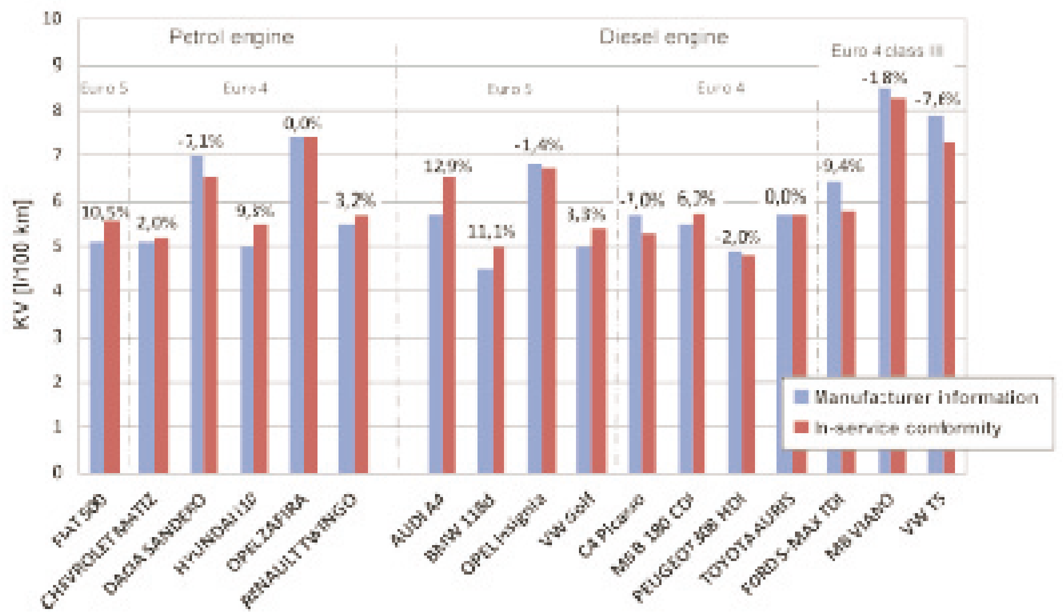


Fig. 4-28: Fuel consumption in the NEDC

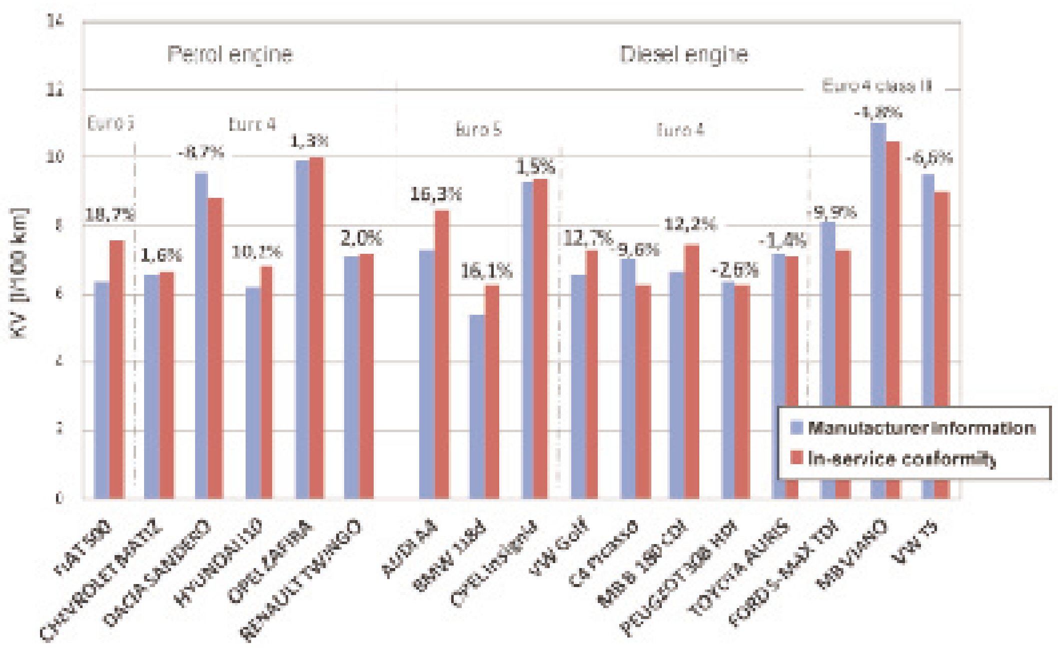


Fig. 4-29: Fuel consumption in the urban part of the UDC

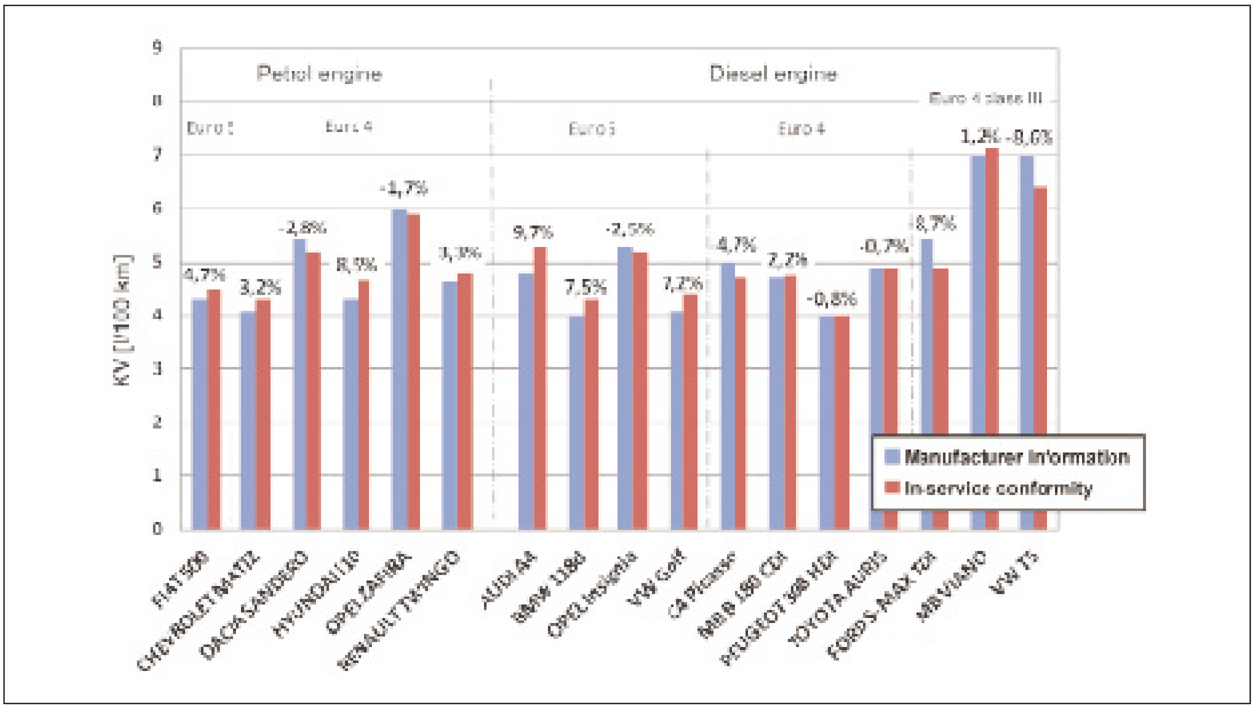


Fig. 4-30: Fuel consumption in the extra-urban part of the EUDC

5 Summary

In the research project "Examination of the pollutants emitted by vehicles in operation and of emission-relevant components" vehicles were examined which were already operating in real traffic. The test sequence was applied in accordance with the Directive 98/69/EC or Regulation (EC) No. 715/2007.

In the selection of the test vehicles reference was made primarily to statistical criteria, such as the licensing figures from the years 2008 and 2009. But in addition statistics and technical aspects from past in-service conformity testing operations or from on-going European projects were also referred to.

Altogether 17 vehicle types were examined. The series of measurements included 6 types of category M with positive-ignition engine, 1 vehicle type corresponding to exhaust emission standard Euro 5 and all the others fulfilling the exhaust emission standard Euro 4. As regards the 11 types with compression-ignition engine they were made up of 4 types with exhaust emission standard Euro 5 category M, 4 types with exhaust emission standard Euro 4 category M and 3 N1 vehicle types with exhaust emission standard Euro 4 class III.

With regard to the limited pollutant emissions no anomalies were found for 16 vehicle types. In one vehicle type, limits were exceeded by individual vehicles. In view of this, additional vehicles were examined for this type in accordance with statistical procedure provided for in the Regulation (EC) No. 715/2007. In all, 8 vehicles were examined and 3 of them exceeded the limits. In accordance with the Directive the random sample was rated as "positive".

More anomalies were revealed by the CO_2 measurements and the fuel consumption calculations. For example, for one vehicle type with petrol engine and exhaust emission standard Euro 5 a substantially elevated CO_2 emission was determined (9.7%). For petrol engines with the exhaust emission standard Euro 4 only one type exhibited elevated CO_2 emissions (7.0%) and all other vehicles examined were within the tolerance range or fell clearly below the manufacturer's information with -6.5%.

As regards the vehicles with diesel engine and exhaust emission standard Euro 5 one vehicle type exhibited no anomalies and all other vehicles exceeded the manufacturer's information. The deviations within the NEDC were between 7.7% and 12.9% and hence also clearly above the permissible 4%. The vehicles with diesel

No.	Manufacturer	Trade Name	Exhaust emission standard	Working principle	Pollutant emissions in the NEDC	CO_2 deviations in the NEDC
1	FIAT	FIAT 500	Euro 5	positive-ignition engine	limit not exceeded	2 vehicles over +10% 1 vehicle over +4%
2	CHEVROLET	MATIZ	Euro 4		limit not exceeded	all 3 vehicles no anomalies
3	DACIA	SANDERO 1.4	Euro 4		limit not exceeded	2 vehicles below manufacturer's information 1 vehicle no anomaly
4	HYUNDAI	i10	Euro 4		limit not exceeded	all 3 vehicles over +4%
5	OPEL	ZAFIRA	Euro 4		limit not exceeded	all 3 vehicles no anomalies
6	RENAULT	TWINGO	Euro 4		limit not exceeded	2 vehicles no anomalies 1 vehicle above +4%
7	AUDI	A4 AVANT	Euro 5	compression-ignition engine	limit not exceeded	all 3 vehicles above +10%
8	BMW	118d	Euro 5		limit not exceeded	all 3 vehicles above +10%
9	OPEL	Insignia	Euro 5		limit not exceeded	all 3 vehicles no anomalies
10	VOLKSWAGEN	GOLF	Euro 5		limit exceeded in 3 of 8 vehicles. 2 vehicles where CO limit exceeded 1 vehicle where THC + NO_x limit exceeded	3 vehicles above +10% 3 vehicles above +4% 2 vehicles no anomalies
11	CITROEN	C4 Picasso	Euro 4		limit not exceeded	all 3 vehicles below manufacturer's information
12	MERCEDES-BENZ	B 180 CDI	Euro 4		limit not exceeded	1 vehicle above +10% 1 vehicle above +4% 1 vehicle no anomalies
13	PEUGEOT	308 HDI	Euro 4		limit not exceeded	all 3 vehicles no anomalies
14	TOYOTA	AURIS D-CAT	Euro 4		limit not exceeded	all 3 vehicles no anomalies
15	FORD	S-MAX TDI	Euro 4 class III		limit not exceeded	all 3 vehicles below manufacturer's information
16	MERCEDES-BENZ	VIANO CDI 2.2	Euro 4 class III		limit not exceeded	2 vehicles no anomalies 1 vehicle below manufacturer's information
17	VOLKSWAGEN	TRANSPORTER/ CARAVELLE.	Euro 4 class III		limit not exceeded	all 3 vehicles below manufacturer's information

Tab. 5-1: Summary

engine and exhaust emission standard Euro 4 achieved a better result. Here only one vehicle type was negatively conspicuous with 6.1%. All other types with Euro 4 showed 4 % and so were within the tolerance range or even showed 9.7% with values substantially below the manufacturer's information. The greatest deviations arose in the first part of the NEDC, the urban cycle.

Table 5-1 gives a summary of the results. It again highlights the respective test results for this in-service conformity testing. In the column “CO_2 deviations in the NEDC“ all vehicles where the value determined is within the range ±4% (manufacturer's information -4% ≤ CO_2 value determined ≤ manufacturer's information +4%) are identified as not anomalous. If the values determined are below -4% these are identified “below manufacturer's information“.

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Tel. (0421) 3 69 03-53
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