Swedish In-Service Testing Program

On Emissions from Passenger Cars and Light-Duty Trucks

Report for the Swedish Transport Agency

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Content

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List of Abbreviations

A4 / A5 / A6	4-speed / 5-speed / 6-speed automatic gearbox
CO	Carbon monoxide
CO2	Carbon dioxide
COP	Conformity of production
CPC	Condensation Particle Counter
CVS	Constant Volume Sampler; exhaust emission sampling system
EC	European Community
UDC	Urban Driving Cycle; Part 1 of the New European Driving Cycle
EUDC	Extra Urban Driving Cycle; Part 2 of the New European Driving Cycle
EURO 1	Type approval test in accordance with Directive 91/441/EEC
EURO 2	Type approval test in accordance with Directive 94/12/EEC
EURO 3	Type approval test in accordance with Directive 98/69/EC
EURO 4	Type approval test in accordance with Directive 98/69/EC, stricter requirements (incl. lower limit values in driving cycle, -7°C test)
M5 / M6	5-speed / 6-speed manual gearbox
M1	Vehicles and a total vehicle mass of up to 2,500kg
N1	Vehicles for transportation of goods and a total vehicle mass of up to 3,500kg
NEDC	New European Driving Cycle according to Directive 98/69/EC
CADC	Common Artemis Driving Cycle
CO	Carbon Monoxide
HC	Hydro Carbon
NOx	Nitrogen Oxides
CO2	Carbon Dioxide
FC	Fuel consumption
PM	Particle Mass
PMP	Particle Measurement Programme
PN	Particle Number
OBD	On-Board Diagnosis
SHED	Sealed Housing for Evaporative Emissions Determination
STA	Swedish Transport Agency

Summary

A great deal of air pollution is caused by emissions from motor vehicles on the road. In Service Testing therefore occupies an important position in an overall concept for a sustainable reduction of emissions in traffic. Directive 70/220/EEC as amended by 98/69/EC established the In Service Testing as part of the type approval procedure.

AVL MTC AB has on the commission of the Swedish Transport Agency carried out The Swedish In-Service Testing Programme on Emissions from Passenger Cars and Light Duty Trucks.

For the year of 2009 In-Service Conformity Testing Programme included a total of 55 vehicles, spread over 11 vehicle families. 6 families with positive ignition engine and 5 families with compressed ignition. 10 of the vehicles were flexi fuel (E85) vehicles and 5 were Bi-fuel vehicles (CNG, Compressed Natural Gas). All the compression ignition vehicles were equipped with particle filter (DPF), except the N1 class III vehicle family (Light-Duty Truck).

The measurements were carried out in the respective type approval cycle, the "New European Driving Cycle“ (Type I / NEDC) in accordance with Directive 70/220/EEC as amended by 2003/76/EC. In addition to this, measurements according to the Common Artemis Driving Cycle (CADC) were conducted for the emission factor programme. For more information regarding CADC see page 16.

During the measurements on the chassis dynamometer, the exhaust emissions were measured and the fuel consumption was calculated from the emissions of the carbon-containing exhaust components. Exhaust emissions at idle speed (Type II test) and crankcase emissions (Type III test) were measured of all vehicles with positive ignition engine. At two vehicles per type with positive ignition engine the evaporative emissions (Type IV test) were determined.

On two vehicles per type with positive ignition engine type-approved according to EURO 4, the exhaust emissions at low ambient temperatures (Type VI test, -7°C) were measured.

During this programme the OBD-data were registered. On-board diagnosis (OBD) systems were tested with simulated errors on one vehicle/family.

The particulate measurement (PM) has been conducted according to the new procedure in the PMP-protocol to be implemented in the EU from the 1 September 2011 and is a part of UNECE reg.83.

All test fuels used is shown in Appendix 1. The programme used reference fuels according to Halterman. The fuel specifications are according to directive 2002/80/EC.

One of the vehicles with positive ignition engine tested exceeded the Euro 4 limit during Type I test. Two of 25 vehicles with compression ignition exceeded the Euro 4 limit during Type I test. The vehicles that failed the Type I test were of different vehicle types. This means that a minimum of four vehicles per type, tested during this programme, complied with the limits. According to the statistical procedure for In-Service testing defined in Directive 70/220/EEC as amended by 98/69/EC a sample of five vehicles has passed if at least four vehicles comply with the limits. Therefore all tested vehicle types with positive and compression ignition engines fulfilled the legal requirements for In-Service testing.

During the NEDC, the deviation from the values given by the manufacturer was less than 8 percent regarding fuel consumption and CO2 emissions.

Measuring exhaust emissions at idle speed during the Type II test no emission related problems were detected.

For the type III test four of thirty vehicles showed crankcase overpressure at different loads. The manufacturers are notified about the phenomenon and more detailed investigation has to be done to see find out the root cause.

Five of the sixteen vehicles exceeded the limit for evaporative emissions during Type IV test. These results imply a failure rate of 31%. Average test result for all the tested vehicles was 1.45 g per test.

During the exhaust emission test at low ambient temperatures (Type VI test), all positive ignited vehicles complied within limits according to Directive 70/220/EEC as amended by 98/69/EC. None of the CNG/E85 vehicles complied with the HC - limits and three out of six CNG/E85 vehicles complied with the CO – limits according to Directive 70/220/EEC as amended by 98/69/EC.

During this project the OBD-data were registered. In addition some emission relevant defects were simulated to control the function of the OBD system at one of the vehicles per type. All simulated failures were detected by the OBD system.

Introduction

During In Service Testing in use vehicles are examined in a complete testing procedure involving the type approval cycle. The results of several surveys show that In Service Testing is useful to recognize type specific design faults or inadequate servicing regulations which cause an inadmissible increase in exhaust emissions after an extended operating period for the motor vehicle. In Service Testing is intended to enable the manufacturer to rectify the emission relevant defects on the vehicles in traffic and in series production.

Definition of Conformity of in service vehicles:
According to Directive 70/220/EEC as amended by 98/69/EC, Annex I, §7.1.1., the definition of in service vehicles is: "With reference to type approvals granted for emissions, these measures must also be appropriate for confirming the functionality of the emission control devices during the normal useful life of the vehicles under normal conditions of use (conformity of in service vehicles properly maintained and used). For the purpose of this Directive these measures must be checked for a period of up to 5 years of age or 80 000 km, whichever is the sooner."

The objective with the Swedish test programme is to conduct screening tests on a number of vehicle models, picked out on a spot-check basis, to verify durability in the emission control concept. This is done by STA in close collaboration with AVL.

Besides In-Service Conformity testing it is also an objective of the programme to get information of emissions from vehicles during real world driving. These data will be used to update the European emission model ARTEMIS. ARTEMIS is used in Sweden for national emission inventories and as input to local air pollution calculations. The In Service Testing program has been carried out on behalf of the Swedish Transport Agency and the call-off agreement no TSA 2009:235.

Implementation of programme

General information

Within the framework of this programme a total of 6 vehicle types with spark ignition engine and 5 vehicle types with compression ignition engine were examined with respect to the exhaust emissions limited by law. Three of the tested vehicle types were vehicles with flex fuel engines.

The measurements were carried out in accordance with Directive 70/220/EEC as amended by 2003/76/EC. The cycles used were the "New European Driving Cycle“ (NEDC) and also the Common Artemis Driving Cycle (CADC). The different driving cycles are shown in page 16 to 18.

During the measurements on the dynamometer the emissions of Carbon Monoxide (CO), Hydrocarbons (HC), Nitrogen Oxides (NOx) and Carbon Dioxide (CO2) were collected in bags in accordance with the regulations and the integral values were determined.

For all vehicles, both spark ignited and compression ignited, Particle Mass (PM) and Particle Number (PN) were measured according to the Particle Measurement Programme (PMP). The exhaust emissions were measured continuously every second (modal measurement).

Fuel consumption was determined in the respective type approval cycle in accordance with Directive 80/1268/EEC. The fuel consumption was calculated (carbon mass method) from the emissions of the carbon-bearing exhaust components (CO2, CO and HC).

Exhaust emissions at idle speed (Type II test) and crankcase emissions (Type III test) were measured of all vehicles with positive ignition engine.

On two vehicles per type with positive ignition engine the evaporative emissions (Type IV test) were determined.

Of two vehicles per type with positive ignition engine, type approved according to EURO4, the exhaust emissions at low ambient temperatures (Type VI test) were measured.

During this programme the OBD-data were registered. In addition some emission relevant failures were simulated to control the function of the OBD system at one vehicle per type.

The car manufacturer or importer was invited to participate during the tests. Representatives of the respective vehicle manufacturer were present during most of the time to witness the conduct of the tests.

Test programme vehicles

After collaboration with Swedish Transport Agency the vehicles were selected spread across a wide spectrum of different manufacturers, to cover all the aspects from which STA´s desideratum. In all, vehicle types from 11 different manufacturers were investigated in the programme of 2009.

Table 1 shows the exhaust emission limits valid for the type approval test of passenger cars and light duty vehicles according to Directive 70/220/EEC as amended by 2003/76/EC.

Engine	MK (Limit)	Vehicle class (1)	Reference Mass (RM) [kg]	CO [g/km]	HC [g/km]	Nox [g/km]	HC+Nox [g/km]	PM [g/km]
Gasoline/ Ethanol	2000 (Euro 3)	M1 ≤ 2500kg	All	2,30	0,20	0,15	-	-
		N1 class I	RM ≤ 1305	2,30	0,20	0,15	-	-
		N1 Class II	1305 < RM ≤ 1760	4,17	0,25	0,18	-	-
		N1 class III	1760 < RM	5,22	0,29	0,21	-	-
	2005 (Euro 4)	M1 ≤ 2500kg	All	1,00	0,10	0,08	-	-
		N1 class I	RM ≤ 1305	1,00	0,10	0,08	-	-
		N1 Class II	1305 < RM ≤ 1760	1,81	0,13	0,10	-	-
		N1 class III	1760 < RM	2,27	0,16	0,11	-	-
Diesel	2000 (Euro 3)	M1 ≤ 2500kg	All	0,64	-	0,50	0,56	0,05
		N1 class I	RM ≤ 1306	0,64	-	0,50	0,56	0,05
		N1 Class II	1305 < RM ≤ 1760	0,80	-	0,65	0,72	0,07
		N1 class III	1760 < RM	0,95	-	0,78	0,86	0,10
	2005 (Euro 4)	M1 ≤ 2500kg	All	0,50	-	0,25	0,30	0,025
		N1 class I	RM ≤ 1305	0,50	-	0,25	0,30	0,025
		N1 Class II	1305 < RM ≤ 1760	0,63	-	0,33	0,39	0,04
		N1 class III	1760 < RM	0,74	-	0,39	0,46	0,06
	2005PM	M1 ≤ 2500kg	All	0,50	-	0,25	0,30	0,005
		N1 class I	RM ≤ 1305	0,50	-	0,25	0,30	0,005
		N1 Class II	1305 < RM ≤ 1760	0,63	-	0,33	0,39	0,005
		N1 class III	1760 < RM	0,74	-	0,39	0,46	0,005

(1) N1 limits are also valid for class M vehicles with maximum mass > 2500kg

Table 1: Emission limits for passenger cars and light-duty heavy vehicles

Following criteria were used when selecting the individual vehicles.

- same type approval for vehicles of one type
- kilometre reading between 15,000 km (alternatively at least 6 months in traffic) and 80,000 km
- regular service committed to manufacturers' advice
- vehicle is unmodified series production model
- no mechanical damage to components

The vehicle types, which were selected and investigated, can bee seen in table 2 and table 3.

No.	Manufacturer	Type	Trade name	Engine type	Engine capacity	Power	Emission approval	Swedish enviroment class	Milage min (km)	Milage max (km)	Registration
1	HONDA	RD8	CR-V	K20A4	1997 cm3	110 kW	EURO4	2005	34259	68290	2006-03-03 to 2006-12-21
2	FORD	DA3	Focus FF	Q7DA	1798 cm3	92 kW	EURO4	2005	24198	57439	2006-02-02 to 2006-08-25
3	VOLVO	J	V70 Bi-fuel	B5244SG	2401 cm3	103 kW	EURO4	2005	30307	49359	2006-07-04 to 2007-03-30
4	SAAB(*)	YS3F	9-3 Aero	B284L	2792 cm3	184 kW	EURO4	2005	33369	66954	2006-05-05 to 2006-09-29
5	RENAULT	Megane II	Megane	K4MJ856	1598 cm3	77 kW	EURO4	2005	30307	49359	2008-01-31 to 2008-01-31
6	VOLKSWAGEN	1K	Golf 1,4 Tsi	BMY	1390 cm3	103 kW	EURO4	2005	37779	76771	2006-10-19 to 2007-03-28

Table 2: Test programme vehicles, spark ignition

(*) **In addition to chassis dynamometer testing three of the Saab 9-3 Aero V6 was also tested on-road with a portable exhaust measurement system - PEMS. Test results are presented in Appendix 2**

No.	Manufacturer	Type	Trade name	Engine type	Engine capacity	Power	Emission approval	Swedish enviroment class	Milage min (km)	Milage max (km)	Registration
1	VOLVO	S	V70 D5	D5244T4	2435 cm3	136 kW	EURO4	2005PM	30454	48202	2006-09-04 to 2007-09-02
2	AUDI	8E	A4 Tdi	BPW	1968 cm3	103 kW	EURO4	2005PM	18826	71882	2006-08-10 to 2007-08-31
3	TOYOTA	T25	Avensis 2,0 Tdi	1AD	1998 cm3	93 kW	EURO4	2005PM	34259	68290	2006-10-18 to 2007-12-27
4	BMW	560L	525 D	256D2	2500 cm3	130 kW	EURO4	2005PM	37300	71268	2006-06-08 to 2007-03-12,
5	MITSUBISHI	KA0T	L200	4D56	2477 cm3	100 kW	EURO4 N1/III	2005	34259	68290	2006-10-03 to 2007-08-22

Table 3: Test programme vehicles, compression ignition

Actual test programme

Within the framework of the programme 11 vehicle types were tested. The investigations were implemented with reference to Directive 70/220/EEC as amended by 2003/76/EC. In order to obtain a reliable assessment if type-specific defects are present on a vehicle type, initially five vehicles per vehicle type selected were measured with respect to exhaust emissions.

In table 4 the application of tests for type fore type approval of passenger cars and light duty vehicles are illustrated.

Test	Description	Positive ignition vehicles	Compression ignition vehciles
Type I	tailpipe after colds start	yes	yes
Type II	carbon monoxide emissions at idling speed	yes	-
Type III	emission of crankcase gases	yes	-
Type IV	evaporative emissions	yes	-
Type V	durability of anti-pollution control device	yes	yes
Type VI	low ambient temperature tailpipe emissions after a cold start	yes	-
OBD	on board diagnosis	yes	yes

Table 4: Application of tests for type approval

After the vehicles had been received, a check was made as to whether the specified maintenance intervals had been observed and that the vehicles were in a proper condition. Proof was provided by means of the service record manual.

Preparations were made before the actual tests. The vehicles were checked with respect to the tightness of the exhaust system, catalytic function, oil and filter, fuel filter, air filter sparkplugs and of course OBD information was read to ensure that no emission relevant fault code was detected.

After that the vehicles were refuelled and sent to the soak area. Before the vehicles were tested on the chassis dynamometer the vehicles were refuelled with reference fuel (see Appendix 1 for more details regarding relevant fuels).

For dynamometer settings AVL received inertia weight and coast down values from the manufacturer. These data were same as for the type approval test. A deterioration factor was not used for evaluating the Type I test results.

For Type I tests, all vehicles were conditioned (1xNEDC for vehicles with positive ignition and 3xNEDC Part Two (Extra Urban Cycle) for vehicles with compression ignition, all according to the Directive 70/220/EEC as amended by 2003/76/EC.

Type II tests were performed on vehicles with positive ignition directly when the vehicles arrived to AVL MTC. Type III tests were performed on vehicles with positive ignition immediately after the Type I test. The OBD check was done at the end of the test procedure to make sure that the simulation of emission relevant failures could not affect the results of the other tests.

Table 5 displays the procedure of the different tests during the programme

Actions	**Positive Ignition**	**Compressed Ignition**
Re-fuel with reference fuel	5 vehicles per car family	5 vehicles per car family
CADC – ARTEMIS	3 vehicles per car family	3 vehicles per car family
Conditioning of vehicle	5 vehicles per car family (1xNEDC)	5 vehicles per car family (3xNEDC – Part Two)
Type I test	5 vehicles per car family	5 vehicles per car family
Type II test	5 vehicles per car family	N/A
Type III test	5 vehicles per car family	N/A
Type IV test	2 vehicles per car family	N/A
Type VI test	2 vehicles per car family (1xNEDC Part one)	N/A
OBD check	1 vehicles per car family	1 vehicle per car family

Table 5: Test programme

Figure 1 gives a simplified illustration of the programme conducted at AVL MTC.

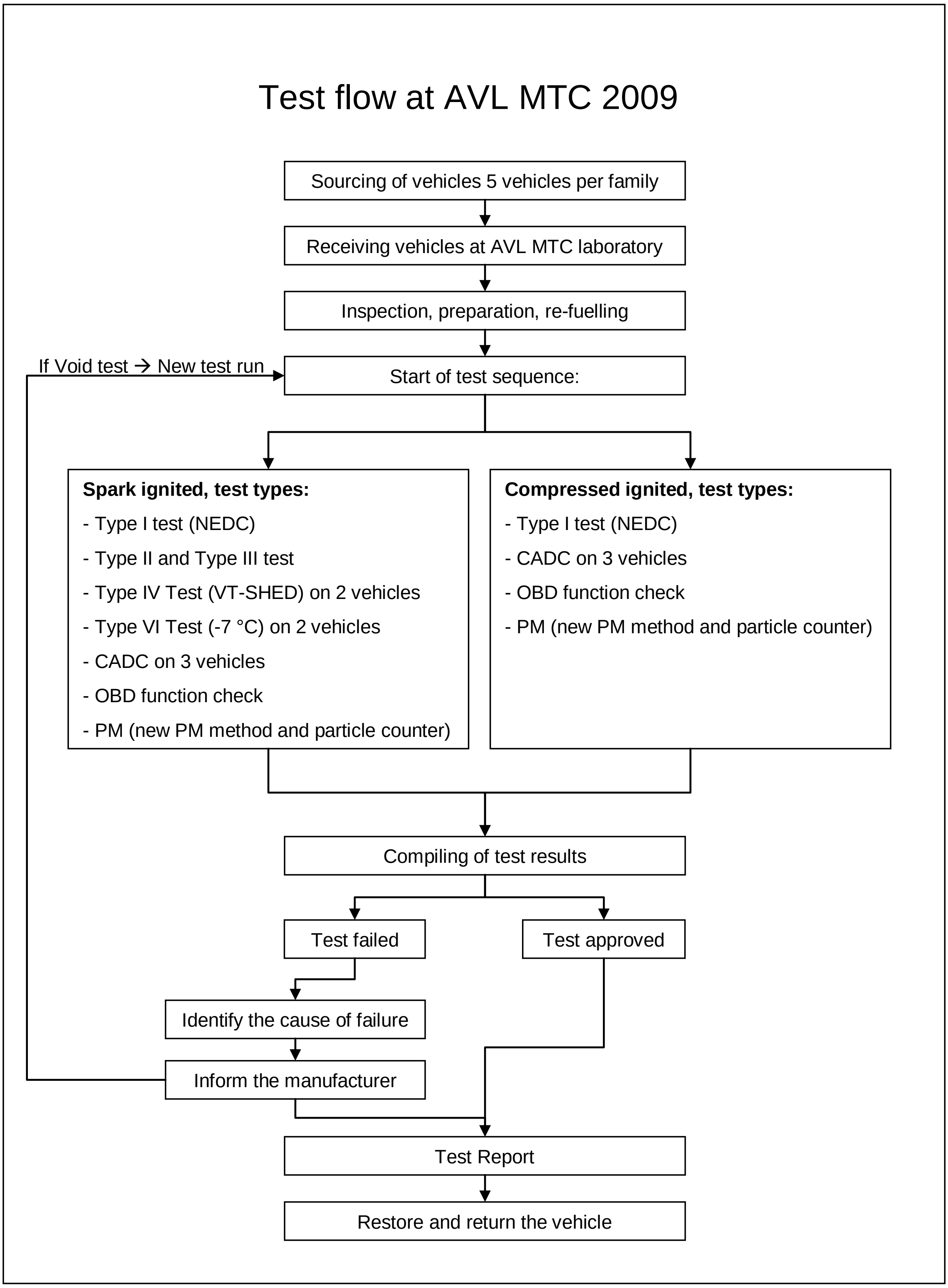


Figure 1: Illustration of the work flow for the In-Service Testing programme at AVL MTC 2009

Test Fuels

According to Directive 70/220/EEC as amended by 2003/76/EC reference fuels shall be used when performing the Type 1 and Type VI tests. During the test programme different batches of reference fuels was used.

For more detailed information regarding fuel compositions see Appendix 1

Test Cycles

New European Driving Cycle (NEDC)

After the test vehicles were conditioned in AVL MTC´s soak area for a minimum of 6 hours, at an ambient temperature of 20 °C up to 30 °C, the test sequence could began with the New European Driving Cycle (NEDC) cold start.

The Urban Driving Cycle (UDC, duration 780 seconds) is followed by an Extra Urban Driving Cycle (EUDC, duration 400 seconds). Exhaust emissions of both UDC and EUDC are collected and combined in a total test result.

Figure 2 shows the breakdown of the Type I test (NEDC).

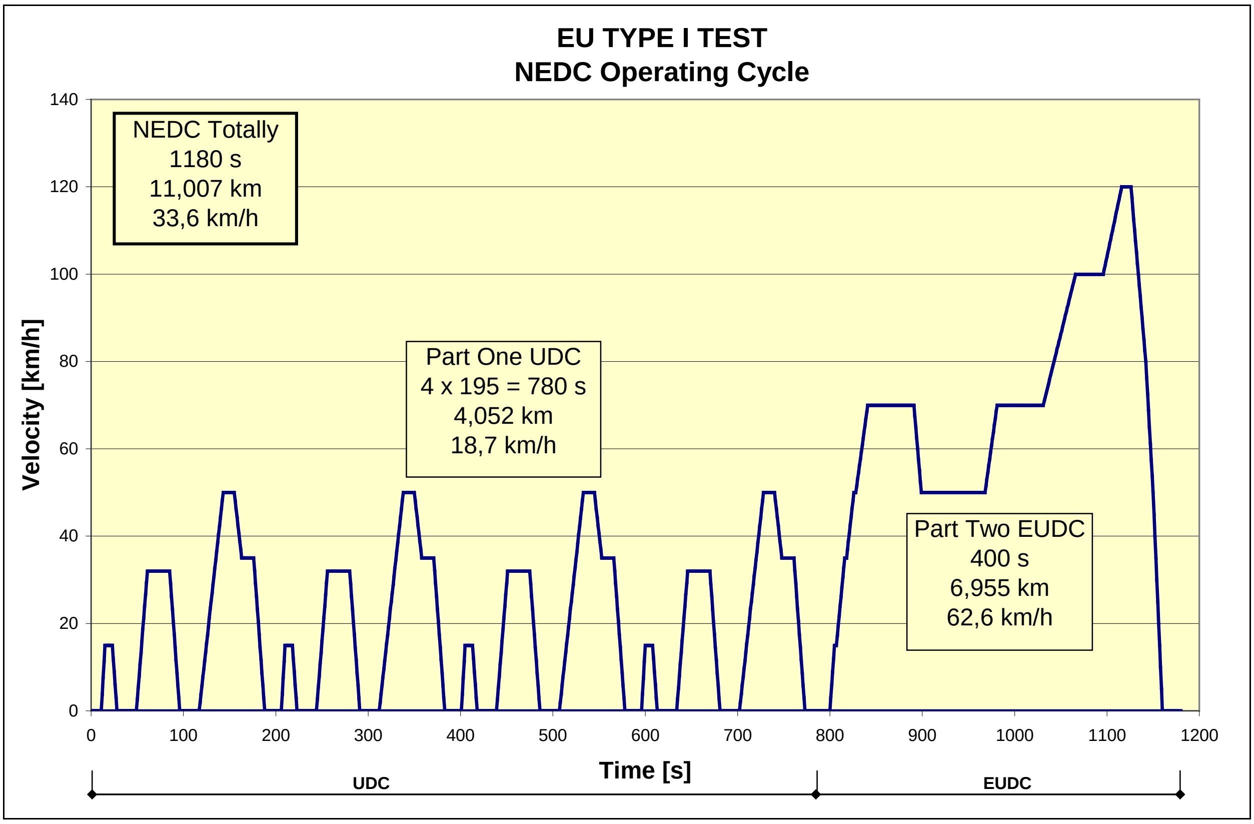


Figure 2: EU TYPE I Test - NEDC - New European Driving Cycle

Common Artemis Driving Cycle (CADC)

Besides in-service conformity testing the objective of the programme is also to get information on emissions from vehicles during real world driving. This data will be used to update the European emission model ARTEMIS. The ARTEMIS emission data base is used for emission inventories and as input to air pollution estimations. The CADC was created in order to gain a better knowledge about emissions in real traffic.

Three of five test vehicles / family were measured during the Common Artemis Driving Cycle (CADC). Carbon Monoxide (CO), Carbon Dioxide (CO2) Hydrocarbons (HC) Nitrogen oxides (NOx) and the Particle Number (PN) were recorded in modal form.

For the programme of 2009, 4 different measurement cycles were used to cover the specified CADC-range. They are shown in figures 3 to 6.

All the drive cycle is measured second by second on-line from 0s to end of cycle. But the bag samples were taken between the green and the red line, shown in figures 3 to 6.

The Common Artemis Driving Cycle consists of four sub cycles:
- Artemis urban cold cycle, duration 993 seconds, cold start
- Artemis urban cycle, duration 993 seconds, warm start
- Artemis road cycle, duration 1082 seconds, warm start
- Artemis motorway cycle, duration 1068 seconds, warm start

For the urban, road and motorway cycles; all test vehicles are subjected to a pre-conditioning drive to obtain similar start conditions before the actual test. The vehicles are driven 10 minutes at 80 km/h on their individual dyno-setting.

When the program of 2009 started, the ARTEMIS URBAN cycle was also used to run ARTEMIS Urban Cold cycle. Six families where carried out using the originally Urban cycle as “cold start cycle”. After some discussions with EMPA the “cold start cycle” was changed and the 7th family (and onward) used the modified cold start cycle (the first 72 seconds deleted). See figure 3.

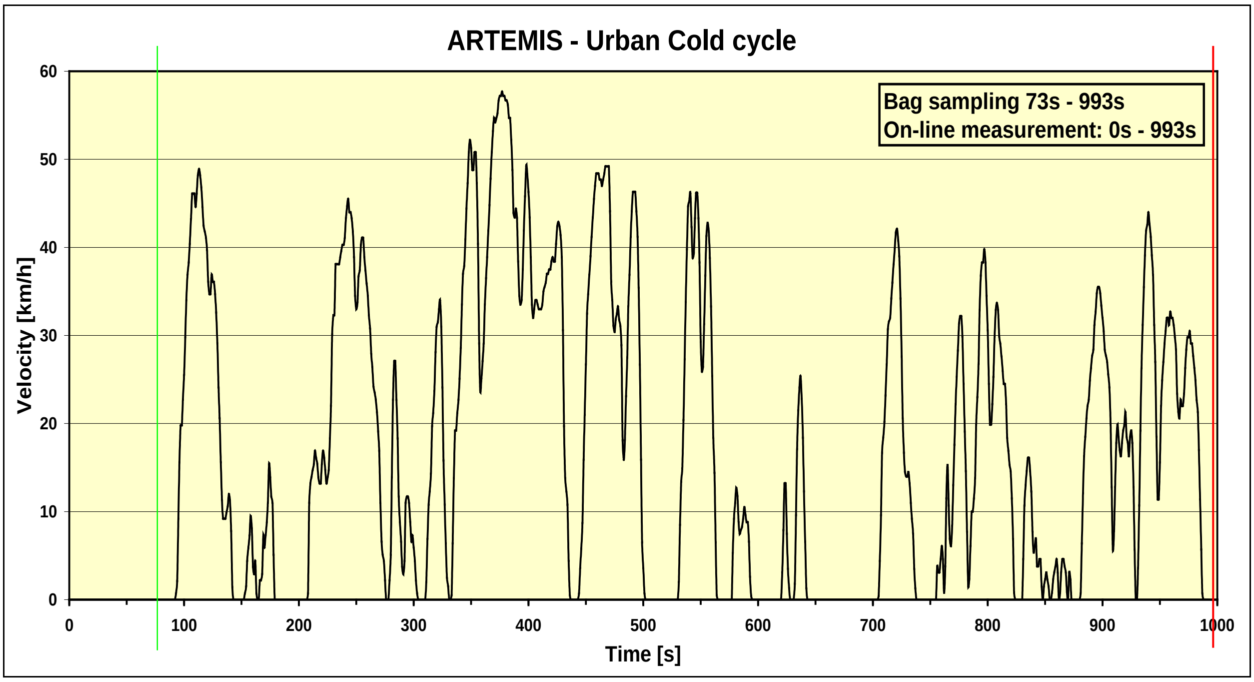


Figure 3: ARTEMIS – Urban Cold Cycle (without pre-conditioning)

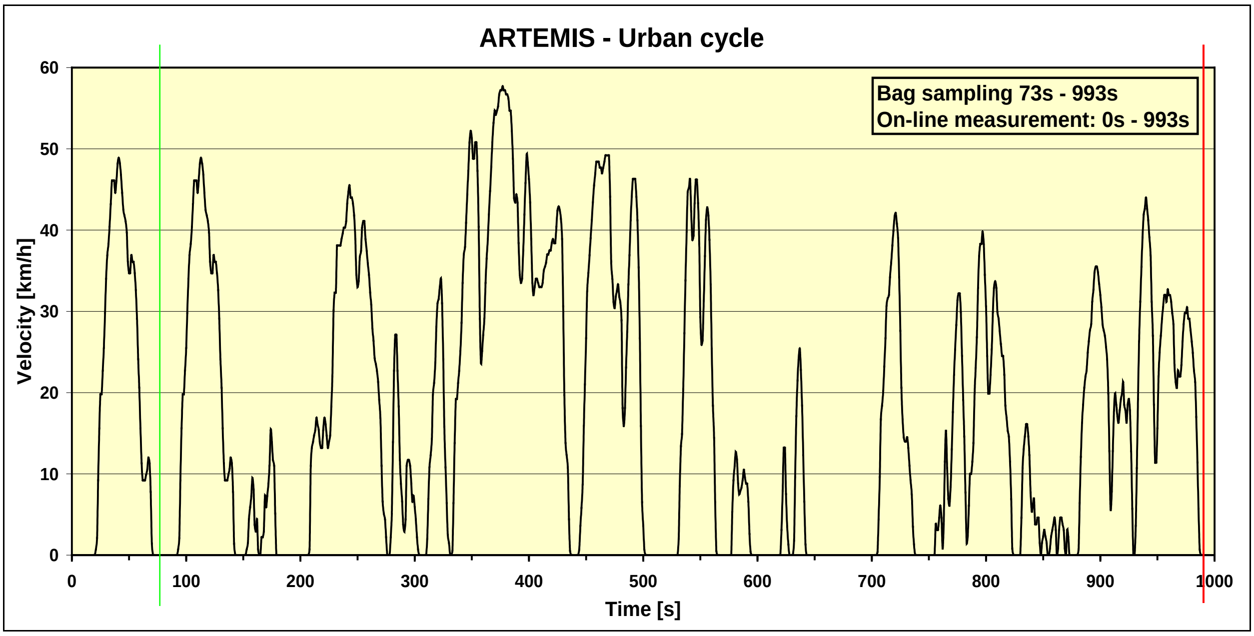


Figure 4: ARTEMIS – Urban Cycle

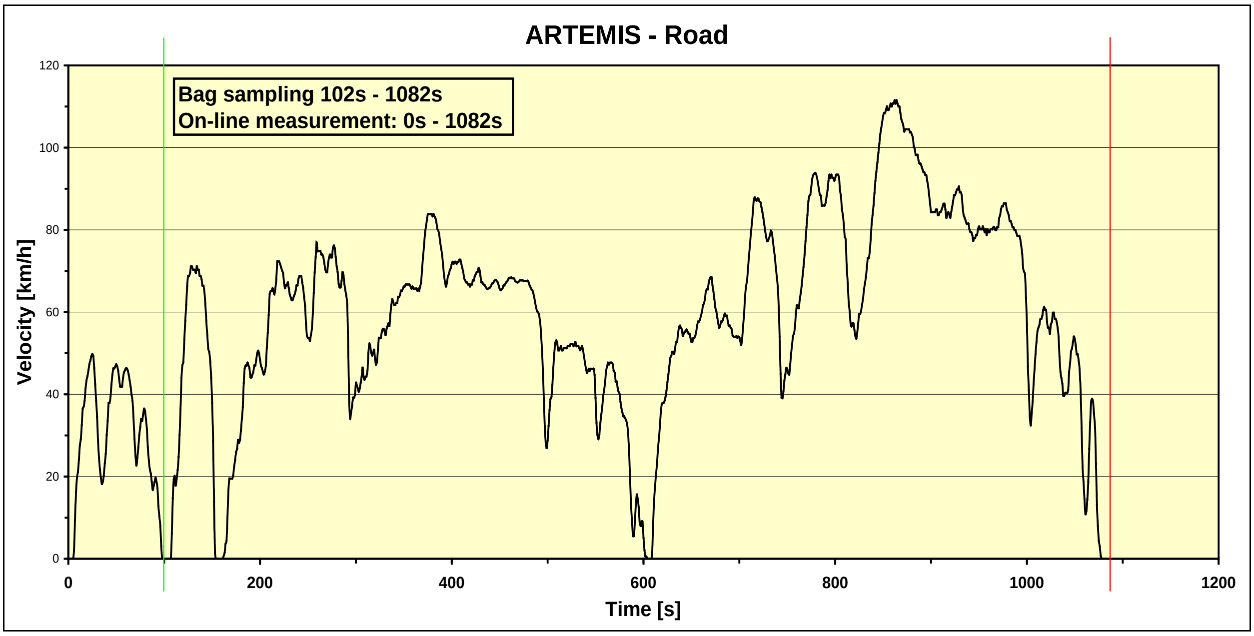


Figure 5: ARTEMIS – Road Cycle

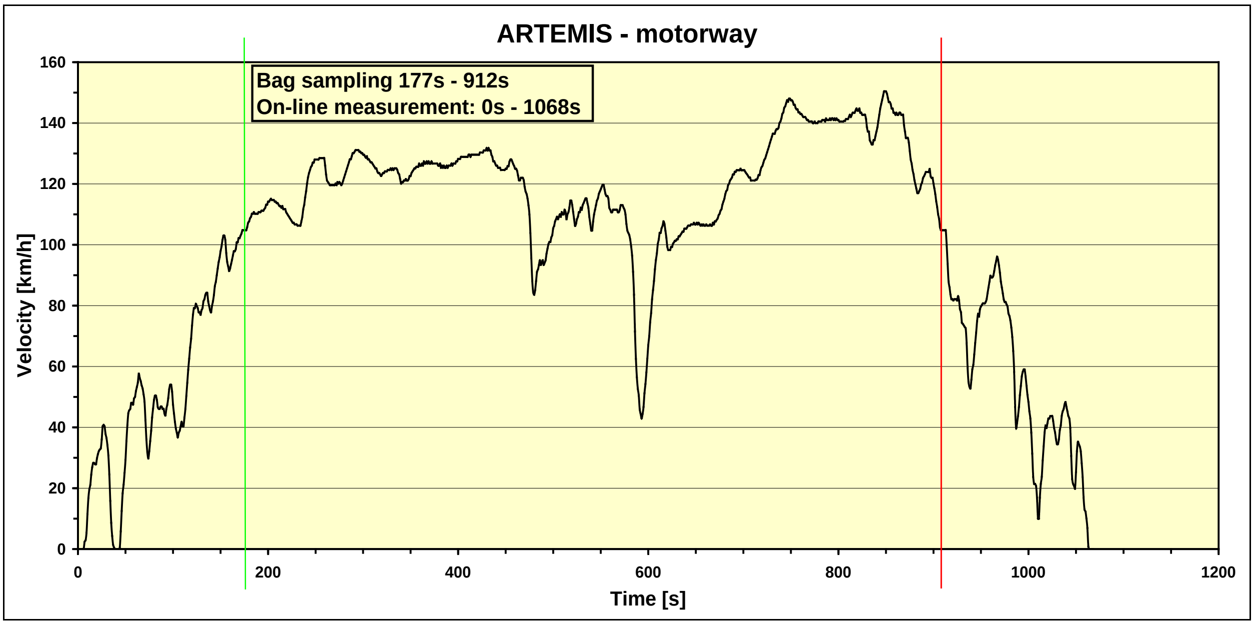


Figure 6: ARTEMIS – Motorway Cycle

Type VI test (-7 C)

The Type VI test is used to verify the average low ambient temperature Carbon Monoxide (CO) and Hydrocarbon (HC) tailpipe emissions after a cold start.

The test cycle is a modified Type I test (NEDC) were only the part one is used (UDC) (see figure 7).

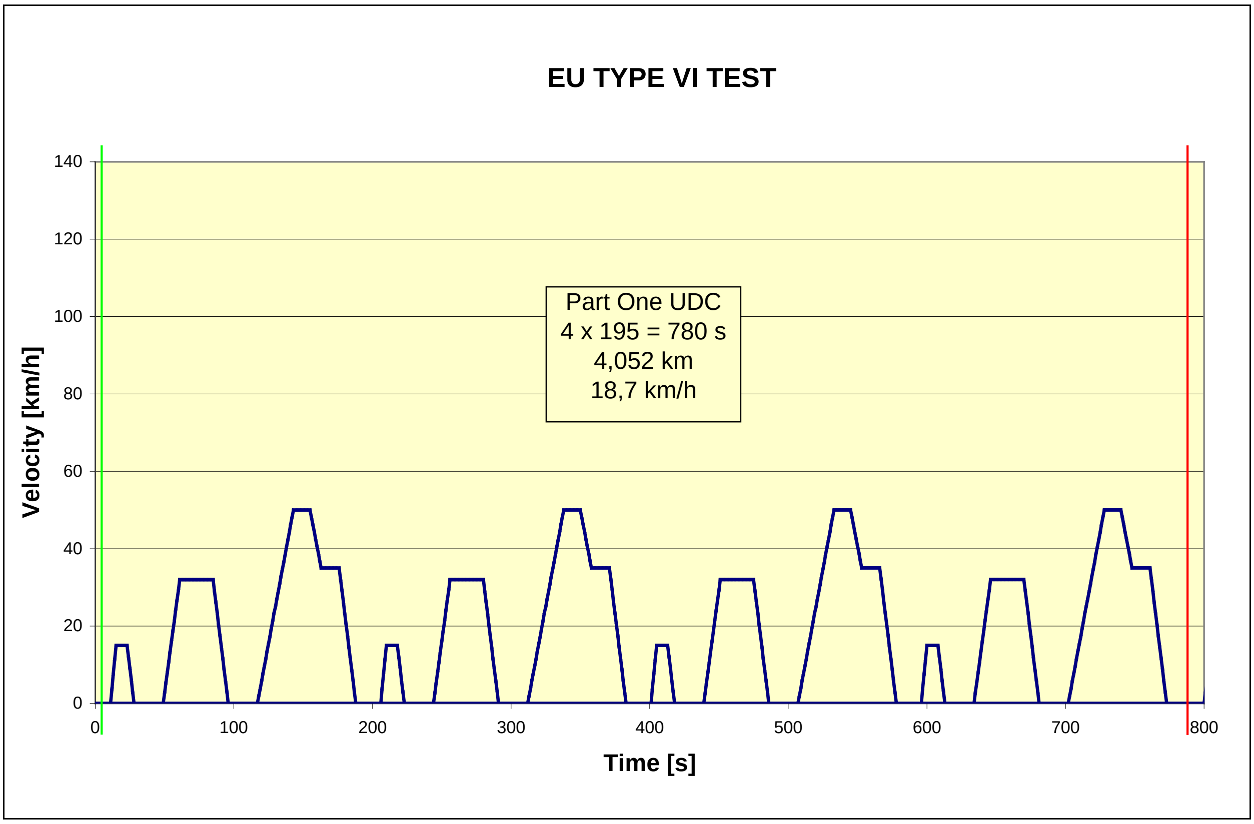


Figure 7: Type VI test cycle

Results

Emissions from Type I Test

Following sections show the average values for exhaust emissions from Type I testing. More detailed information from each family is shown in the test reports previously sent to STA.

In Table 6 the average NEDC values are presented in relevant categories. All the tested vehicle types complied with the given directive.

Category	Directive	CO [g/km]	HC [g/km]	NOx [g/km]	HC+NOx [g/km]	CO2 [g/km]	Fc (1) [L/100km]	PM-PMP [g/km]	PN [#]
Positive Ignition	Euro4	0,61	0,06	0,03	0,09	221	9,3	0,0008	2,99E+11
	Euro4	0,25	0,06	0,04	0,09	244	10,2	0,0003	6,30E+11
	Euro4	0,60	0,06	0,02	0,08	166	7,0	0,0029	3,01E+12
	Euro4	0,59	0,07	0,04	0,11	173	7,3	0,0007	4,46E+12
	Euro4	0,94	0,08	0,01	0,09	224	9,5	0,0002	1,11E+11
	Euro4	0,21	0,04	0,02	0,06	166	7,0	0,0005	5,20E+11
Limit	Euro4	**1,0**	**0,10**	**0,08**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Compression Ignition	MK 2005PM	0,39	0,04	0,20	0,24	185	7,0	0,0003	5,41E+10
	MK 2005PM	0,17	0,02	0,18	0,20	168	6,4	0,0016	3,77E+12
	MK 2005PM	0,26	0,02	0,18	0,21	161	6,1	0,0005	1,03E+12
	MK 2005PM	0,31	0,03	0,19	0,23	214	8,1	0,0002	4,38E+10
	Euro4 N1 class III	0,05	0,02	0,34	0,35	250	9,5	0,0298	1,21E+14
Limit	**MK 2005PM**	**0,50**	**N/A**	**0,25**	**0,30**	**N/A**	**N/A**	**0,005**	**N/A**
	Euro4 N1 class III	**0,74**	**N/A**	**0,39**	**0,46**	**N/A**	**N/A**	**0,060**	**N/A**
E85 (2)	Euro4	0,24	0,05	0,03	0,08	165	10,0	0,0003	2,02E+11
	Euro4	0,62	0,05	0,02	0,07	158	9,9	0,0003	1,95E+11
CNG (2)	Euro4	0,47	0,07	0,02	0,09	178	10,0	0,0001	1,82E+10
Limit	**Euro4**	**1,0**	**0,10**	**0,08**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

(1) Fc for CNG vehicles = **[nm3/100km]**
(2) E85 and CNG vehicles follow the Euro 4 emission regulations

Table 6: Average exhausts emissions during Type I test (NEDC)

The following figures 7 to 12 gives examples of average CO, HC and NOx emissions from Type I tests from vehicles with positive ignition and compressed ignition. As can be seen in the figures the most of the emissions occur at cold start and in the beginning of the test cycles. Regarding the compressed ignition vehicles NOx emissions really rise on the high way part of the NEDC-cycle.

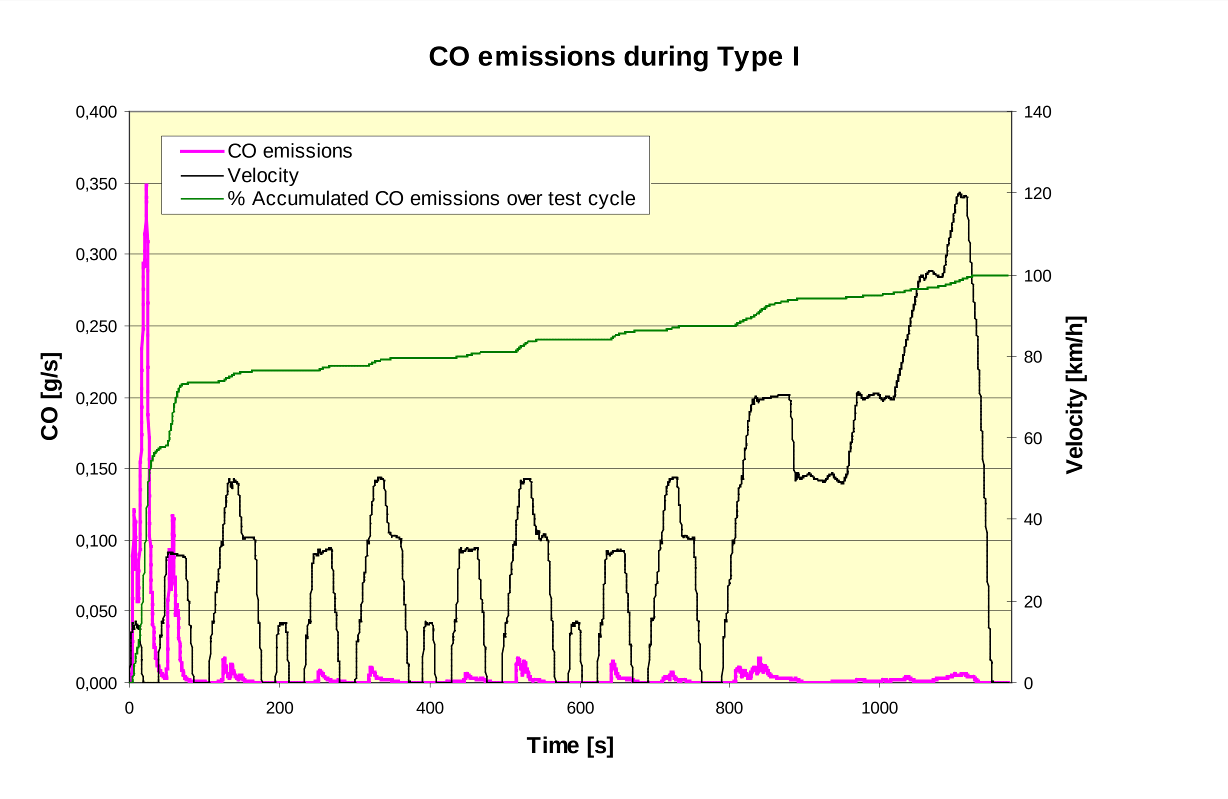


Figure 7: Average CO emitted by a positive ignition vehicle during Type I test

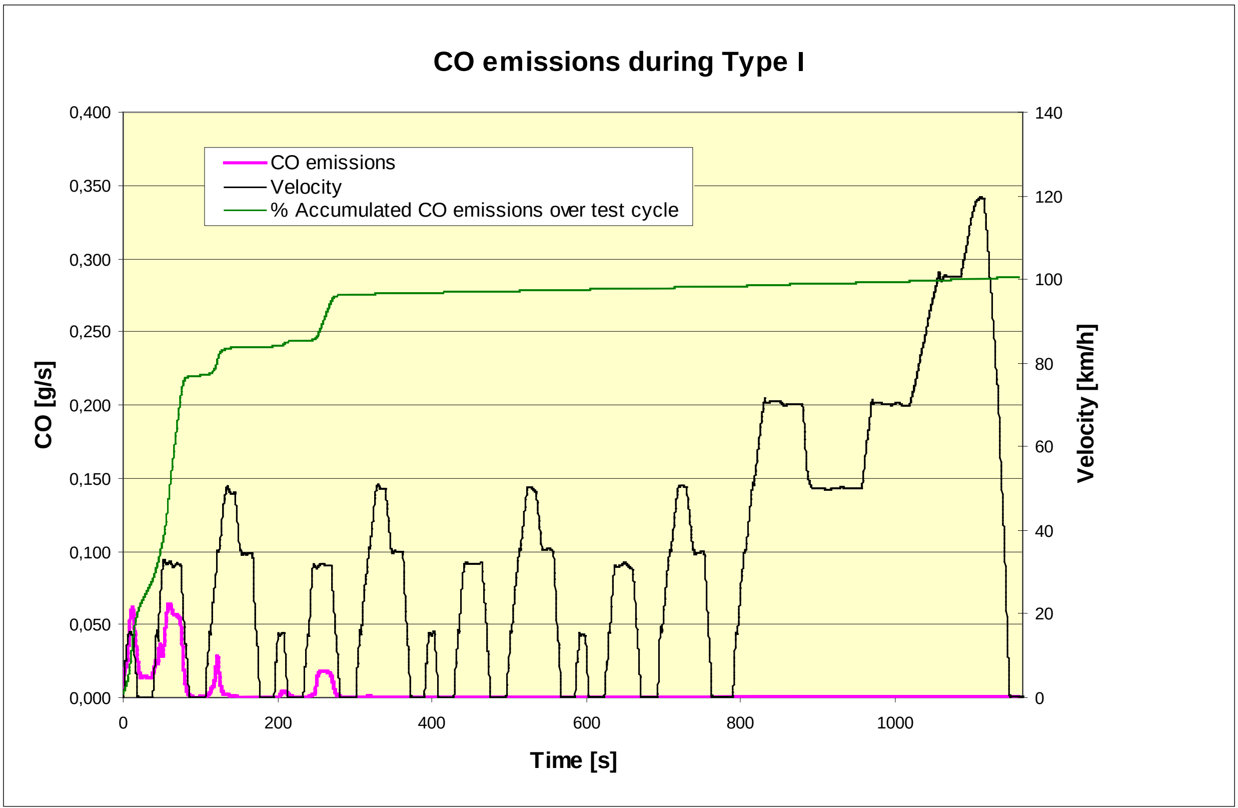


Figure 8: Average CO emitted by a compressed ignition vehicle during Type I test

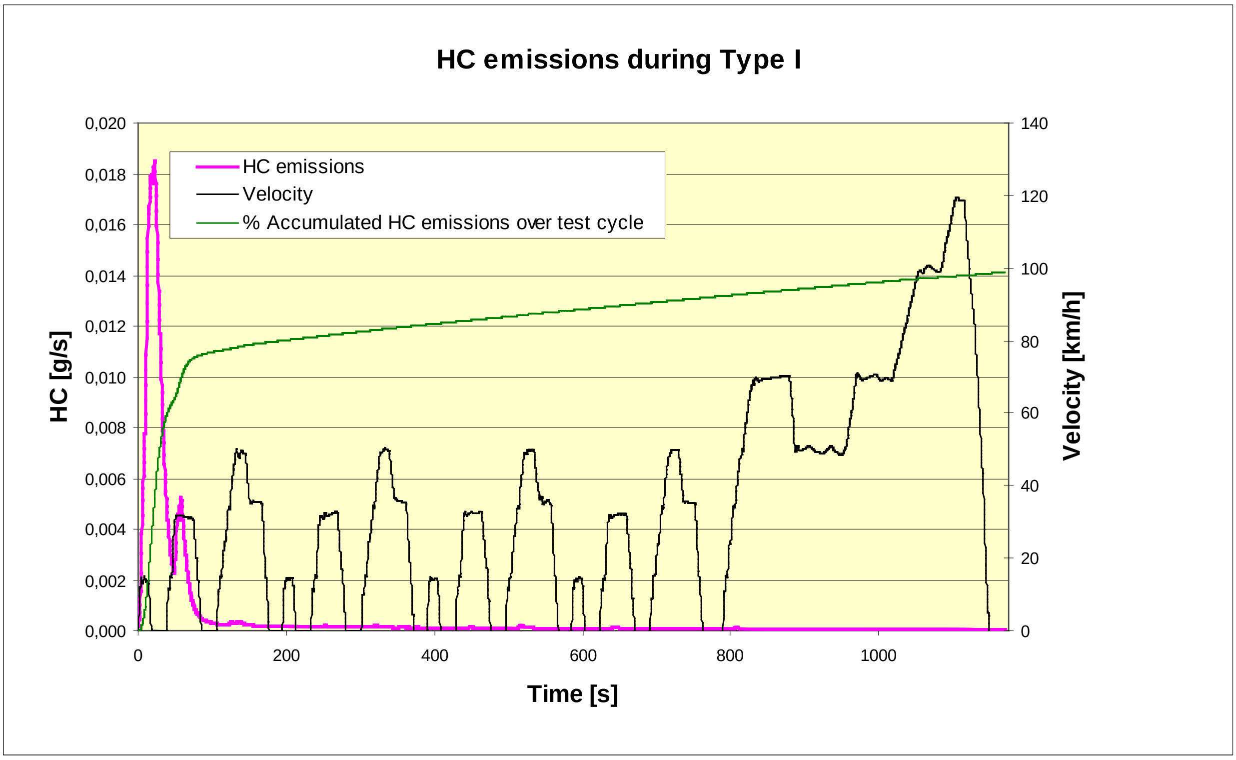


Figure 9: Average HC emitted by a positive ignition vehicle during Type I test

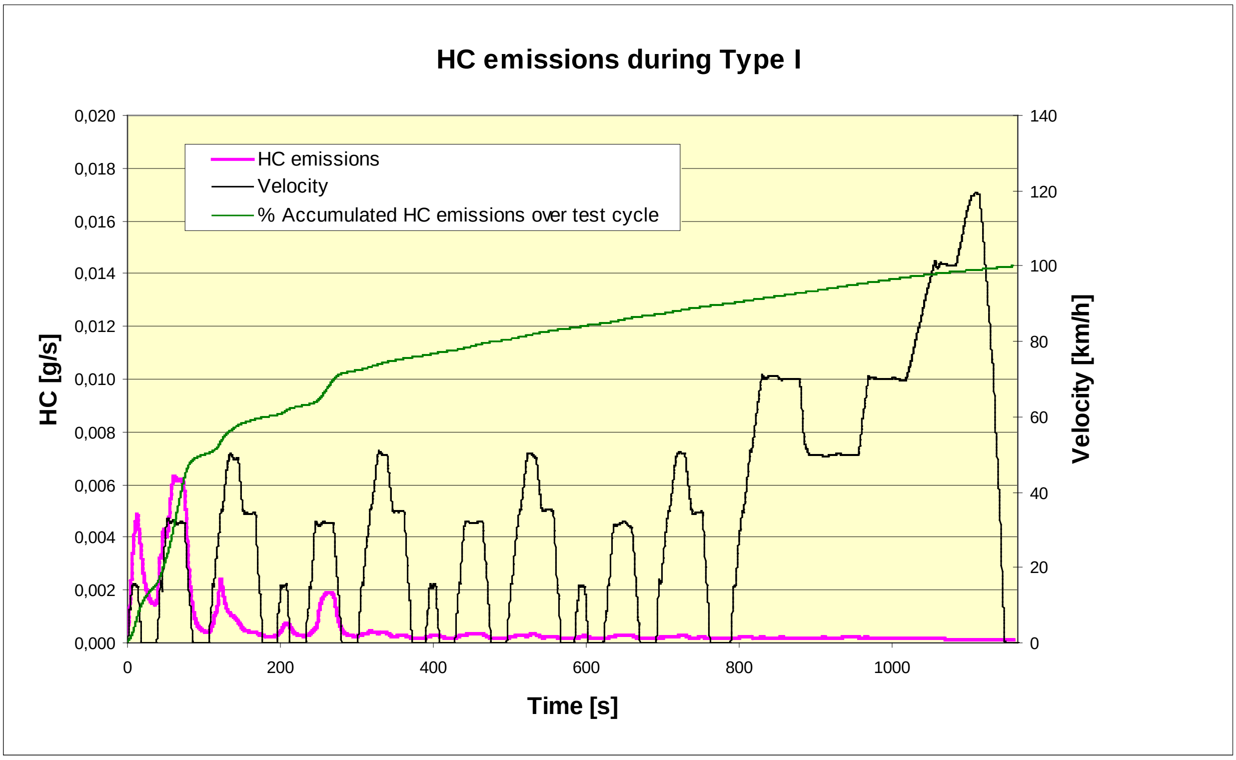


Figure 10: Average HC emitted by a compressed ignition vehicle during Type I test

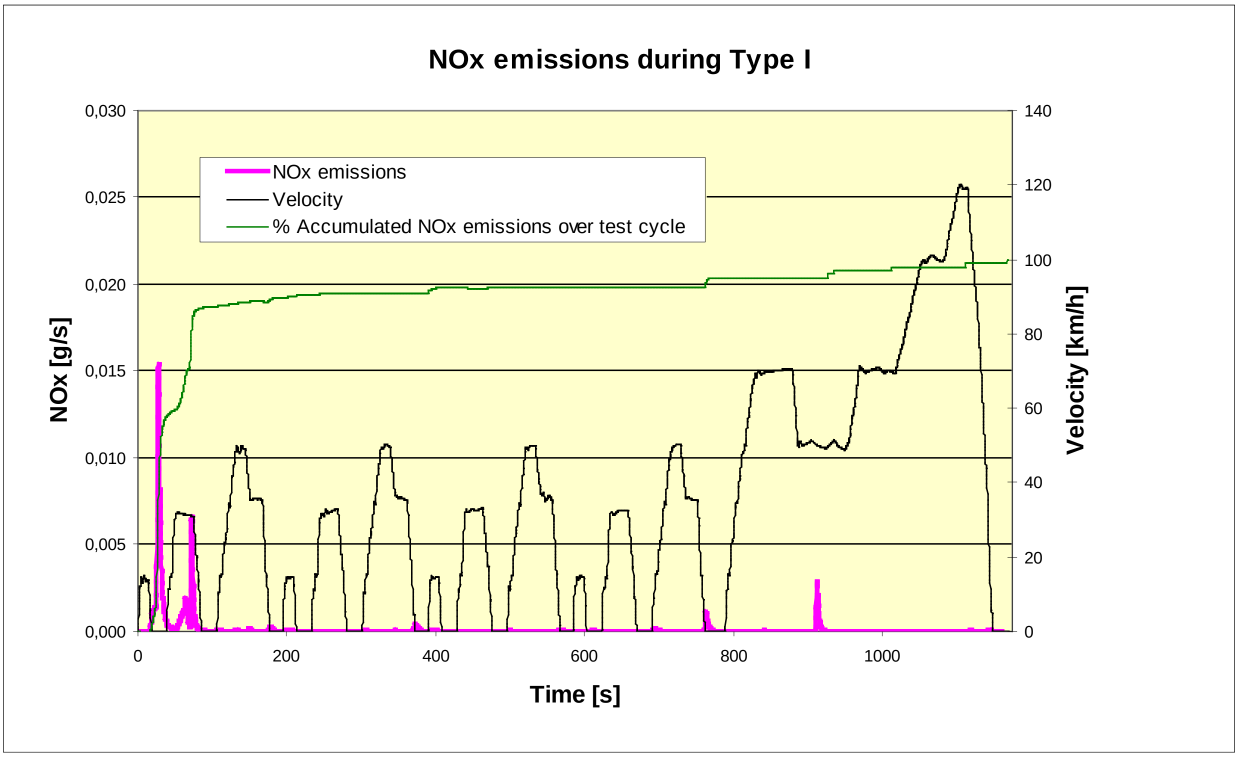


Figure 11: Average NOx emitted by a positive ignition vehicle during Type I test

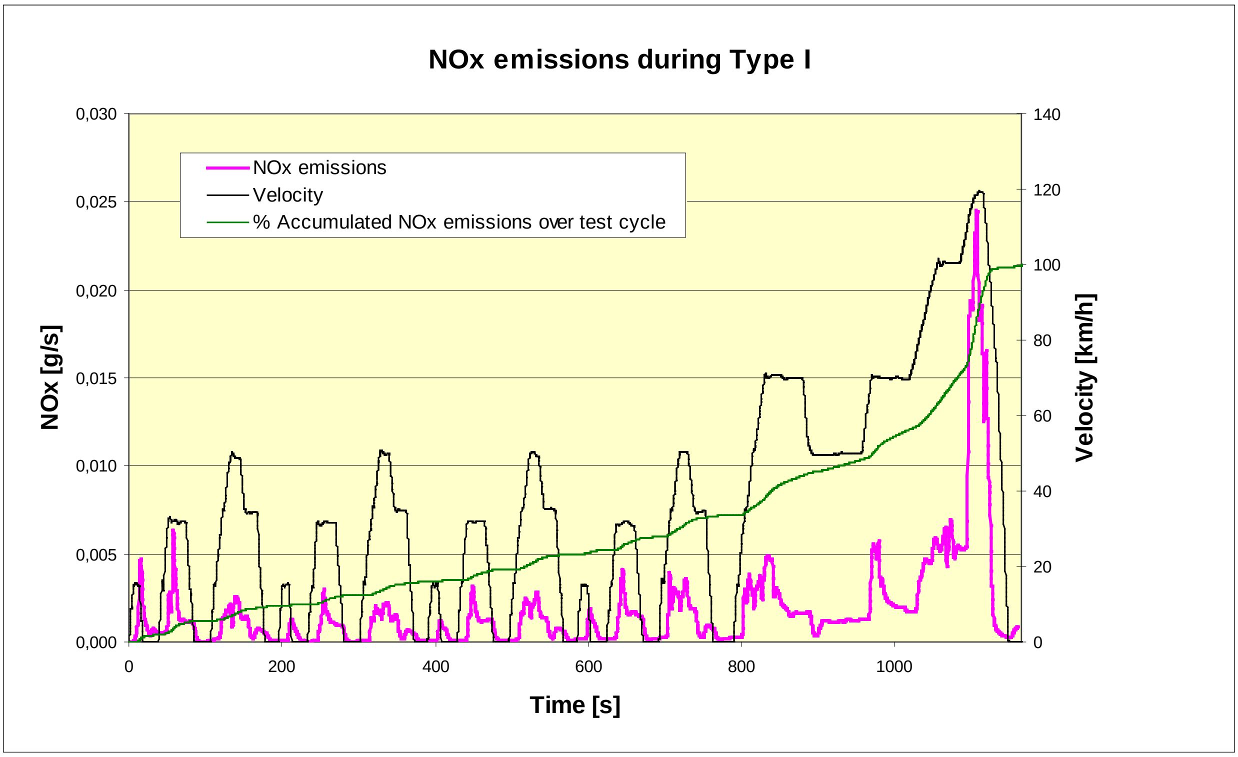


Figure 12: Average NOx emitted by a compressed ignition vehicle during Type I test

Figure 13 shows the average Carbon Monoxide and Hydrocarbon emissions during Type I test of positive ignition vehicles. Only one of the positive ignition vehicles, driven on petrol, exceeded the Euro 4 limit. After a change of spark plugs and re-updated software the vehicle in particular complied within limits.

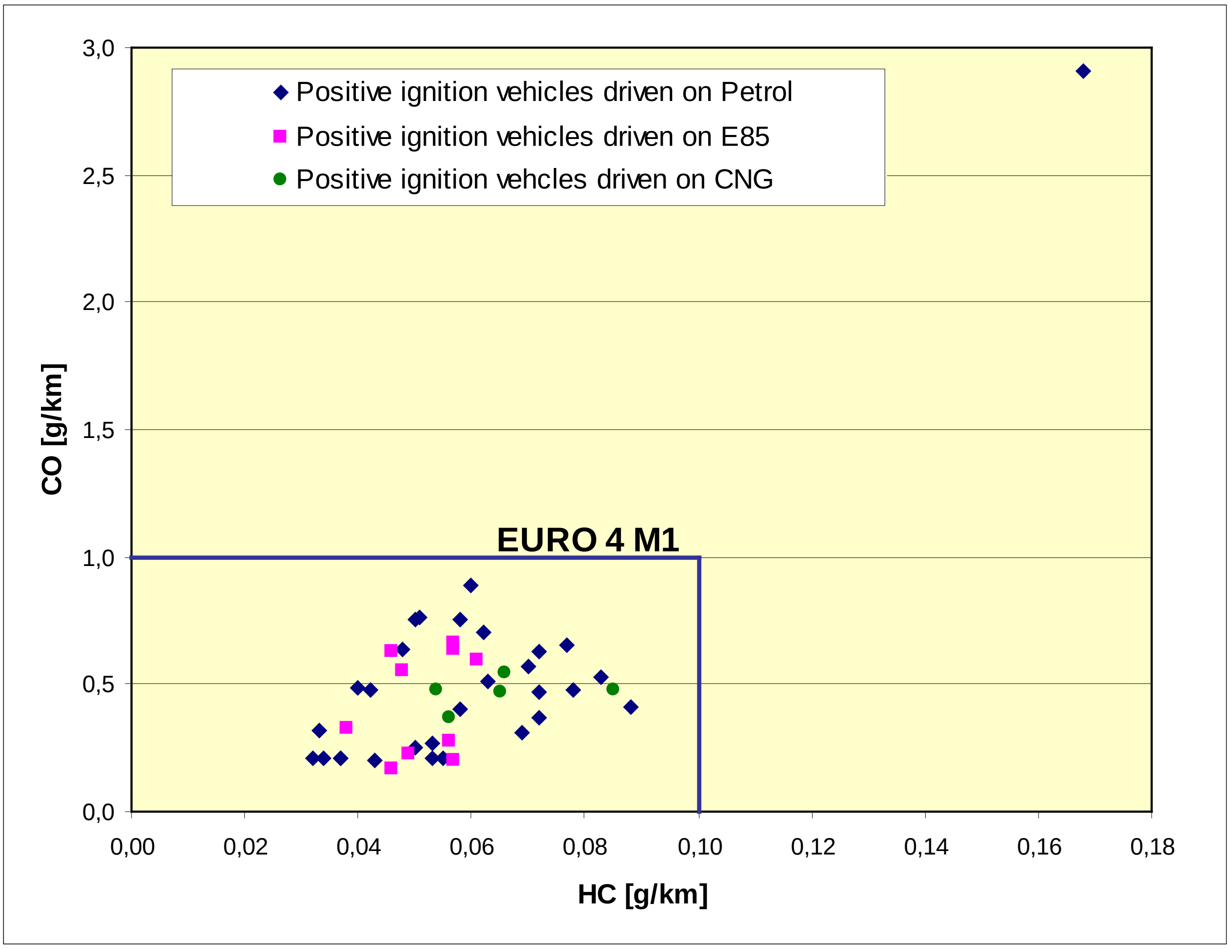


Figure 13: CO and HC emissions of vehicles with positive ignition during Type I test

Figure 14 shows the average Nitrogen Oxides and Hydrocarbon emissions during Type I test of positive ignition vehicles. Only one of the positive ignition vehicles, driven on petrol, exceeded the Euro 4 limit. After a change of spark plugs and re-updated software the vehicle in particular complied within limits.

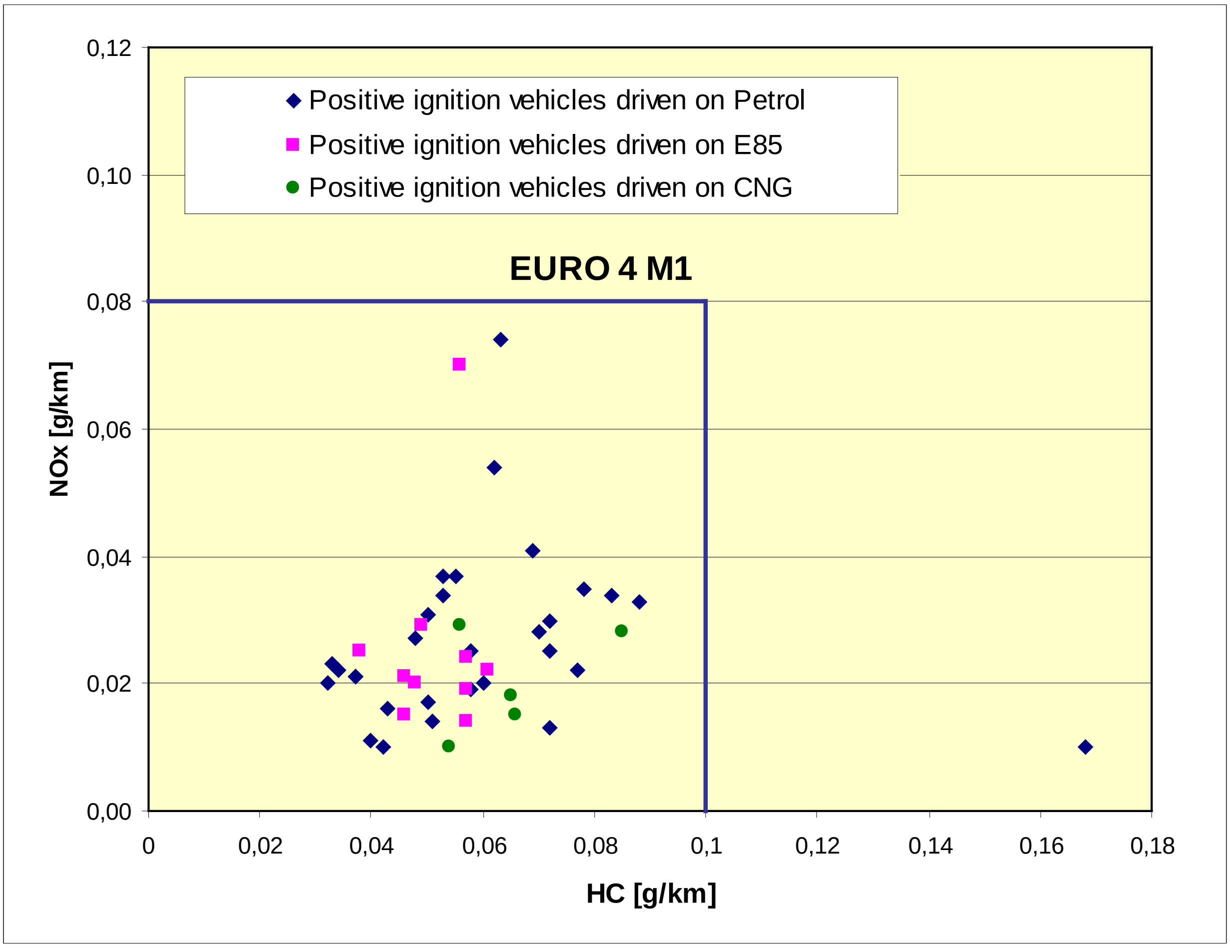


Figure 14: NOx and HC emissions of vehicles with positive ignition during Type I test

Figure 15 shows the average Carbon Monoxide and Nitrogen Oxide emissions during Type I test of compressed ignition vehicles. As can be seen only one of the M1 and one of the N1 class III compressed ignition vehicles exceeded the Euro 4 limit.

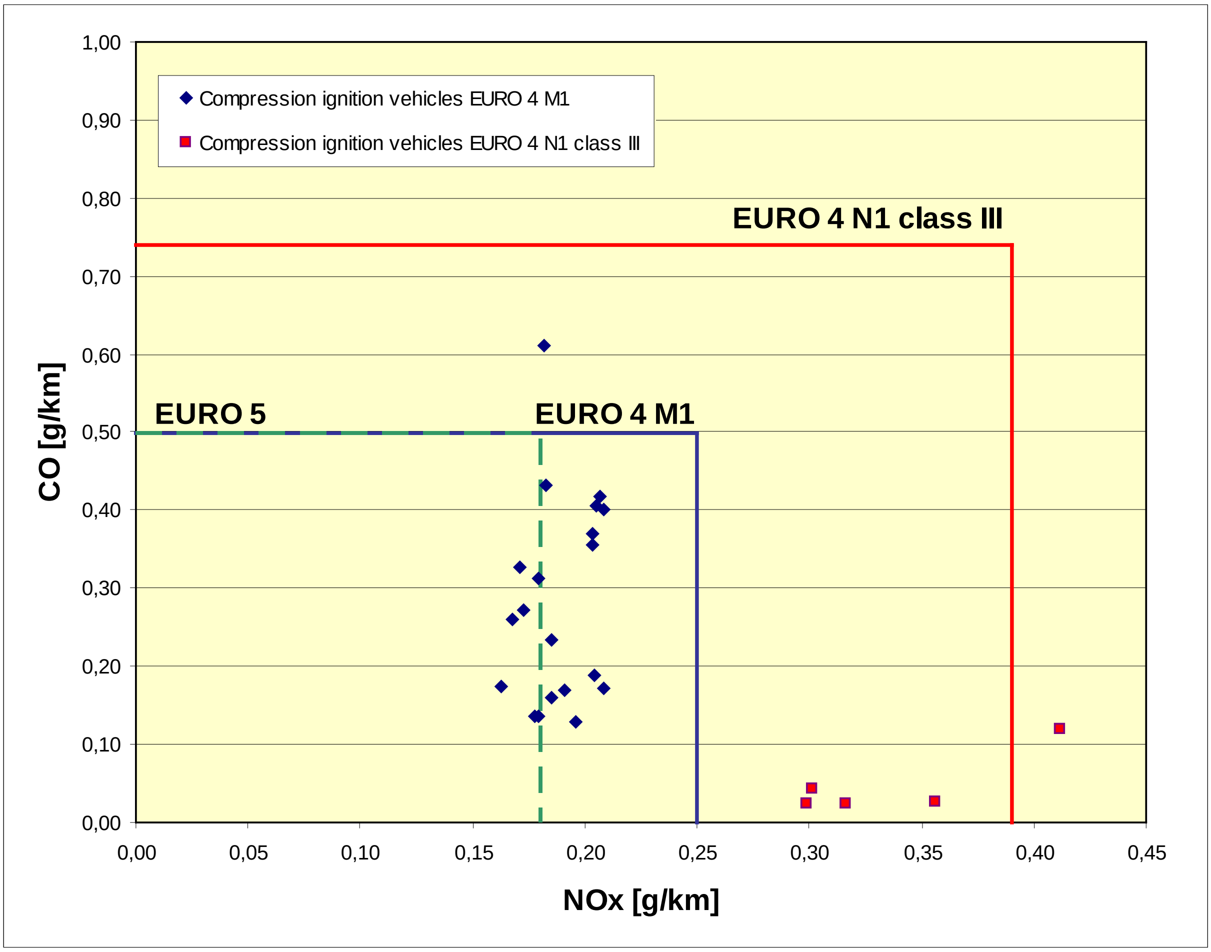


Figure 15: CO and NOx emissions from Euro 4 M1 vehicles and Euro 4 N1 class III vehicles with compressed ignition during Type I test

Figure 16 shows the average Particle Mass and Nitrogen Oxides emissions during Type I test of compressed ignition vehicles. As can be seen only one of the N1 class III diesel vehicles exceeded the limit. The M1 vehicles are gathered well within the Euro 4 limit. The N1 class III vehicles were not equipped with DPF.

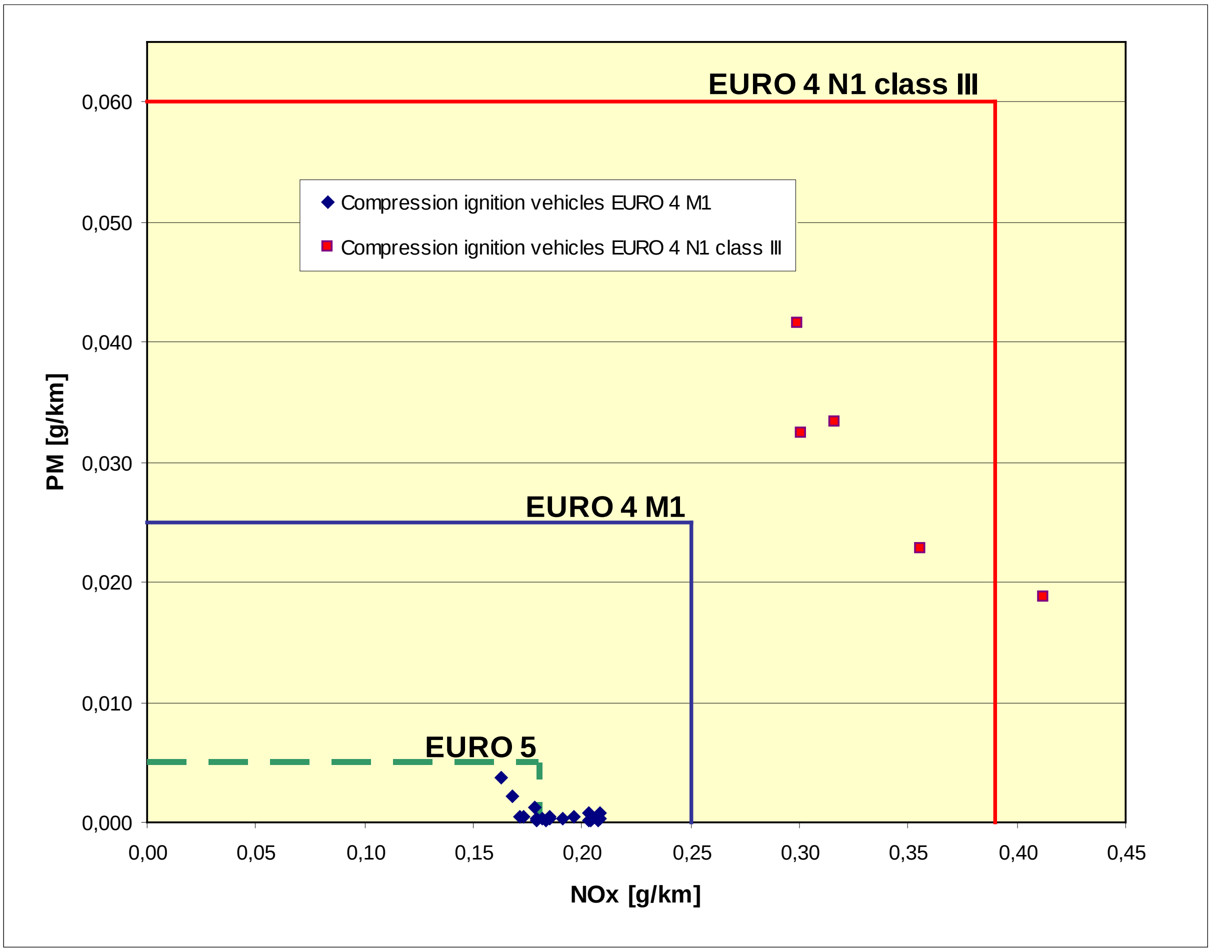


Figure 16: Particle mass and NOx emissions from Euro 4 M1 vehicles and Euro 4 N1 class III vehicles with compressed ignition during Type I test

Carbon Dioxide emissions Vs. Fuel consumption

According to Directive 80/1268/EEC, the member states are not permitted to refuse grant of the EC type approval or conformity of production with national validity for a vehicle type for reasons which are related to the emission of carbon dioxide and fuel consumption if the CO2 emission and fuel consumption are determined in accordance with Annex I of the Directive. These values are therefore a part of the type approval. However, there are no limit values. The CO2 and consumption declarations are for consumer information and in many EU countries used as a basis for vehicle related taxes.

In Sweden for example the annual vehicle tax is a linear function of the CO2 emissions above 100 g/km. The Directive requires that the values are contained in a document which is supplied to the owner by the manufacturer when the vehicle is purchased. If the CO2 and consumption values are considerably exceeded, the buyer could apply warranty claims in the legal sense. The CO2 emissions are measured in the "New European Driving Cycle" (Type I test). The fuel consumption is calculated using the measured CO2 emissions and the other carbon containing emissions (CO and HC). Measurement in accordance with Directive 80/1268/EEC is carried out using reference fuel as in the case of the parallel exhaust emission measurements. The test vehicle must be presented in good mechanical condition. It must be run-in and must have been driven for at least 3,000 km, but for less than 15,000 km.

In figure 17 the measured fuel consumption (incl. max and min values) is compared with the manufacturers given fuel consumption.

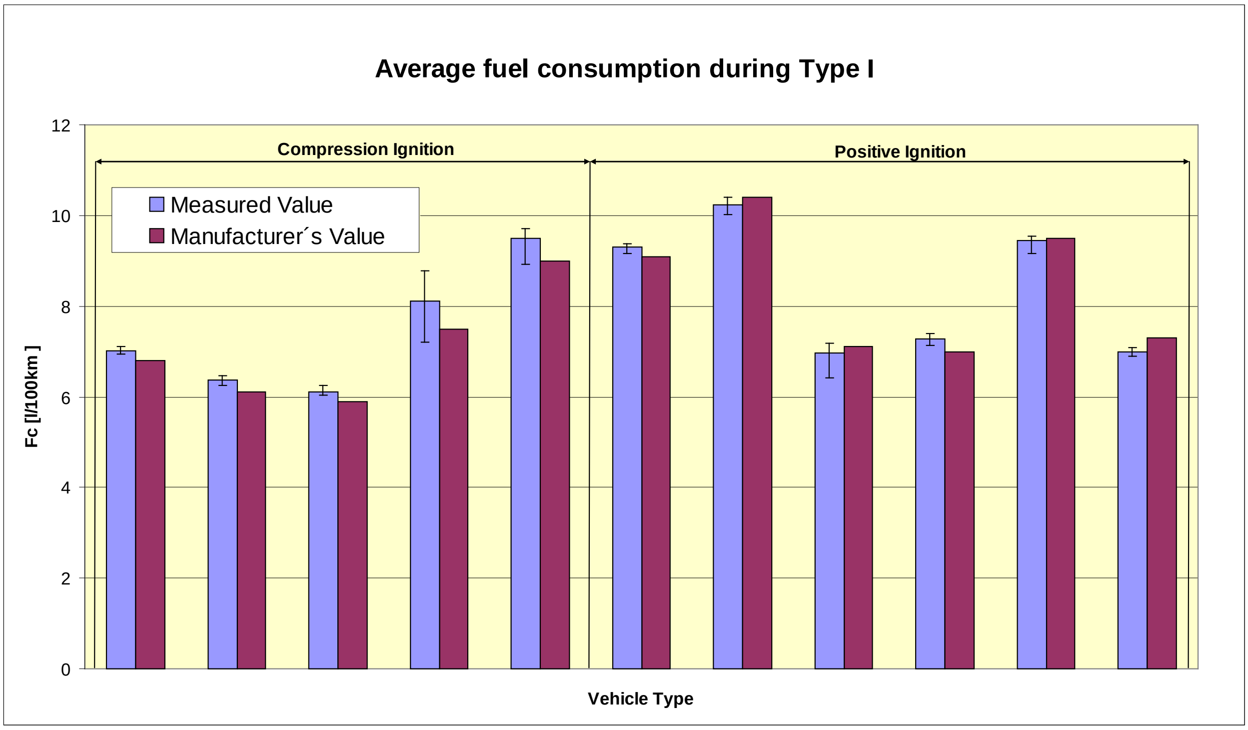


Figure 17: Average fuel consumption during Type I test for different vehicle types

Figure 18 shows the Fc deviation between measured and manufacturer values. Nine of the tested families showed higher Fc compared to the manufacturers' values. Three vehicle types showed lower Fc compared to manufacturers' values.

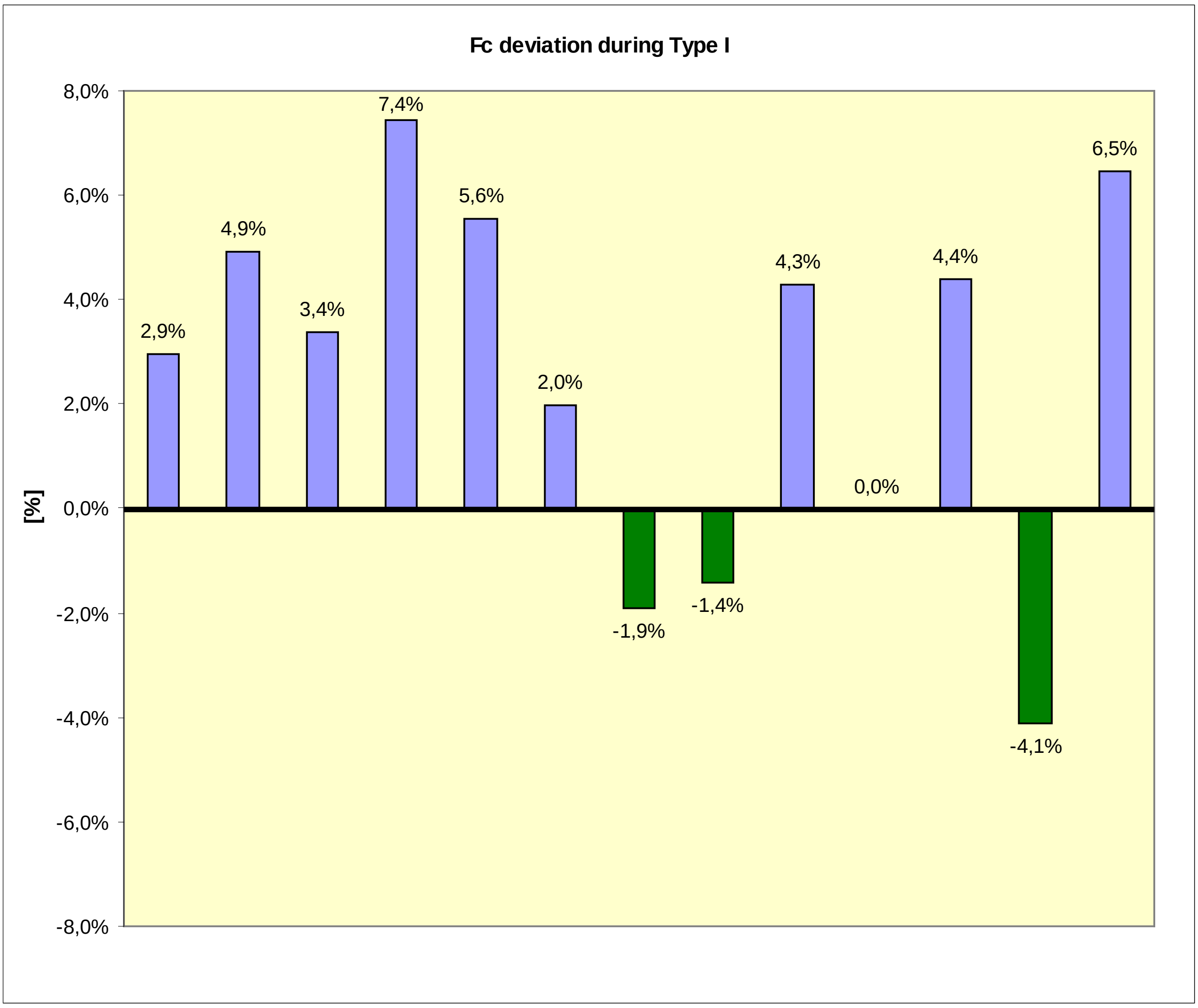


Figure 18: Relative deviation of the Fc towards the manufacturer's values during Type I test for different vehicles types

In figure 19 the measured CO2 emissions is compared with the manufacturers given CO2 emissions.

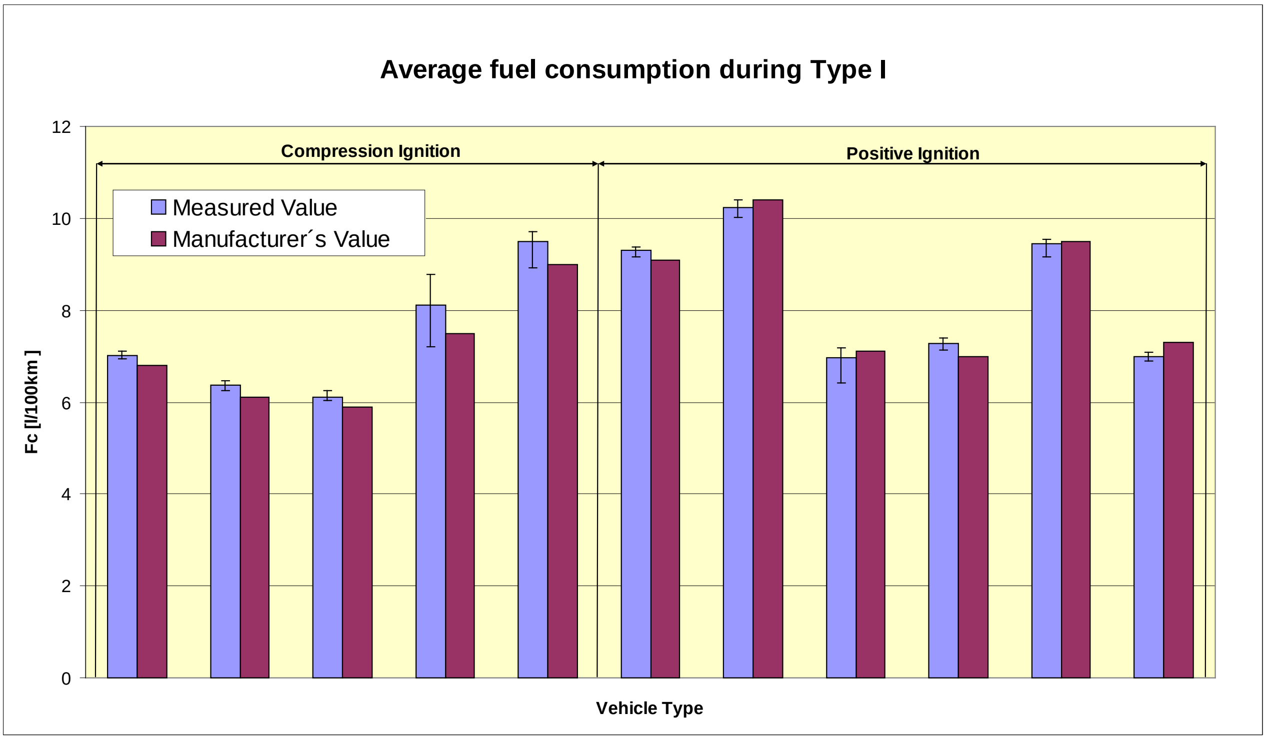


Figure 19: Average CO2 emissions during Type I test for different vehicle types

Figure 20 shows the CO2 deviation between measured and manufacturer values. Eight of the tested families showed higher CO2 compared to the manufacturers' values. Four vehicle types showed lower CO2 emissions compared to the manufacturers' values.

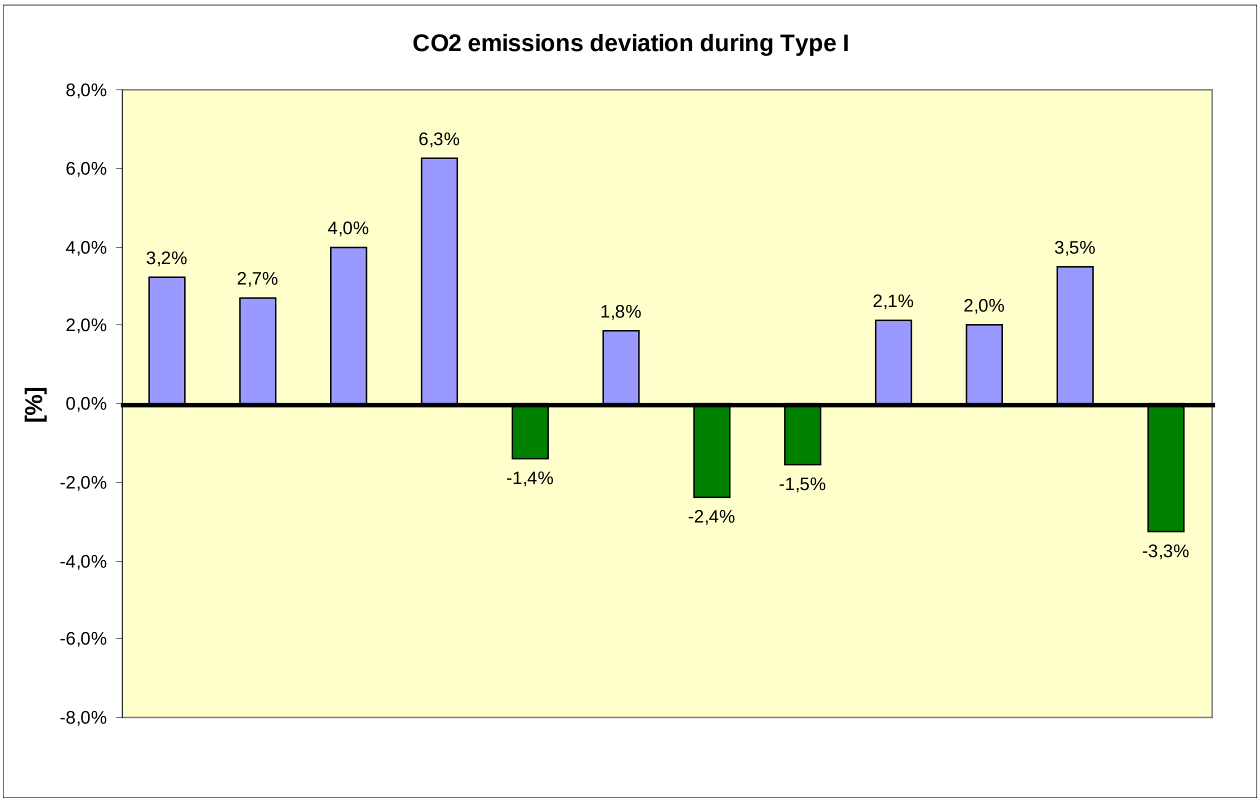


Figure 20: Relative deviation of the CO_2 emissions towards the manufacturer's values during Type I test for different vehicles types

Idle Test (Type II test)

During the Type II test, the environmental temperature must be between 20 and 30 °C.
The exhaust emissions measured at idle speed and at about 2,500 rpm.

None of the tested vehicles with positive ignition had emission related problems. The results are displayed in Table 7.

The Type II test is not relevant for vehicles with compression ignition engine.

	Idle			
	CO [%vol.]	HC [ppm]	CO_2 [%vol.]	λ
Average Gasoline	0,003	4	14,9	1,004
Limits	3,5	-	-	-
	High Idle (2.500 rpm)			
	CO [%vol.]	HC [ppm]	CO_2 [%vol.]	λ
Average Gasoline	0,004	4	14,8	1,009
Limits	-	-	-	-
	Idle			
	CO [%vol.]	HC [ppm]	CO_2 [%vol.]	λ
Average E85	0,003	2	14,6	1,002
Limits	3,5	-	-	-
	High Idle (2.500 rpm)			
	CO [%vol.]	HC [ppm]	CO_2 [%vol.]	λ
Average E85	0,002	4	14,5	1,004
Limits	-	-	-	-
	Idle			
	CO [%vol.]	HC [ppm]	CO_2 [%vol.]	λ
Average CNG	0	2	11,2	1,002
Limits	3,5	-	-	-
	High Idle (2.500 rpm)			
	CO [%vol.]	HC [ppm]	CO_2 [%vol.]	λ
Average CNG	0,002	5	11,2	1,006
Limits	-	-	-	-

Table 7: Exhausts emissions during Type II test (Idle test)

Crankcase Ventilation (Type III test)

Exhaust gases passing by the piston rings could cause environmental pollution. Therefore vehicles with positive ignition engine are equipped with a crankcase ventilation system.

The crankcase gases are routed to the intake manifold and are combusted in the engine. The crankcase ventilation system is tested by measuring the pressure within the system. The pressure measured in the crankcase may not exceed the atmospheric pressure at different load conditions. Measuring the crankcase emissions is not relevant for vehicles with compression ignition engine.

On four of thirty vehicles crankcase overpressure were detected at different loads. The manufacturers is notified about the phenomenon and more detailed investigation has to be done to see find out the root cause.

Evaporative Emissions (Type IV test)

If the petrol located in the fuel system tank is heated, hydrocarbons evaporate. These vapours escaping into the environment cause considerable pollution. For this reason, modern vehicles with positive ignition engine are equipped with a system for retaining such fuel vapours.

For type approval testing, in addition to exhaust emissions in the driving cycle, the amount of evaporative hydrocarbon emissions escaping mainly from the vehicle fuel system is measured. For this Type IV test a Sealed Housing for Evaporative Emissions Determination (SHED) is used. The Type IV test is designed to determine hydrocarbon evaporative emissions caused by hot soaks during parking and by diurnal temperatures variation. The measurement of evaporative emissions according to Directive 70/220/EEC includes three phases:

- Test preparation including a NEDC (Type I test)
- Hot soak loss determination
- Diurnal loss determination

For measuring the hot soak emissions, the test vehicle is placed in a SHED for one hour directly after having finished a New European Driving Cycle. During the diurnal test the vehicle is placed in the SHED for 24 hours to determine the fuel-system and tank ventilation losses.

The vehicle is exposed to an ambient temperature cycle which simulates the temperature profile for a summer day, and the hydrocarbons released are then measured. In this way, hydrocarbon emissions due to permeation and micro-leaks in the whole fuel-bearing system are considered.

During this In-Service Conformity testing programme of 2009, measurement of the evaporative emissions was carried out on two vehicles per type with positive ignition engine. Before the vehicles were tested, all loose things, such as perfumes, rugs, bottles etc. were removed to prevent void results.

Figure 21 visualize the Type IV test flow.

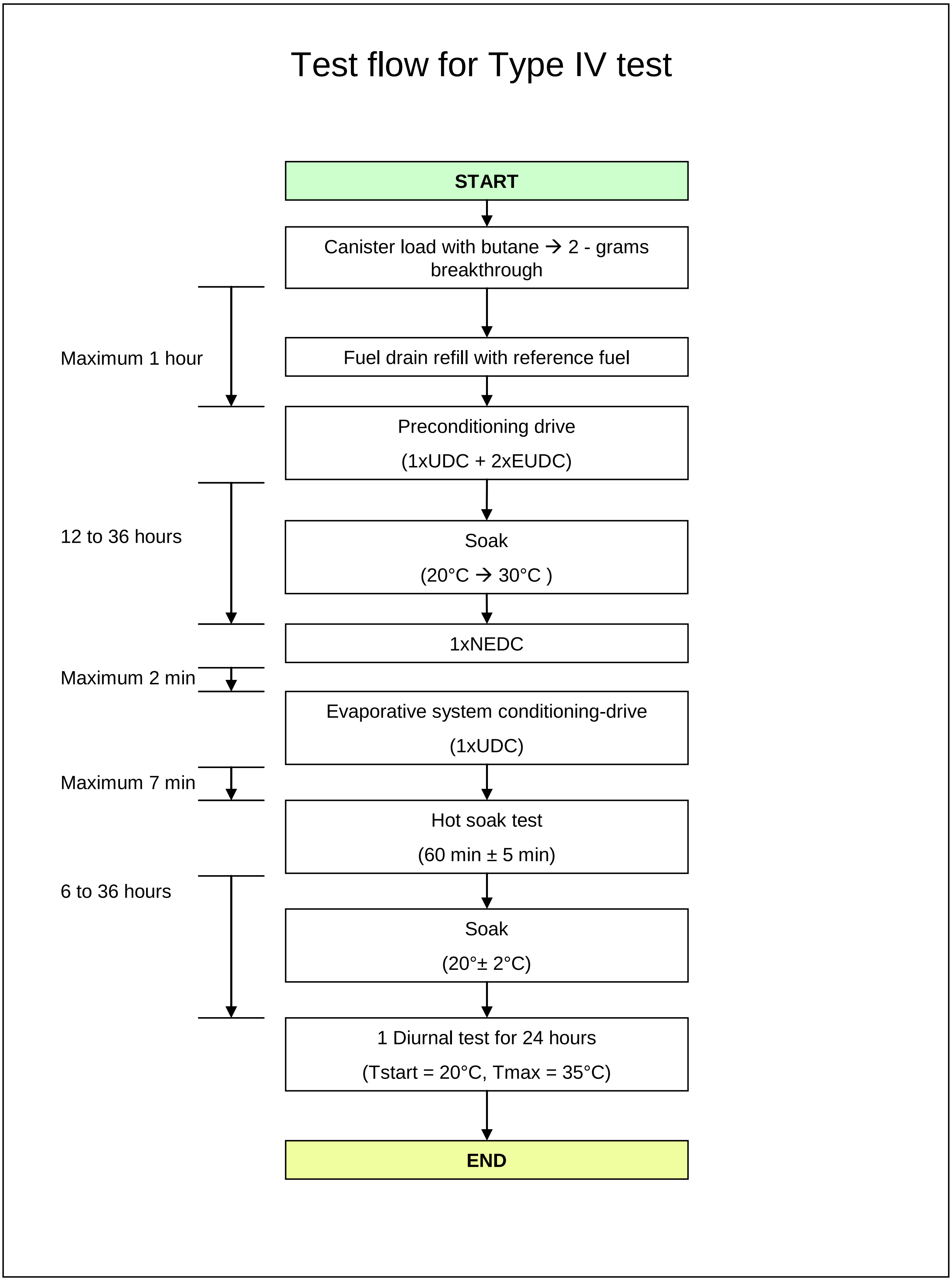


Figure 21: Type IV test procedure

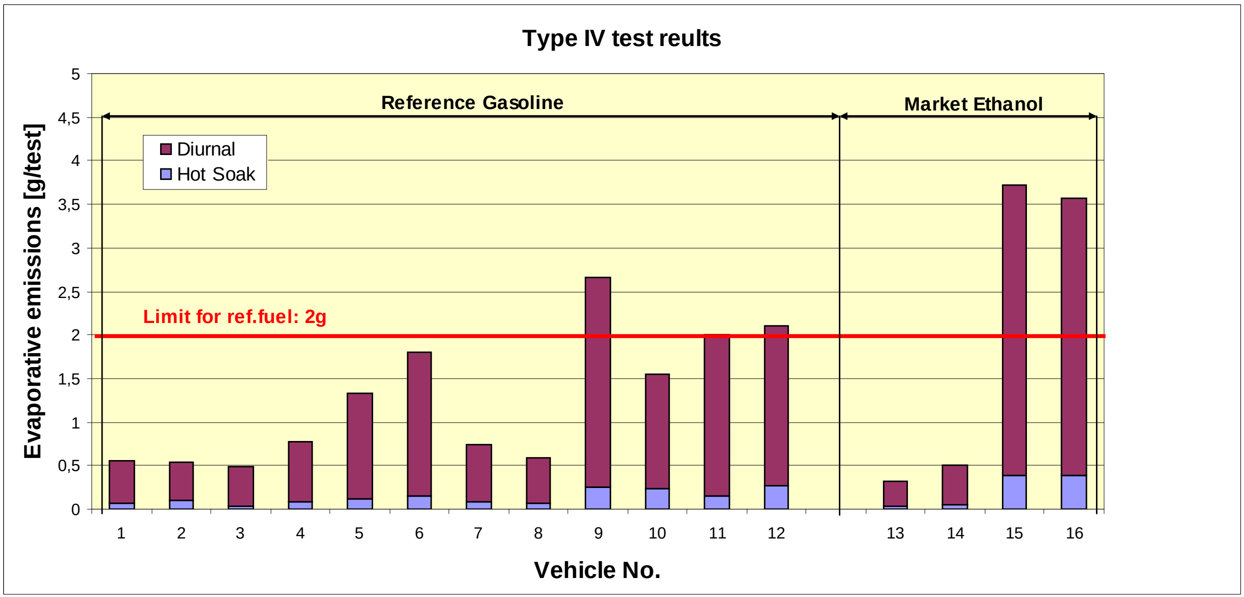


Figure 22: Results from Type IV test

For the 2009 In-Service programme gasoline, E85 and CNG were used as fuel for positive ignited vehicles. In total, 16 measurements were made and the result is summarised in figure 22.

Table 8 shows the average of all tested vehicles. According to Directive 70/220/EEC and its last amendment, Annex I, paragraph 5.3.4.2. say “When tested in accordance with Annex VI, evaporative emissions shall be less than 2 g/test.”

The average result of all tested vehicles was 1,45 g HC/test. Based on the directive, three of the gasoline vehicles failed to comply with the Euro 4 limits. Noteworthy is that two of the flexi fuel vehicles evaporated more than all the others. The manufacturer is notified about the phenomenon and more detailed investigation has to be done to find out the root cause.

	Evaporative emissions [g HC]		
Vehicle	**Hot Soak**	**Diurnal**	**Total**
Vehicle 1	0,07	0,482	0,55
Vehicle 2	0,099	0,447	0,55
Vehicle 3	0,037	0,451	0,49
Vehicle 4	0,084	0,698	0,78
Vehicle 5	0,112	1,213	1,33
Vehicle 6	0,144	1,665	1,81
Vehicle 7	0,09	0,647	0,74
Vehicle 8	0,071	0,511	0,58
Vehicle 9	0,255	2,407	2,66
Vehicle 10	0,234	1,316	1,55
Vehicle 11	0,146	1,859	2,01
Vehicle 12	0,274	1,833	2,11
Vehicle 13	0,04	0,279	0,32
Vehicle 14	0,043	0,468	0,51
Vehicle 15	0,391	3,326	3,72
Vehicle 16	0,392	3,175	3,57
	Average		
	0,16	**1,30**	**1,45**
	Euro 4 Limit		
	—	—	**2**

Table 8: Type IV Average evaporative emissions

Figure 23 and 24 shows the difference between a vehicle that failed respectively passed the Type IV test.

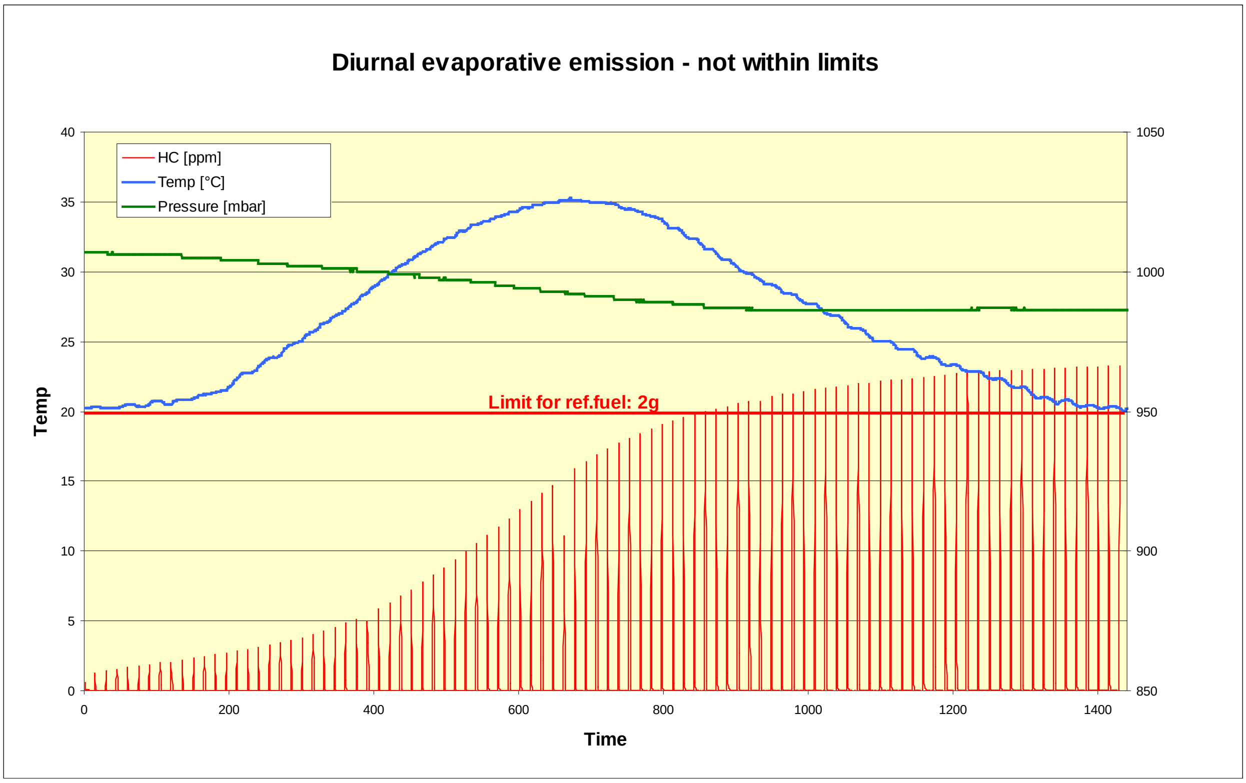


Figure 23: Type IV test - vehicle not within limits

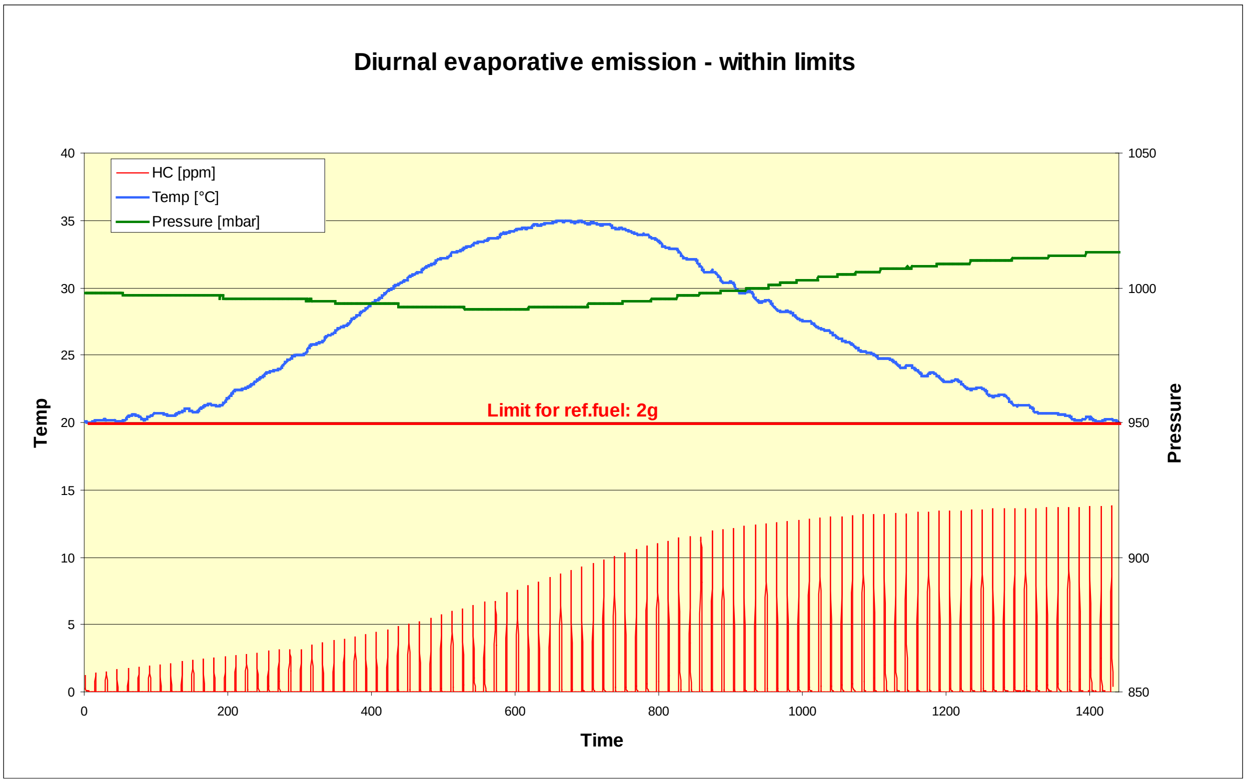


Figure 24: Type IV test – vehicle within limits

The correlation between diurnal loss and total result of the Type IV test is shown I Figure 25.

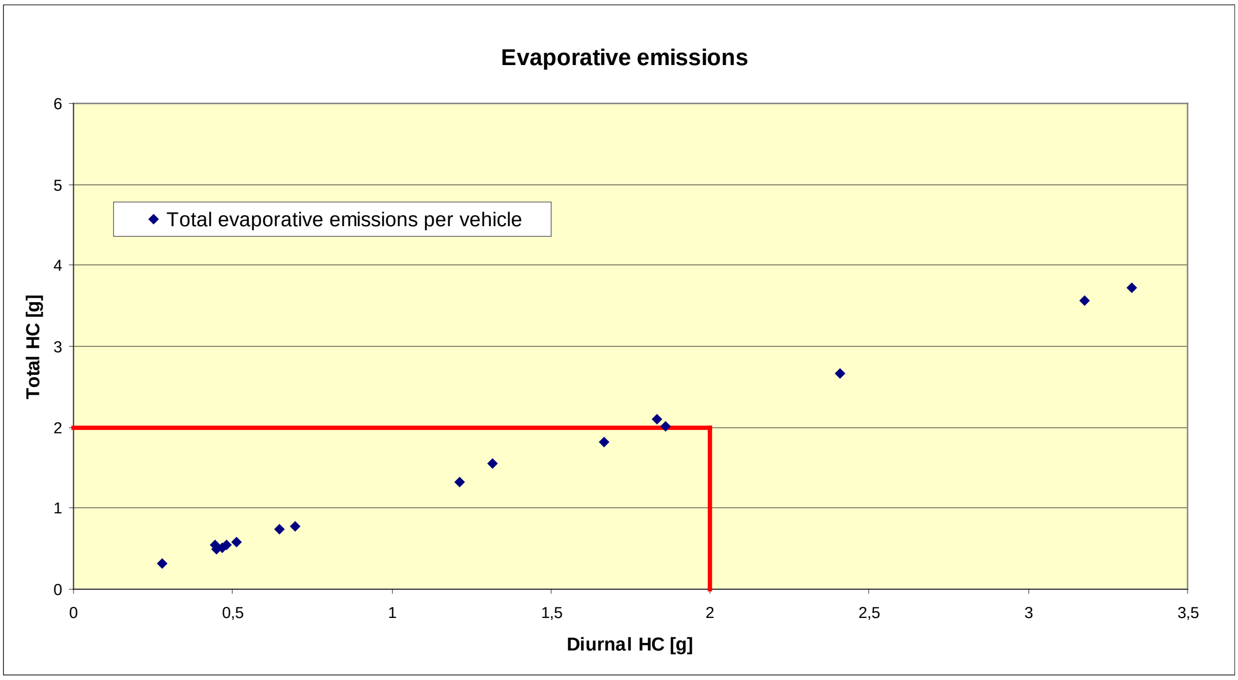


Figure 25: Evaporative emissions correlation from Type IV test

Exhaust emissions at low ambient temperatures (Type VI test, - 7°C)

According to Directive 70/220/EEC as amended by 2003/76/EC an exhaust emission test should be carried out at low ambient temperature. In the 2009 In Service Testing Programme two vehicles per family with positive ignition were tested at -7 C°. The purpose of the Type VI test is to see what happens if the vehicle is driven in realistic conditions. Carbon Monoxide (CO) and Hydrocarbon (HC) emissions are limited by the directive.

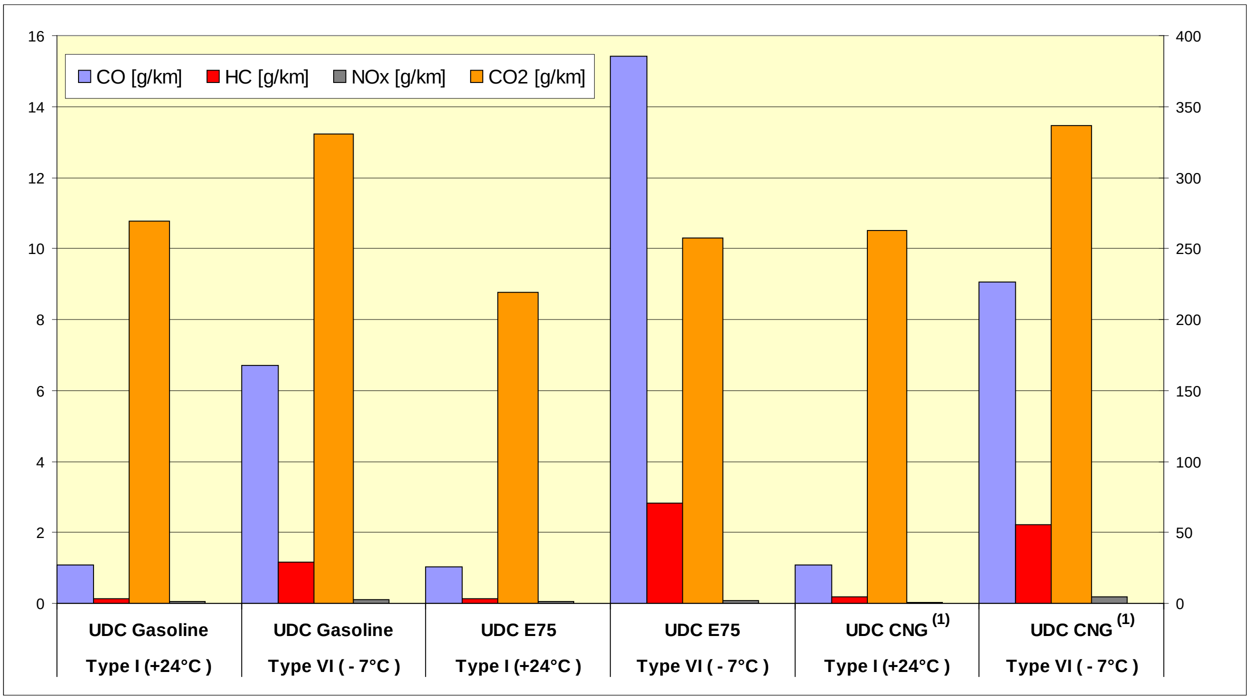
Table 9 and figure 26 show a comparison between the Type I and Type VI test for the UDC cycle. E85 and CNG vehicles average emissions are also included within table 9 and figure 26. Note worthy is that only one of the tested E85 and CNG vehicles did comply within the directive.

The average result for the positive ignition vehicles, driven on petrol, complied within the given directive.

Vehicles with positive egnition		**Exhaust emissions**			
Test	**Cycle**	**CO [g/km]**	**HC [g/km]**	**NOx [g/km]**	**CO2 [g/km]**
Type I	UDC Gasoline	1,071	0,145	0,063	269
	UDC E75	1,024	0,127	0,054	219
	UDC CNG	1,087	0,184	0,034	263
Type VI	UDC Gasoline	6,710	1,163	0,117	331
	UDC E75	15,415	2,814	0,089	258
	UDC CNG	9,049	2,221	0,182	336
Limit VI	**UDC Gasoline**	**15**	**1,8**	**-**	**-**

Table 9: Average exhaust emissions during Type VI and Type I of vehicles with positive ignition, tested at – 7°C

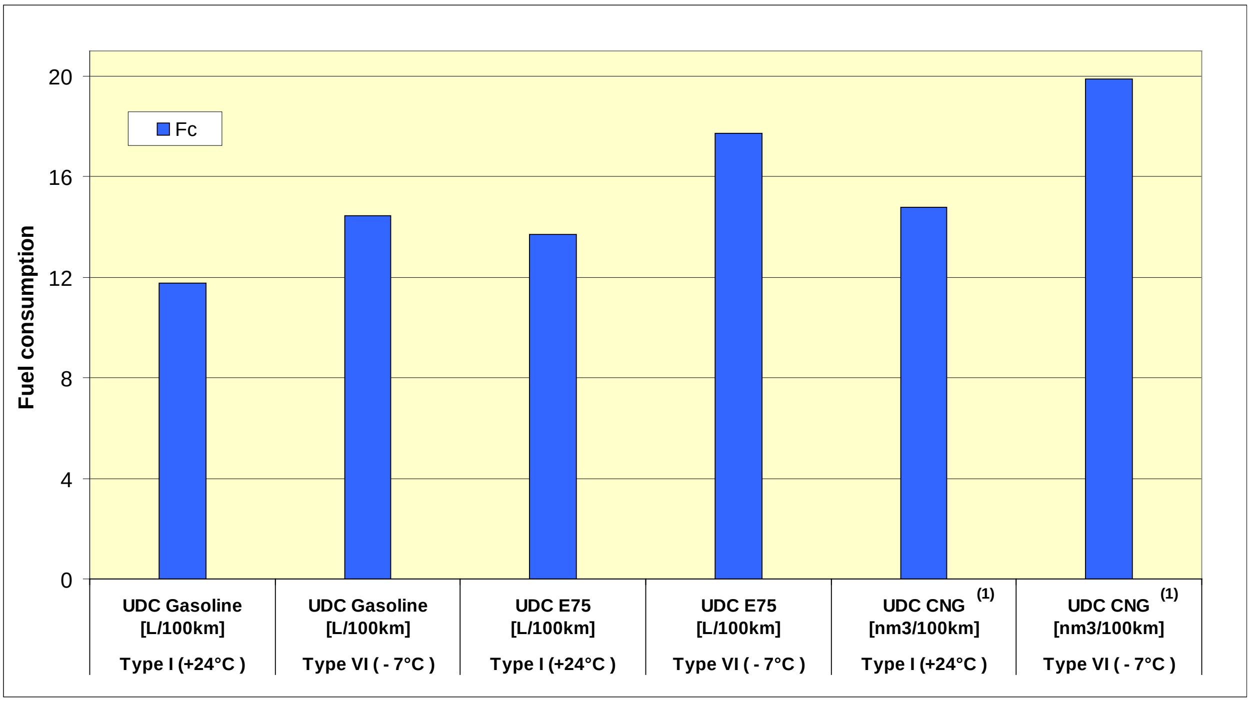
Figure 26 show a comparison between the average exhausts emissions (CO, HC, NOx and CO2) from different fuels during Type VI (- 7°C) and Type I test (+24°C).



(1) Tested CNG vehicles use gasoline for the start-up sequence (during both +24°C and - 7°C) and then switch over to CNG

Figure 26: Compilation of average exhausts emissions at low ambient temperatures during

In figure 27 the average UDC fuel consumption is shown for the Type I test compared with the Type VI test.



(1) Tested CNG vehicles use gasoline for the start-up sequence (during both +24°C and - 7°C) and then switch over to CNG

Figure 27: Average fuel consumption at low ambient temperatures during Type VI compared with Type I test

Figure 28 shows the average Carbon Monoxide and Hydrocarbon emissions during Type IV (- 7°C) test of positive ignition vehicles driven on petrol, E75 and CNG. Only one of the positive ignition vehicles, driven on petrol, exceeded the Euro 4 limit.

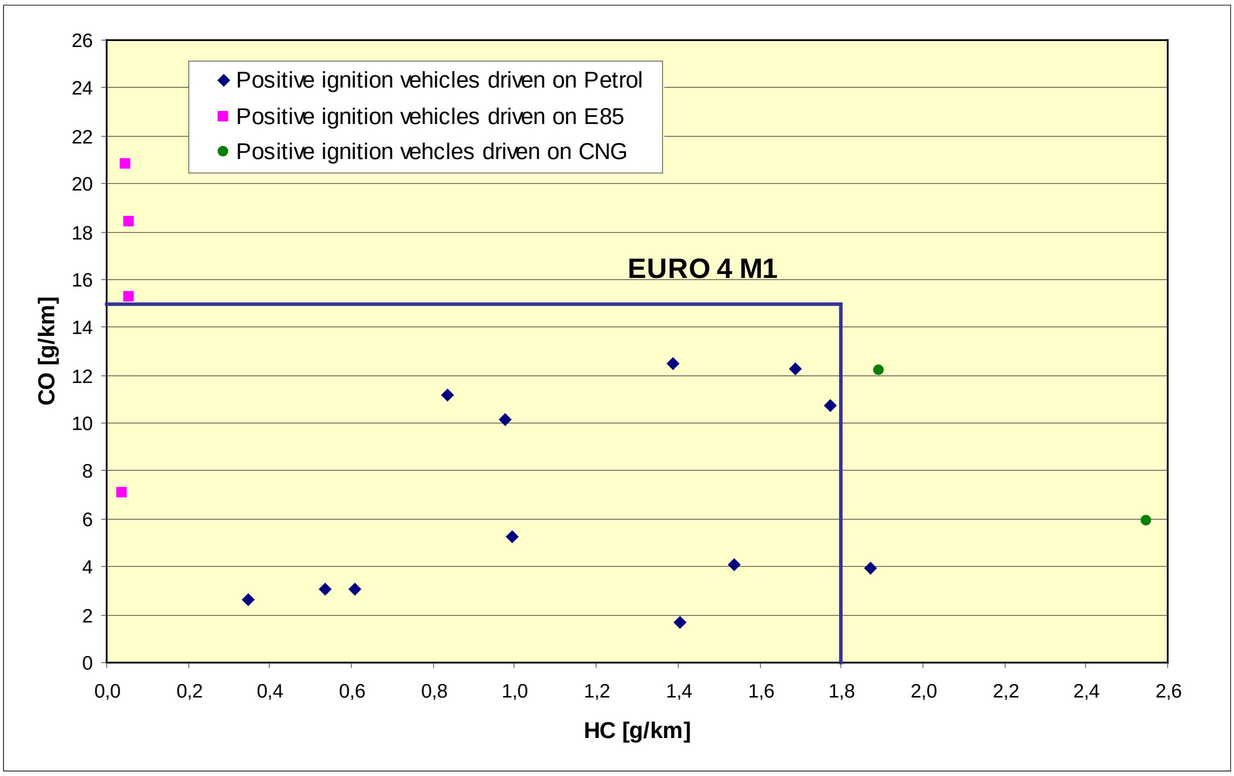


Figure 28: CO and HC emissions at low ambient temperatures

Figure 29 shows the average Hydrocarbon emissions during Type I compared with Type VI (- 7°C) test of positive ignition vehicles. Only one of the positive ignition vehicles, driven on petrol, exceeded the Euro 4 limit.

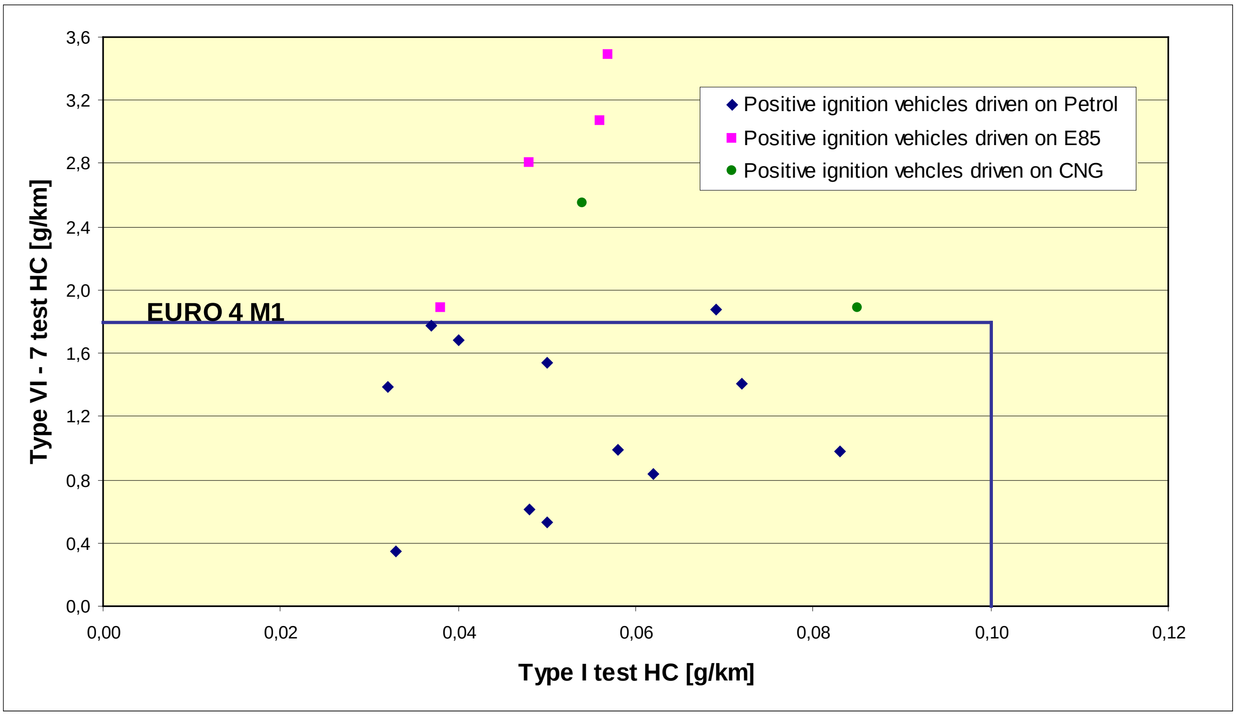


Figure 29: Hydrocarbon emissions during Type I and Type VI test

Exhaust Emissions during ARTEMIS driving cycles

The following figures on page 30 to 53 shows the comparison between a positive and a compressed ignited vehicle regarding CO, HC and NOx emissions during the different ARTEMIS-cycles

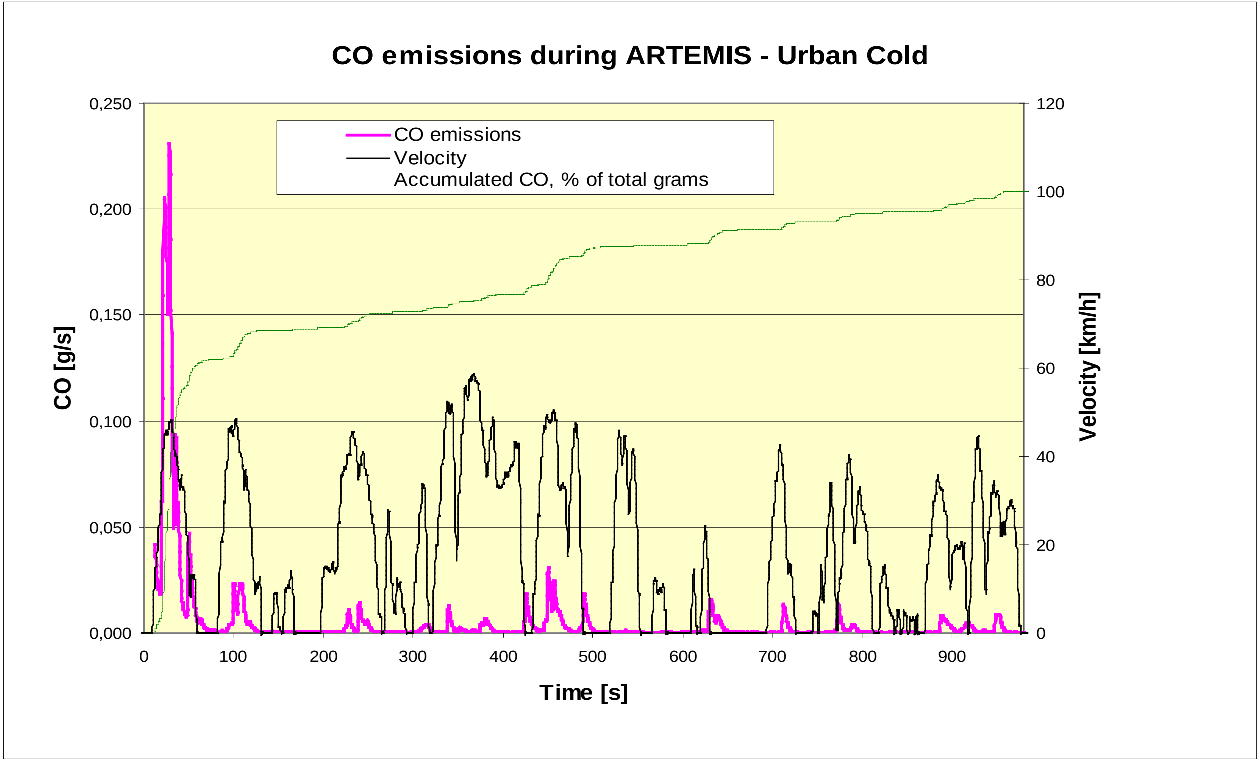


Figure 30: CO emissions during ARTEMIS Urban Cold cycle of a Euro 4 vehicle with positive ignition engine

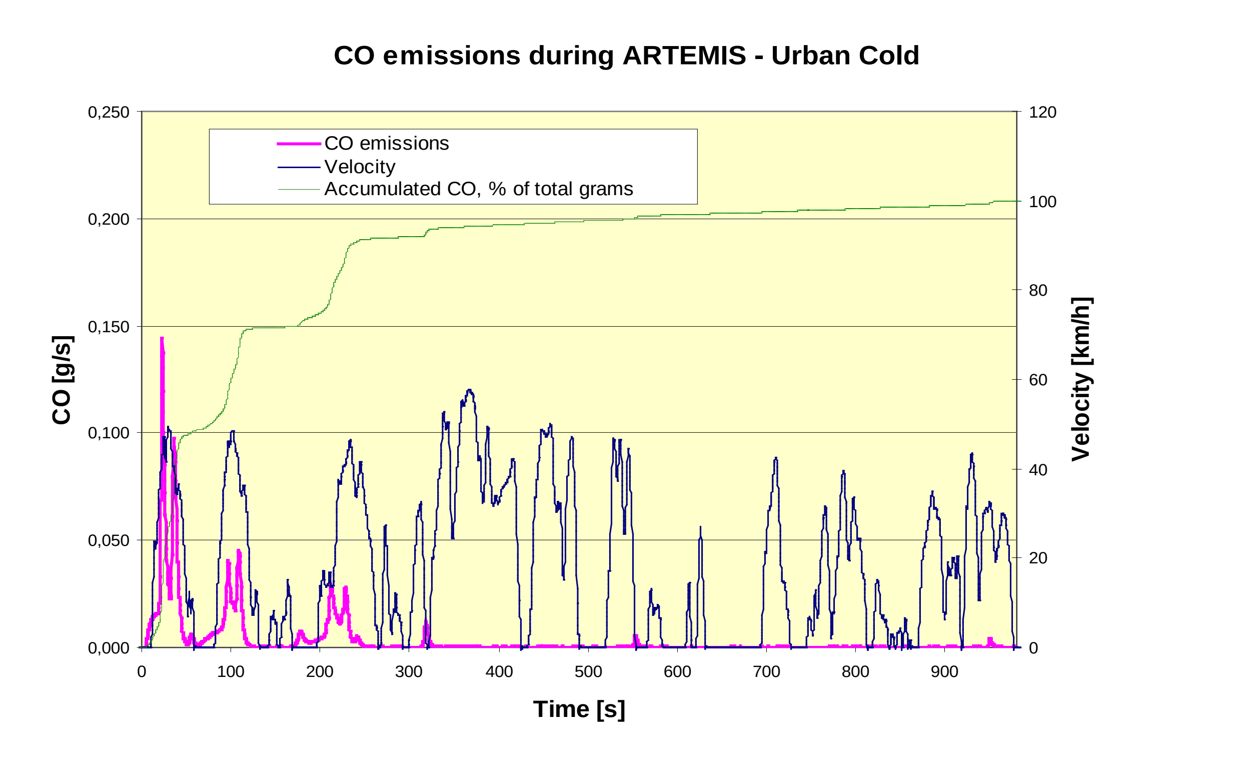


Figure 31: CO emissions during ARTEMIS Urban Cold cycle of a Euro 4 vehicle with compression ignition engine

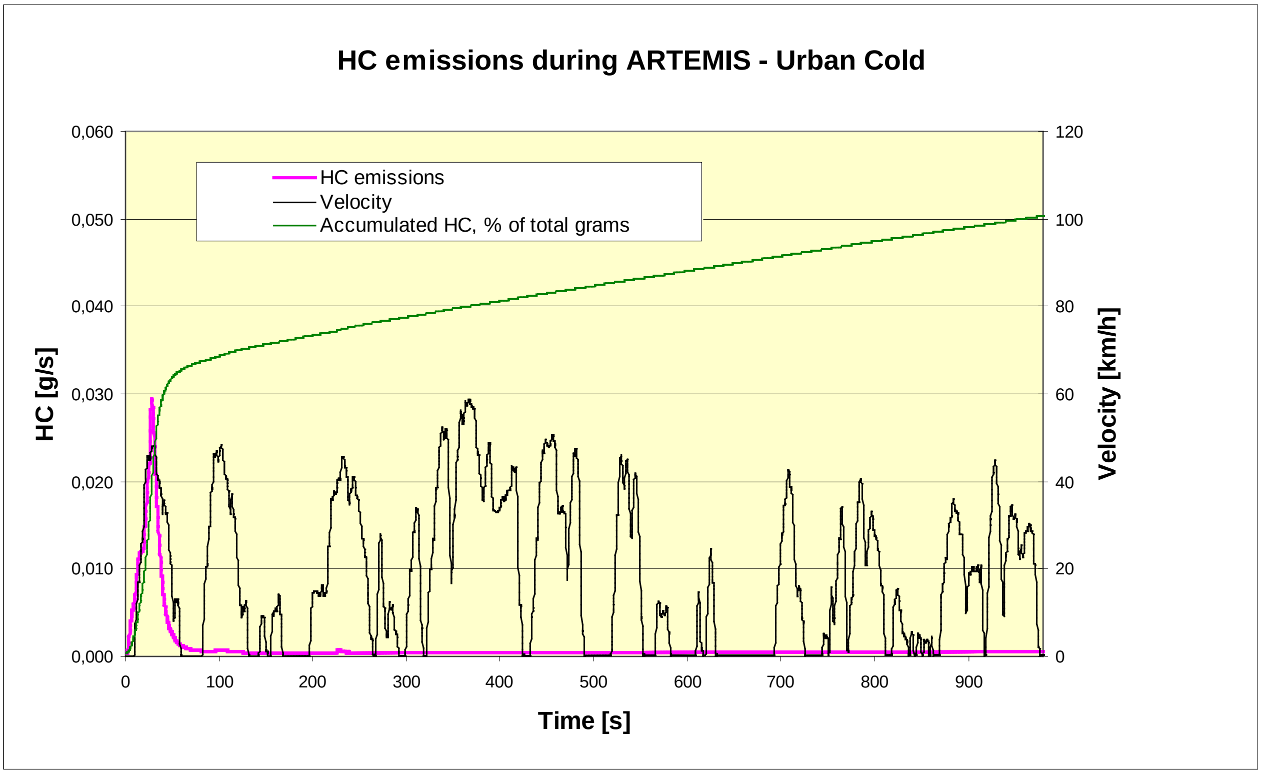


Figure 32: HC emissions during ARTEMIS Urban Cold cycle of a Euro 4 vehicle with positive ignition engine

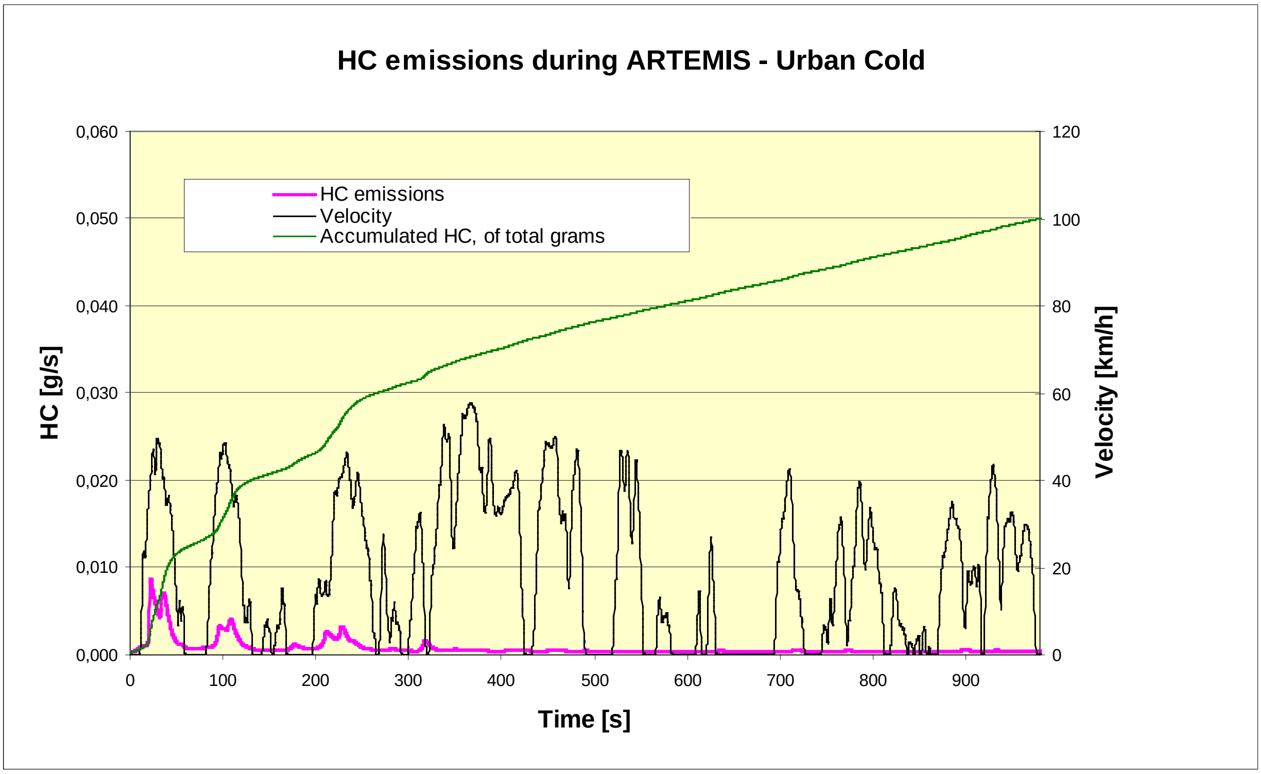


Figure 33: HC emissions during ARTEMIS Urban Cold cycle of a Euro 4 vehicle with compression ignition engine

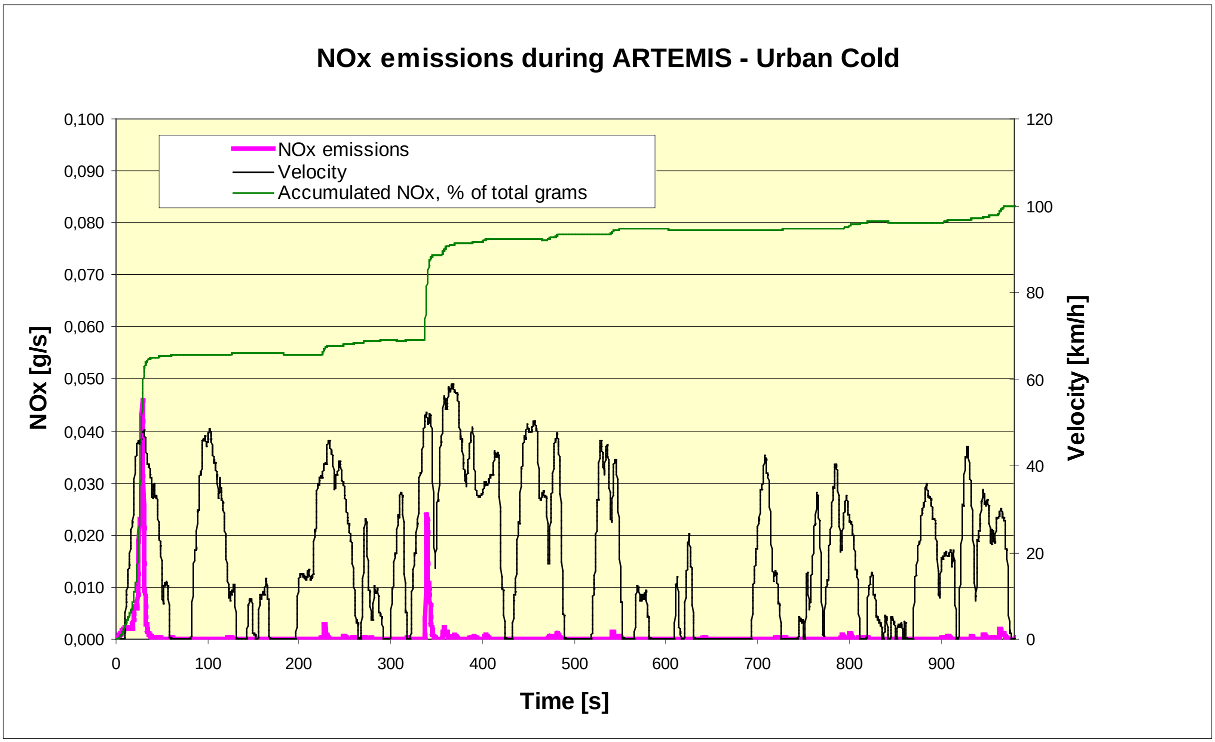


Figure 34: NOx emissions during ARTEMIS Urban Cold cycle of a Euro 4 vehicle with positive ignition engine

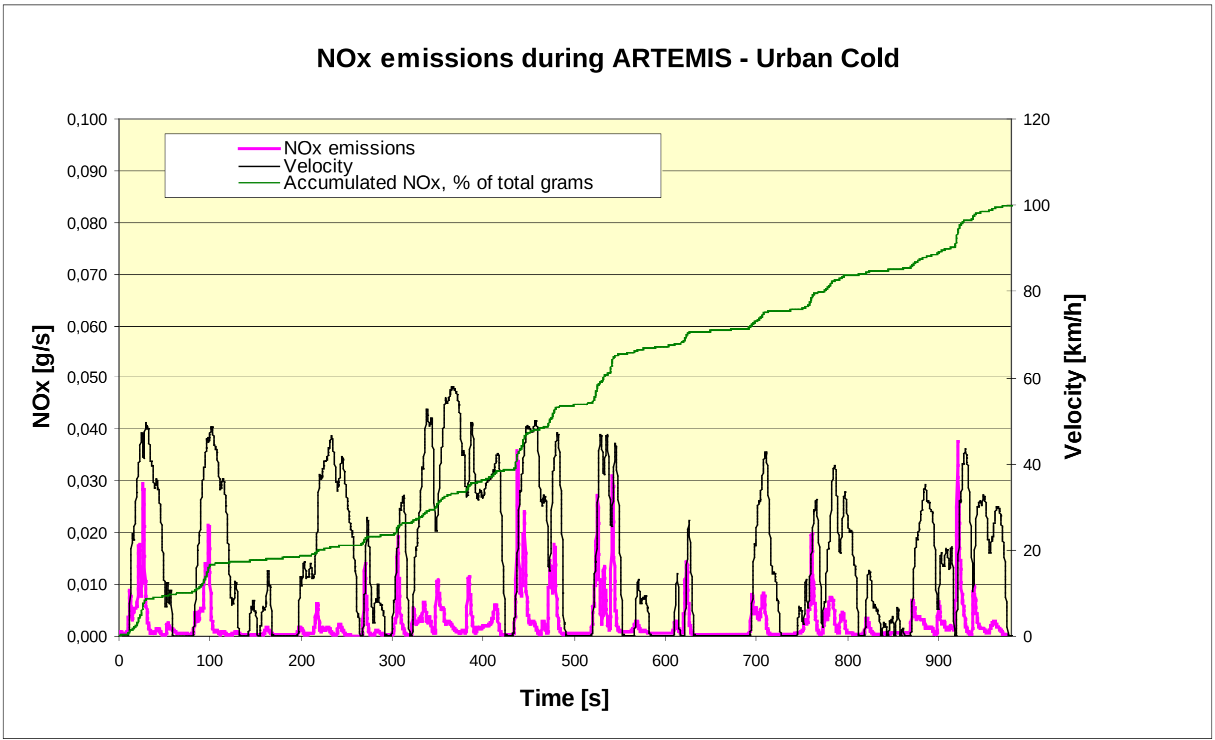


Figure 35: NOx emissions during ARTEMIS Urban Cold cycle of a Euro 4 vehicle with compression ignition engine

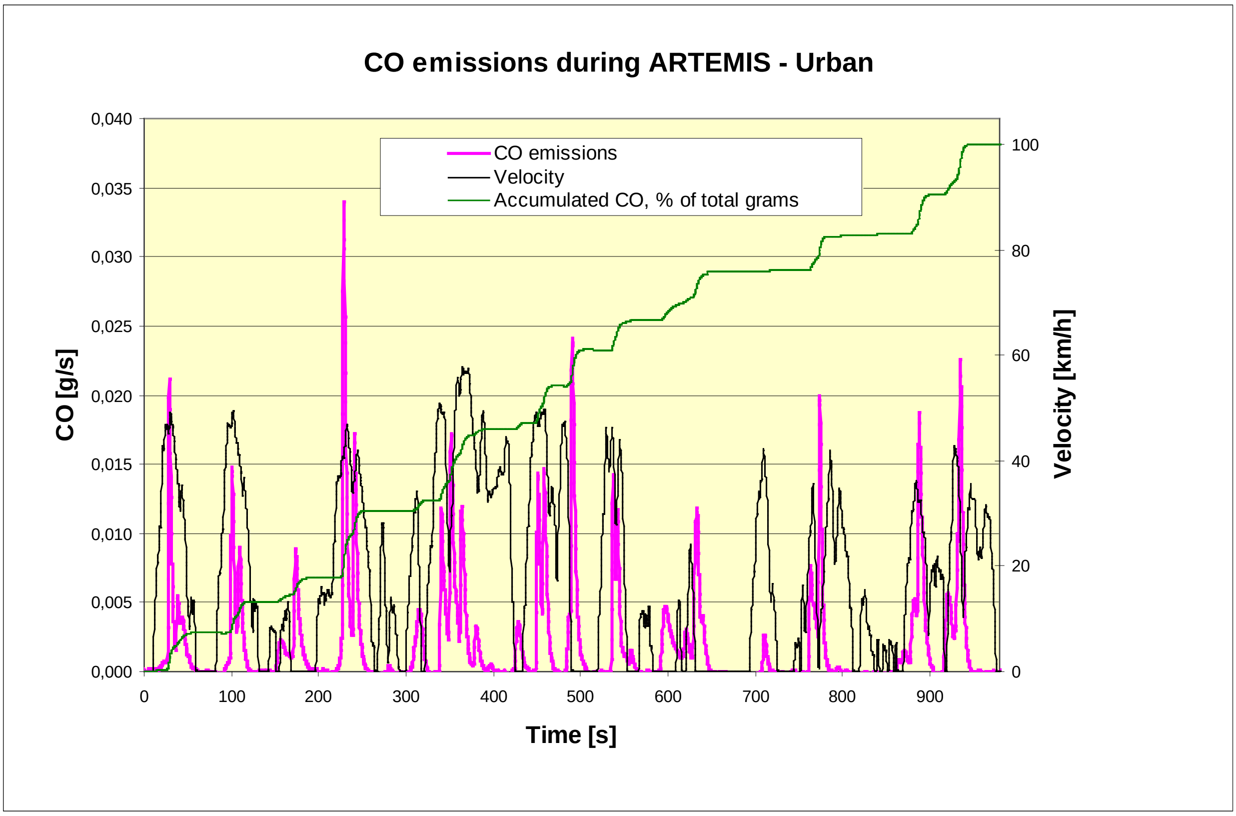


Figure 36: CO emissions during ARTEMIS Urban cycle of a Euro 4 vehicle with positive ignition engine

In figure 37 the CO emission takes a big jump in the middle of the cycle, possible cause may be the catalytic converter diagnosis.

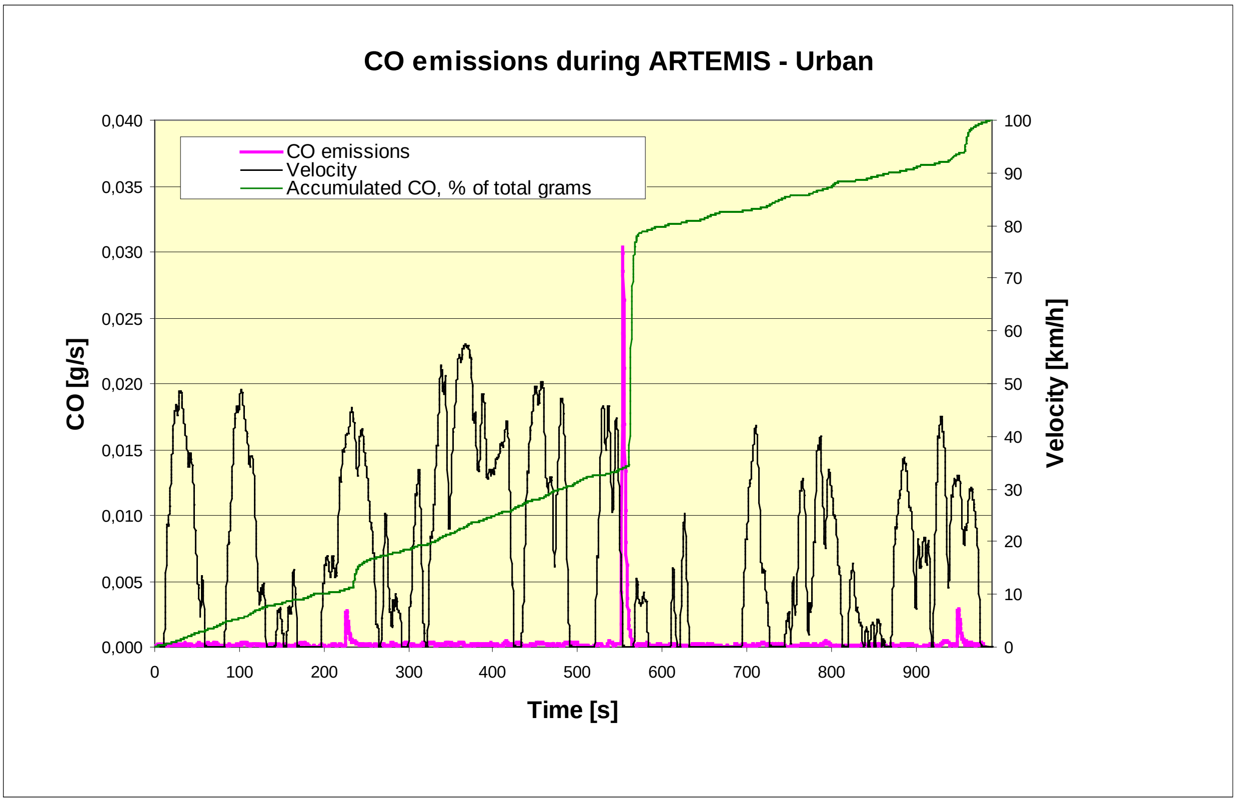


Figure 37: CO emissions during ARTEMIS Urban cycle of a Euro 4 vehicle with compression ignition engine

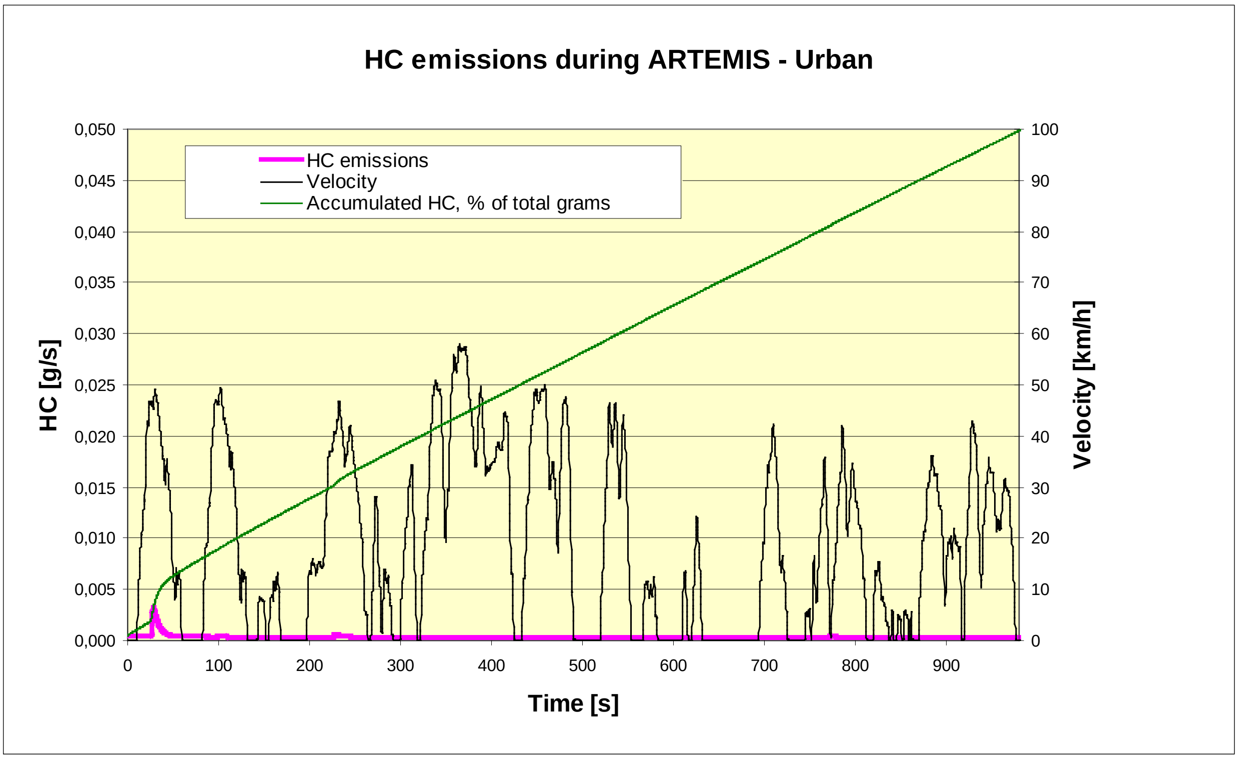


Figure 38: HC emissions during ARTEMIS Urban cycle of a Euro 4 vehicle with positive ignition engine

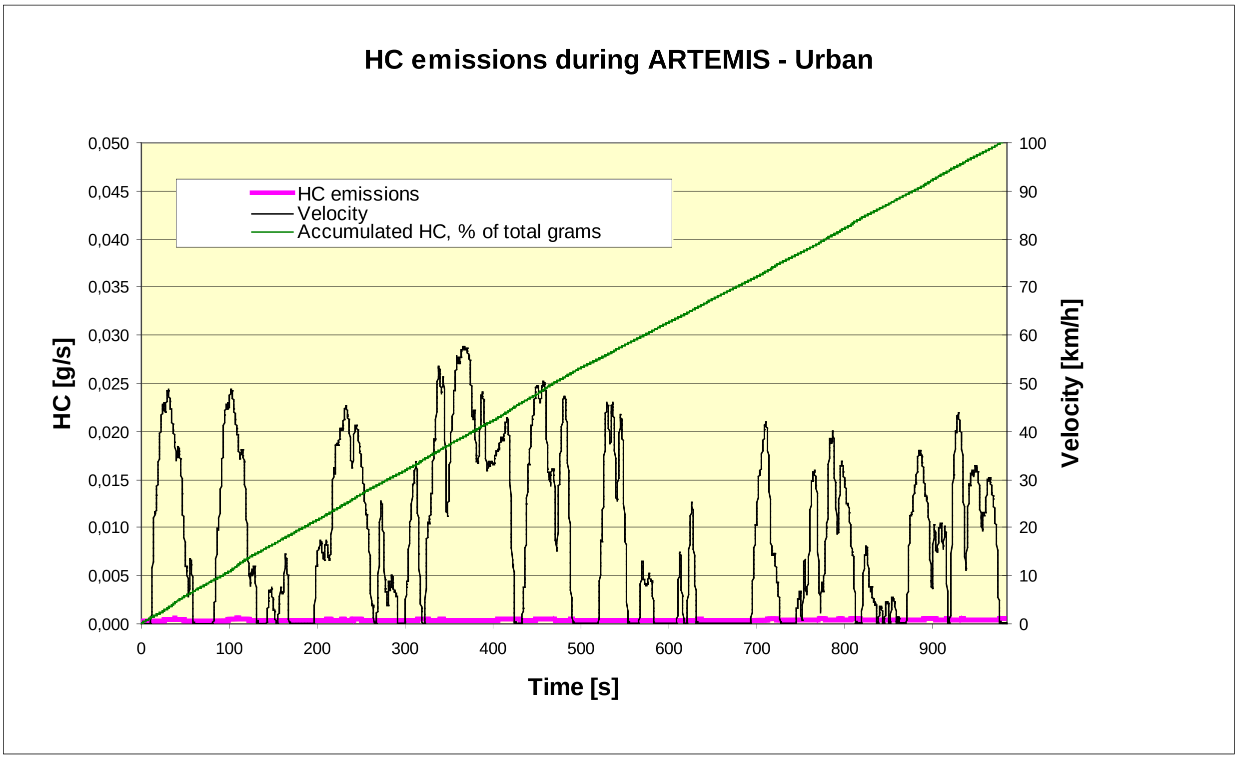


Figure 39: HC emissions during ARTEMIS Urban cycle of a Euro 4 vehicle with compression ignition engine

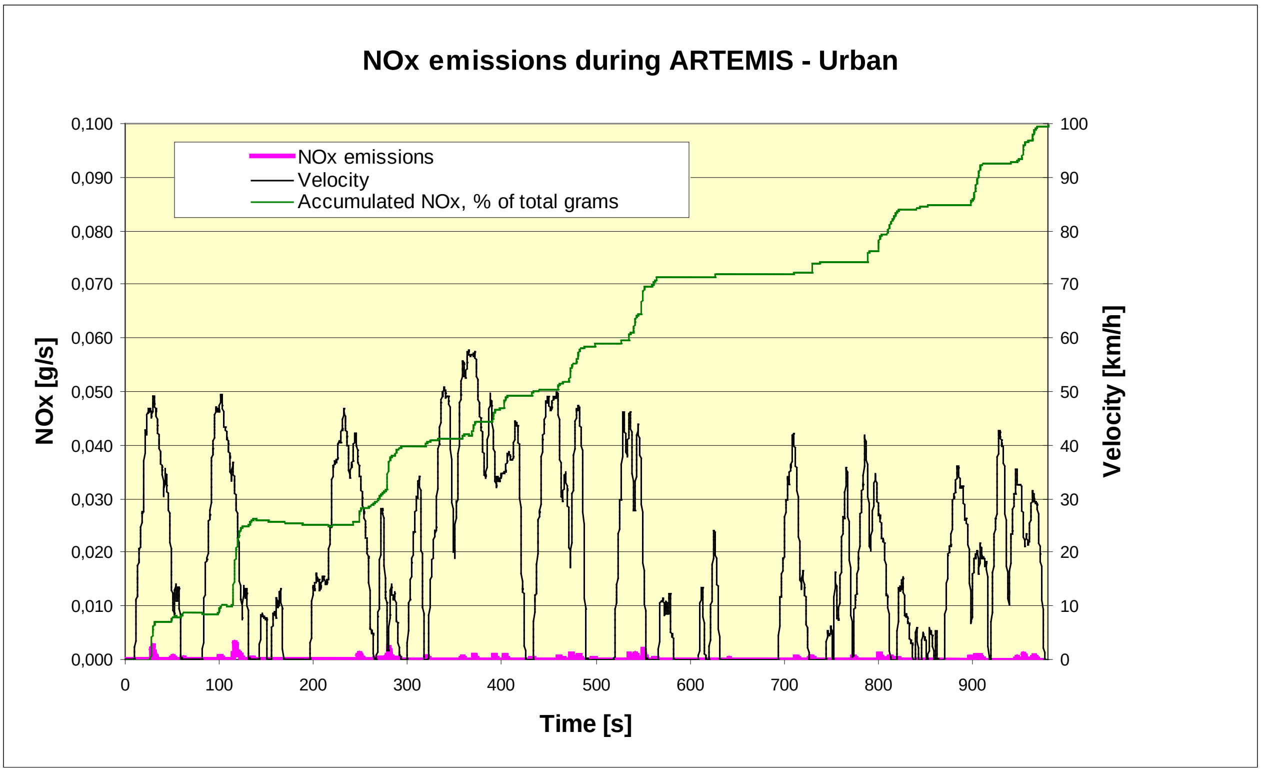


Figure 40: NOx emissions during ARTEMIS Urban cycle of a Euro 4 vehicle with positive ignition engine

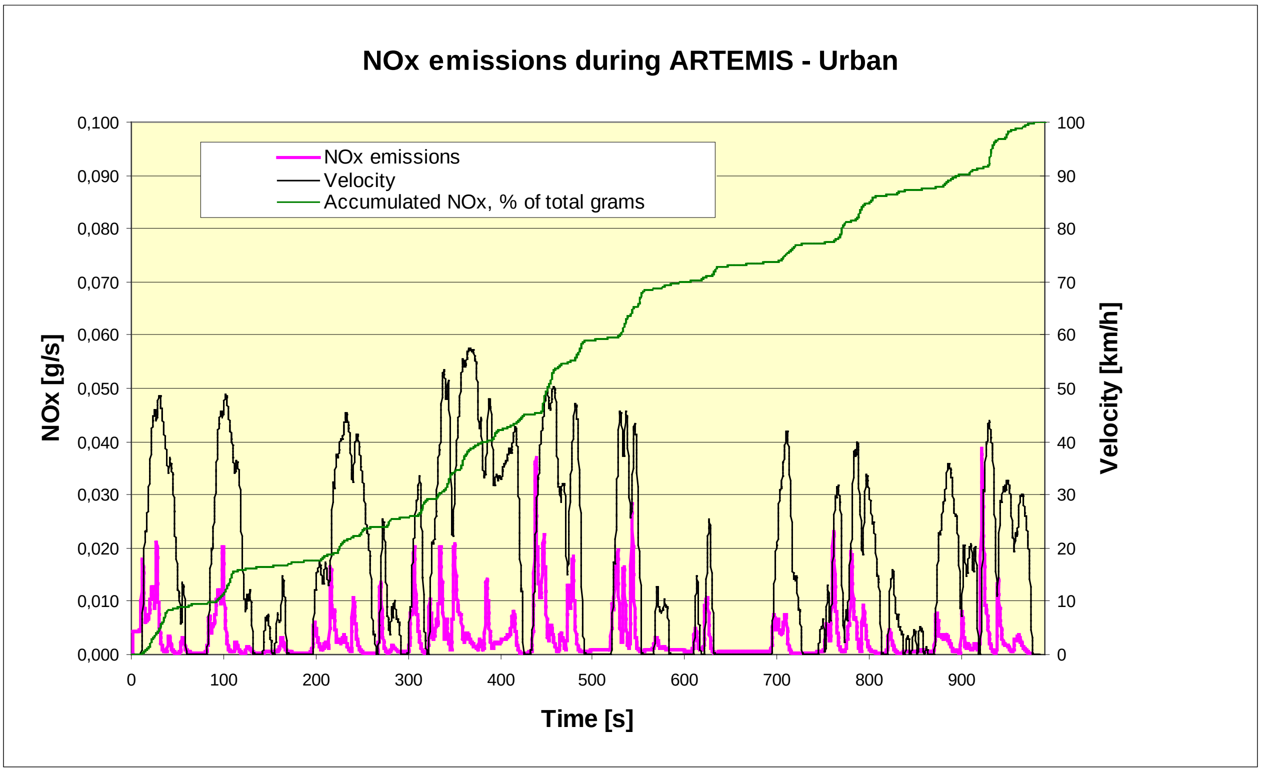


Figure 41: NOx emissions during ARTEMIS Urban cycle of a Euro 4 vehicle with compression ignition engine

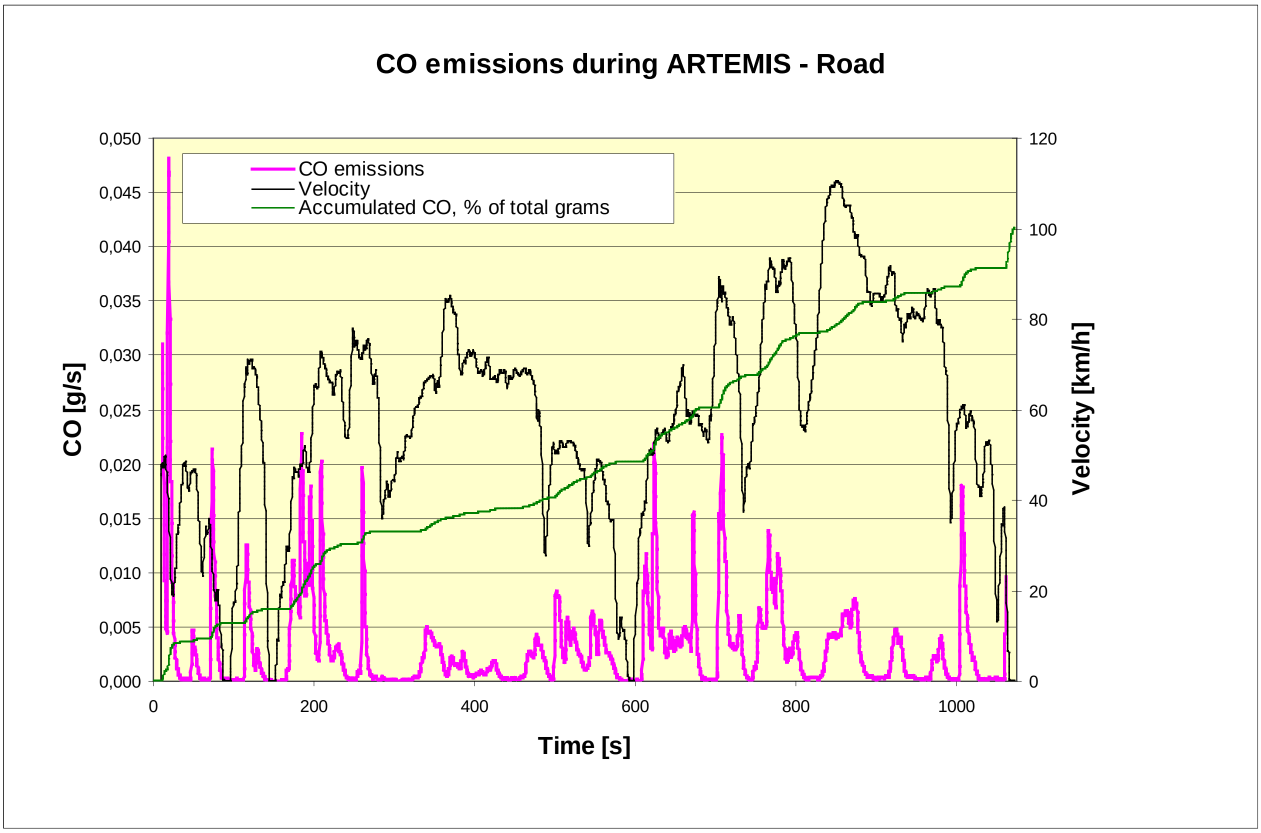


Figure 42: CO emissions during ARTEMIS Road cycle of a Euro 4 vehicle with positive ignition engine

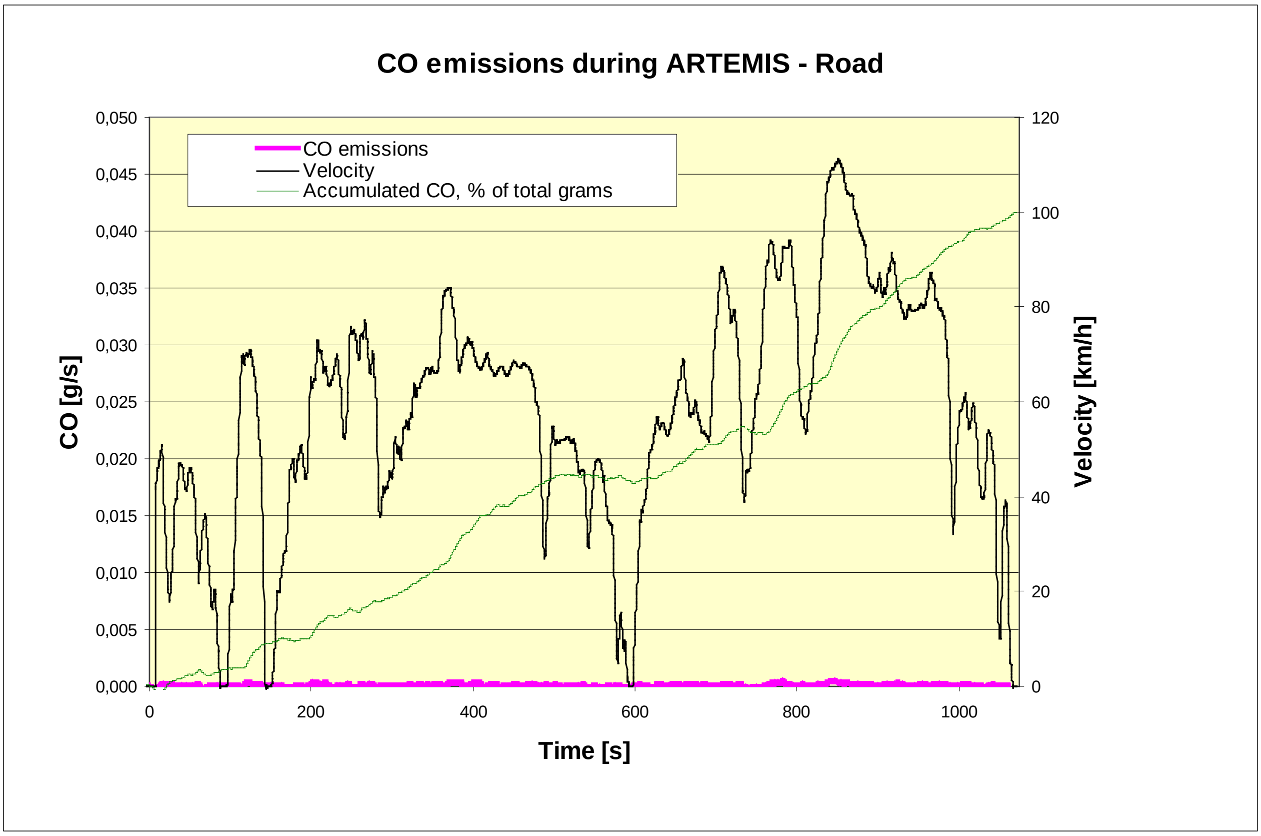


Figure 43: CO emissions during ARTEMIS Road cycle of a Euro 4 vehicle with compression ignition engine

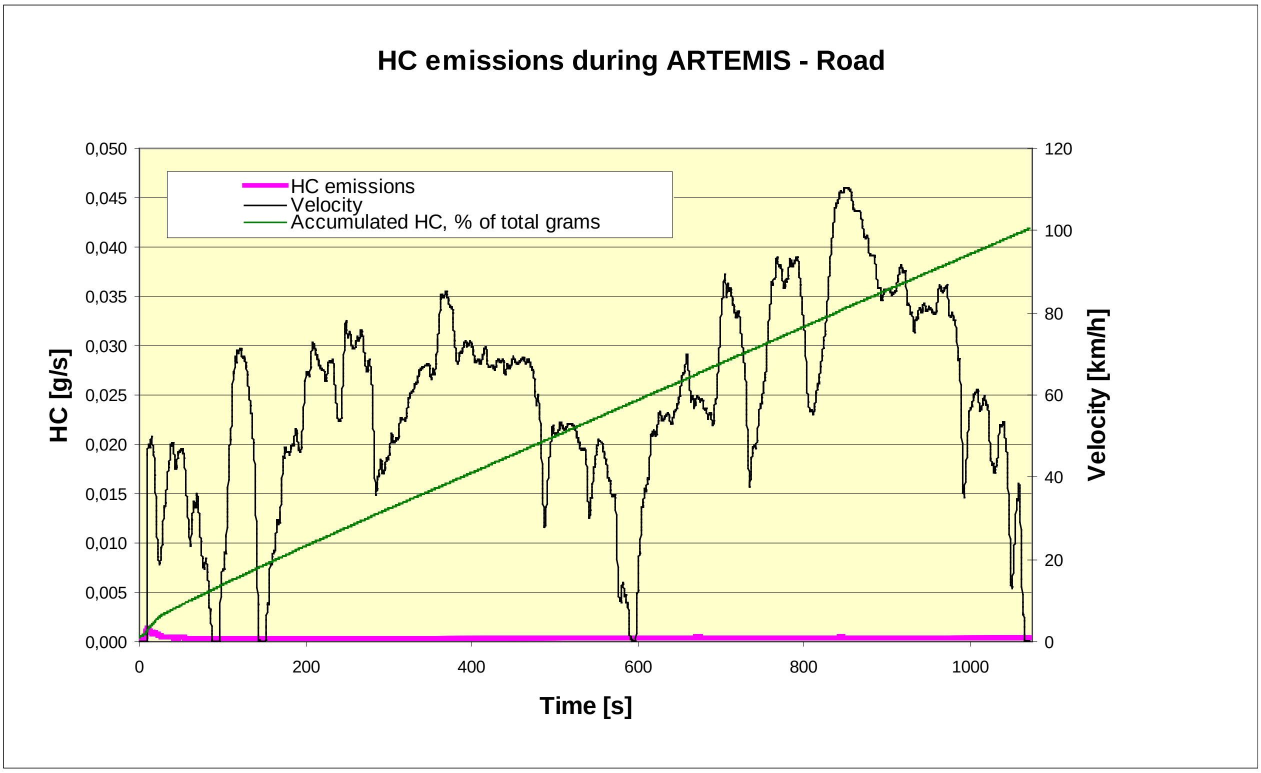


Figure 44: HC emissions during ARTEMIS Road cycle of a Euro 4 vehicle with positive ignition engine

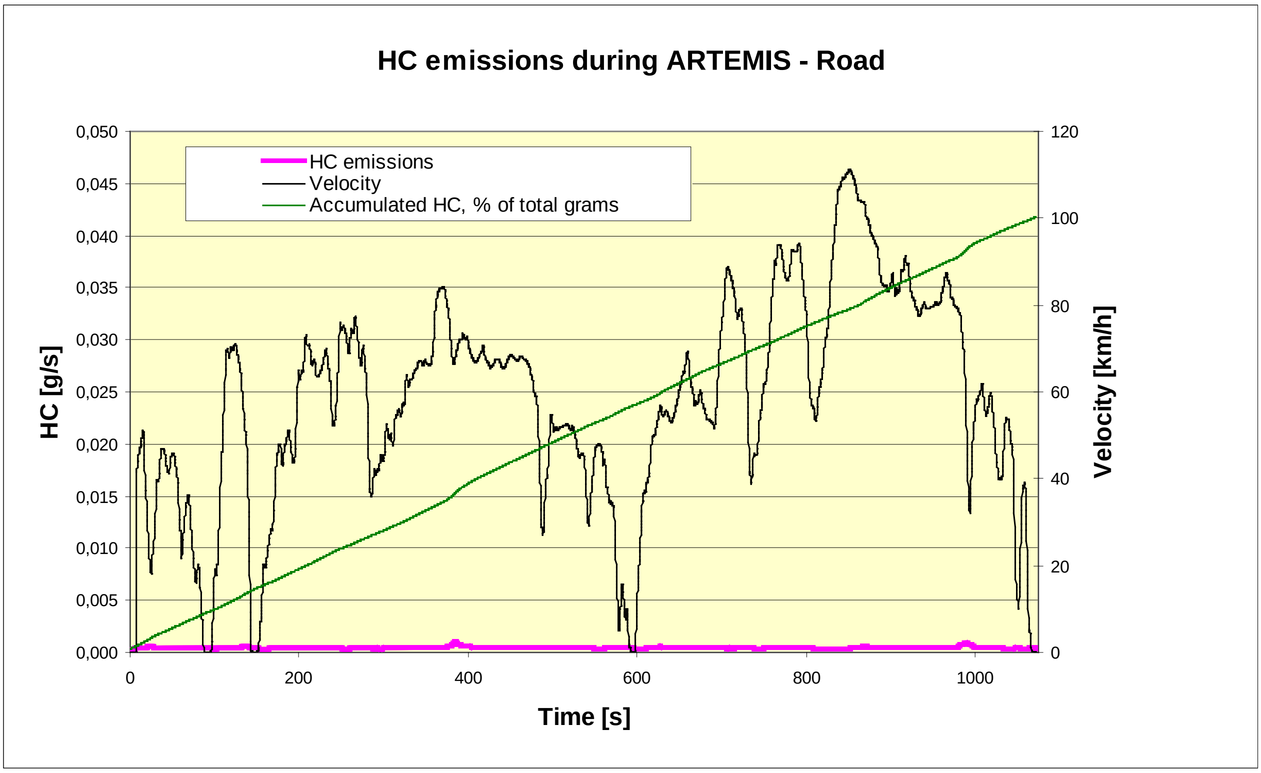


Figure 45: HC emissions during ARTEMIS Road cycle of a Euro 4 vehicle with compression ignition engine

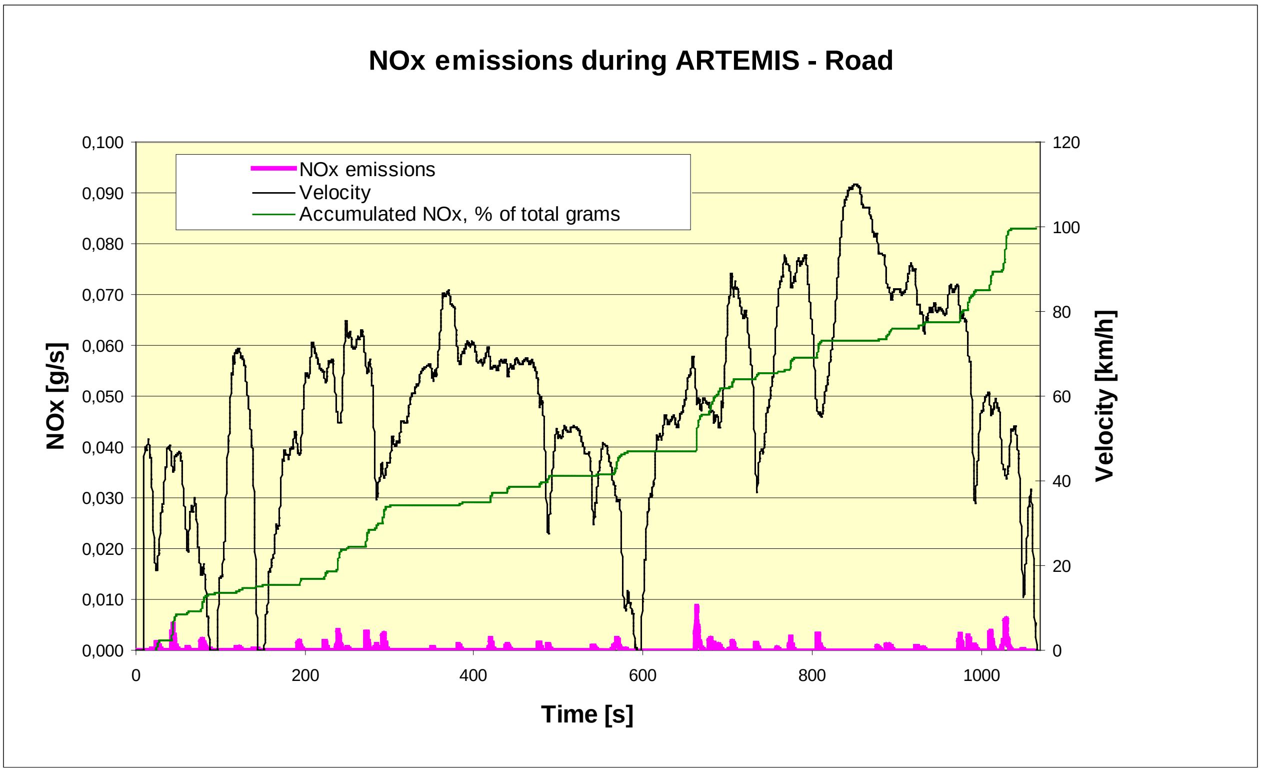


Figure 46: NOx emissions during ARTEMIS Road cycle of a Euro 4 vehicle with positive ignition engine

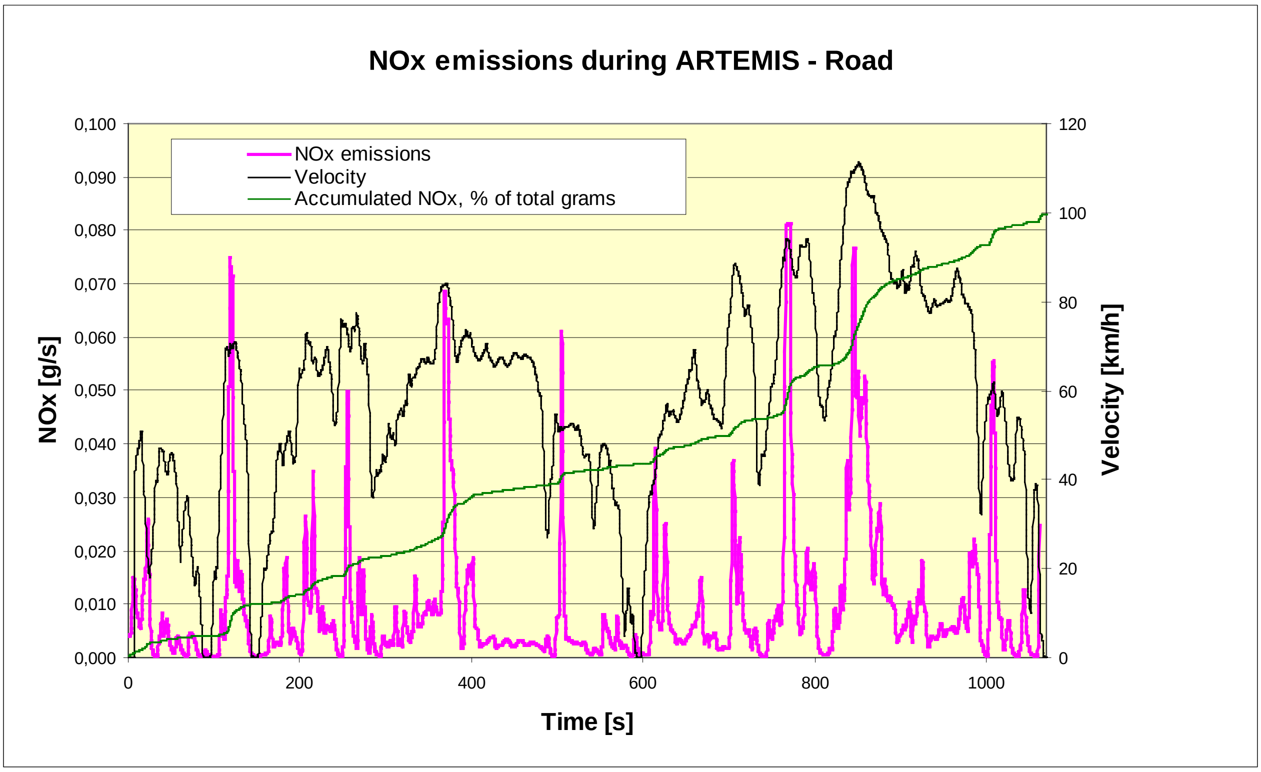


Figure 47: NOx emissions during ARTEMIS Road cycle of a Euro 4 vehicle with compression ignition engine

Figure 48 shows a positive compression vehicle that emitted significantly more CO than the others on the ARTEMIS Motorway cycle. One possible cause may be that the ECU (Engine Control Unit) stops using close loop lambda control. To protect the catalytic converter from overheating, during accelerations/transients, it is common to run the engine at about λ 0,85.

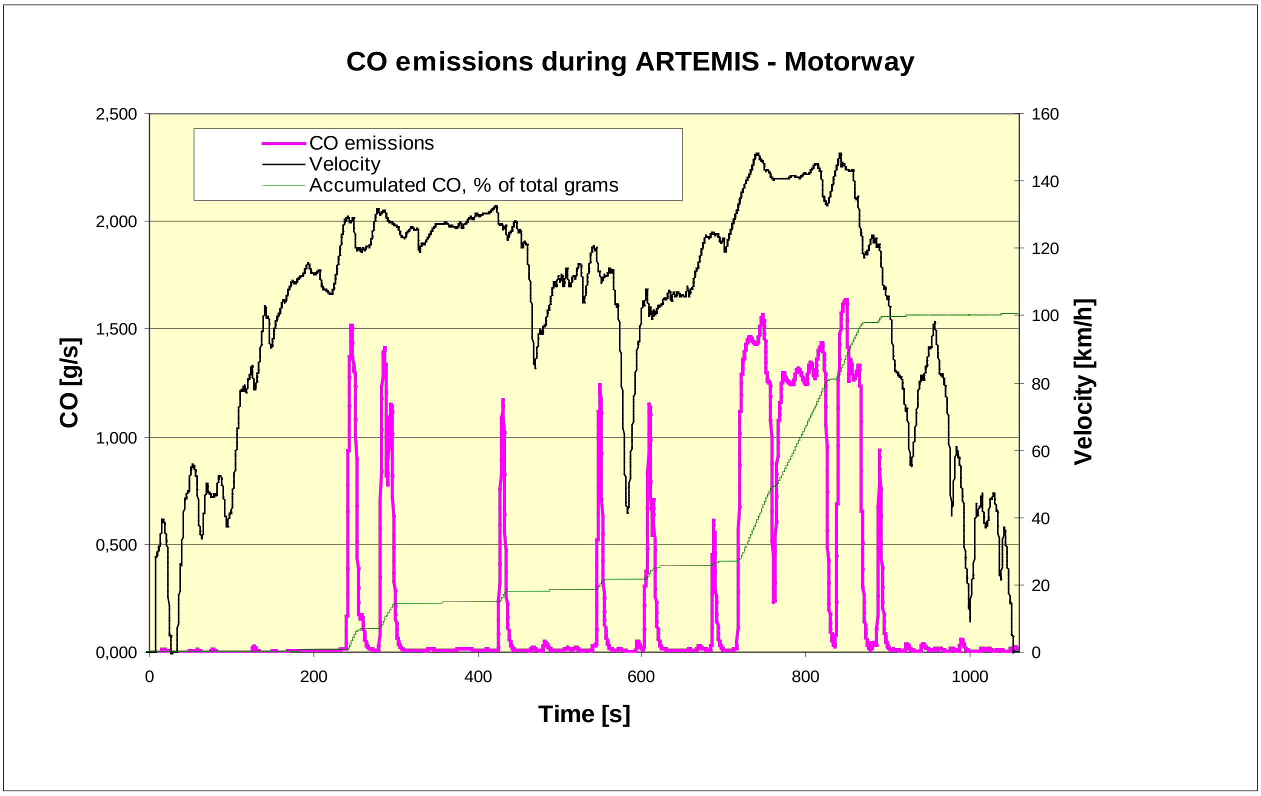


Figure 48: CO emissions during ARTEMIS Motorway cycle of a Euro 4 vehicle with positive ignition engine

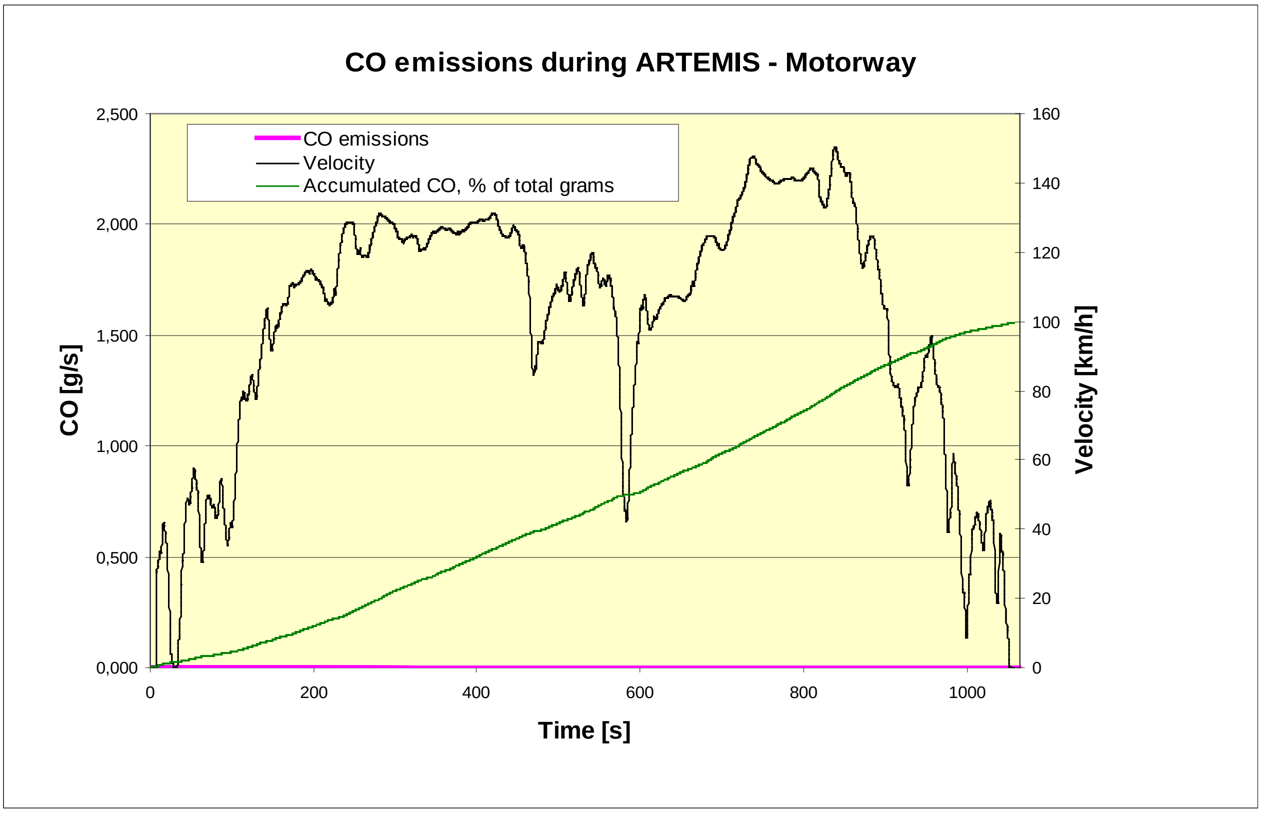


Figure 49: CO emissions during ARTEMIS Motorway cycle of a Euro 4 vehicle with compression ignition engine

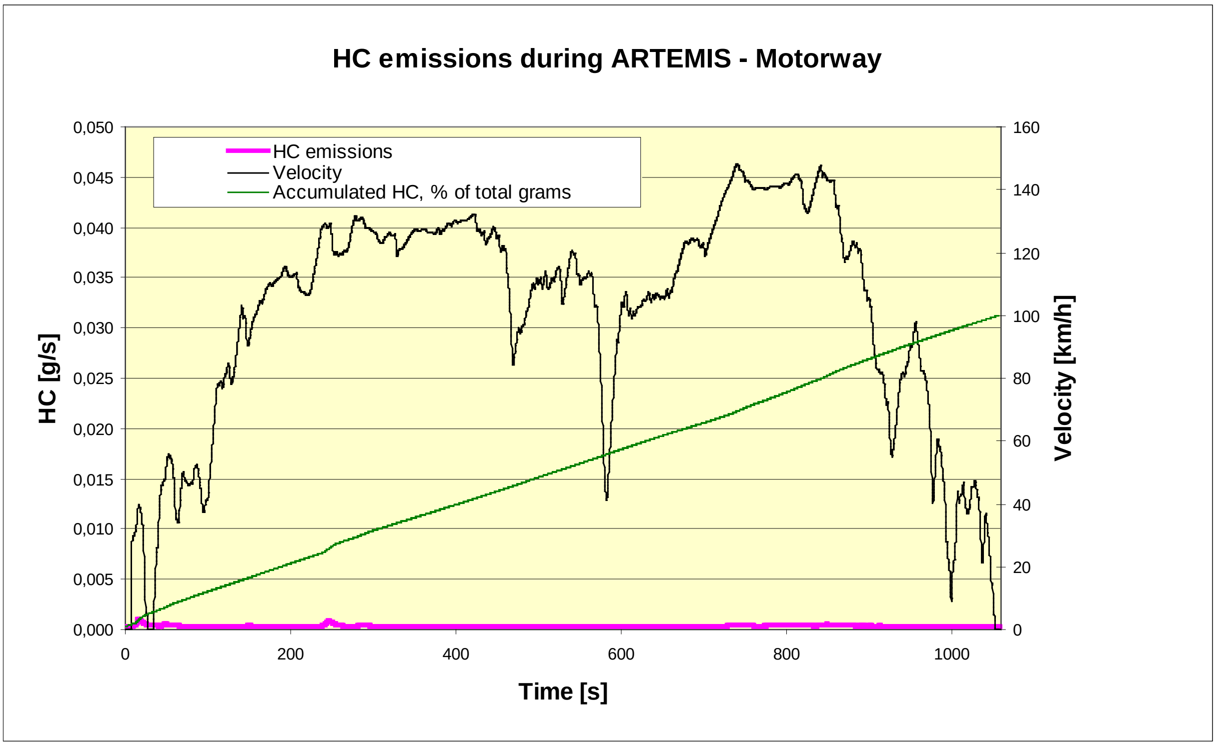


Figure 50: HC emissions during ARTEMIS Motorway cycle of a Euro 4 vehicle with positive ignition engine

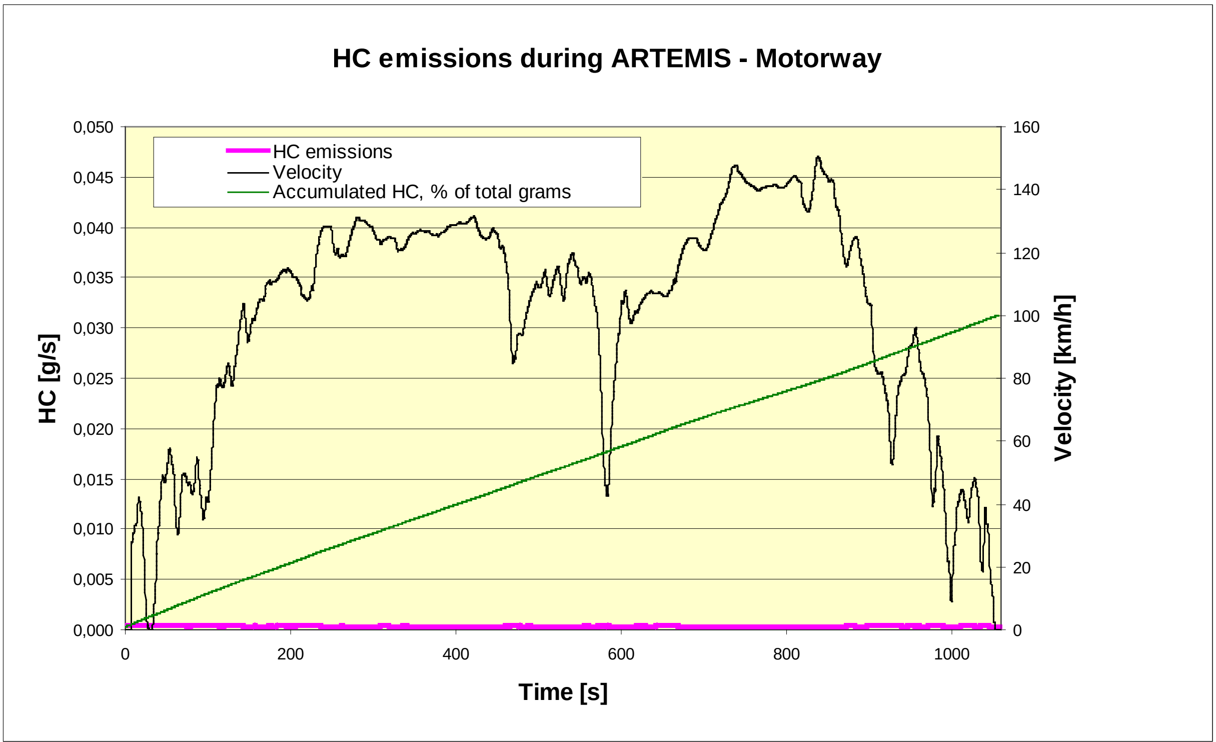


Figure 51: HC emissions during ARTEMIS Motorway cycle of a Euro 4 vehicle with compression ignition engine

The difference between positive and compressed ignition vehicles regarding NOx emissions on the Motorway-part become clear when looking at figure 52 and figure 53.

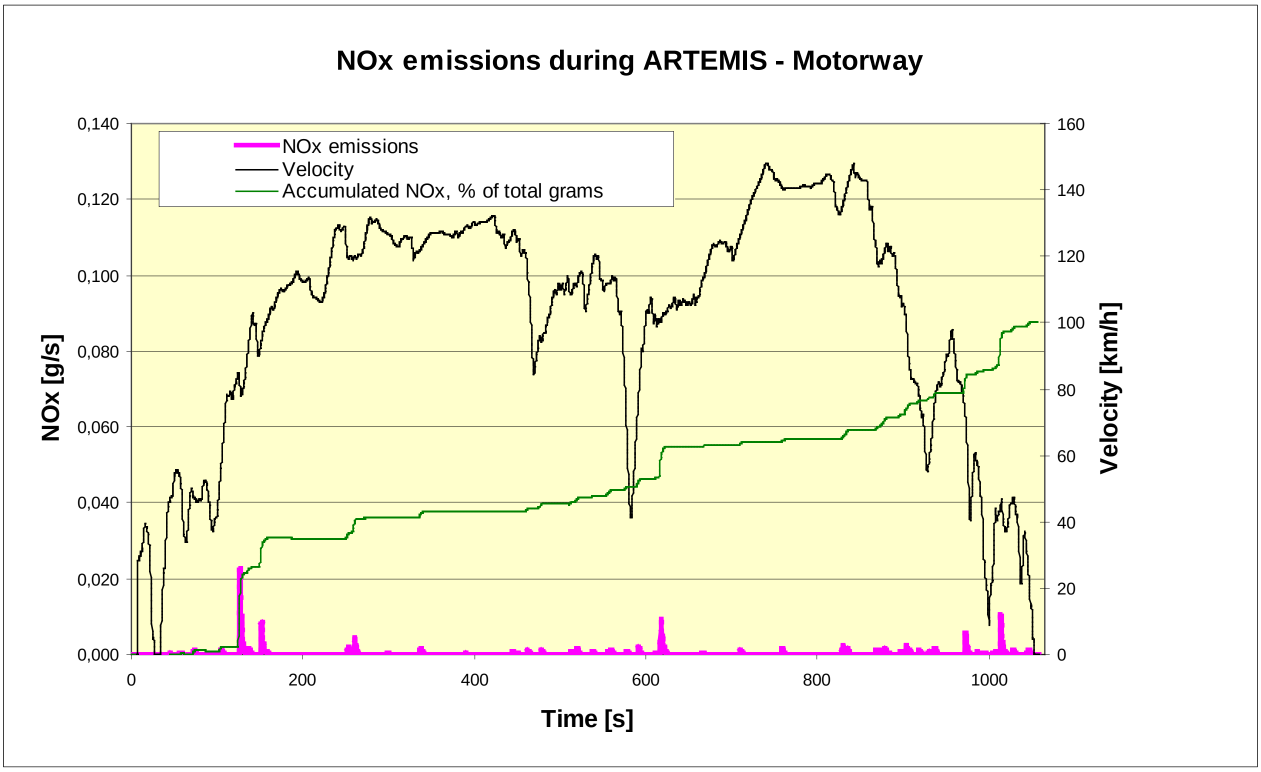


Figure 52: NOx emissions during ARTEMIS Motorway cycle of a Euro 4 vehicle with positive ignition engine

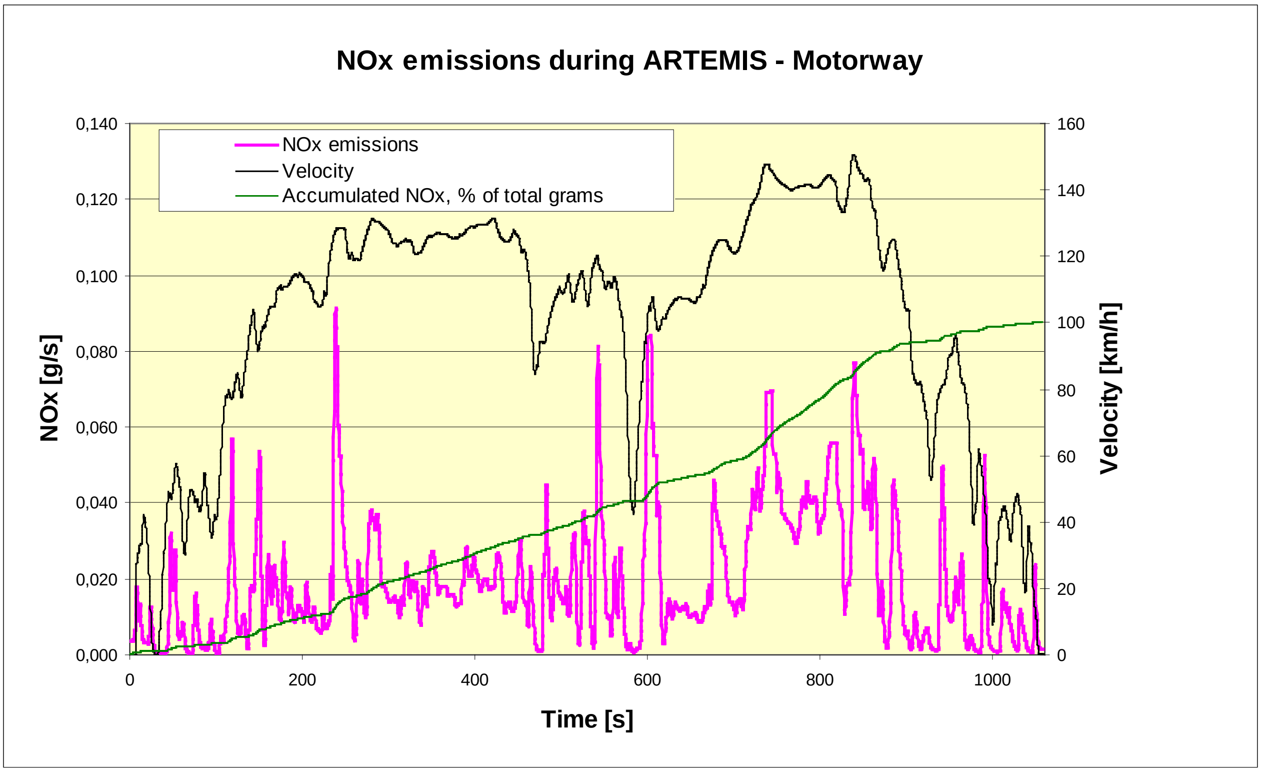


Figure 53: NOx emissions during ARTEMIS Motorway cycle of a Euro 4 vehicle with compression ignition engine

Table 10 show average data from all tested different vehicle types who have performed the ARTEMIS cycles and also Type I test.

	Driving Cycle		CO [g/km]	HC [g/km]	NOx [g/km]	PM-PMP [g/km]
Gasoline Euro 4	NEDC	Average	0,5330	0,0603	0,0268	0,0009
		Std.dev.	0,2706	0,0176	0,0079	0,0007
	ARTEMIS Urban Cold	Average	1,3743	0,1331	0,1135	0,0027
		Std.dev.	0,3137	0,0380	0,0321	0,0008
	ARTEMIS Urban	Average	0,3126	0,0020	0,0331	0,0015
		Std.dev.	0,1696	0,0015	0,0248	0,0008
	ARTEMIS Road	Average	0,3806	0,0030	0,0163	0,0006
		Std.dev.	0,1588	0,0017	0,0081	0,0002
	ARTEMIS Motorway	Average	2,2980	0,0078	0,0108	0,0014
		Std.dev.	0,3786	0,0024	0,0073	0,0006
Diesel Euro 4 M1	NEDC	Average	0,2834	0,0290	0,1886	0,0007
		Std.dev.	0,0874	0,0141	0,0127	0,0005
	ARTEMIS Urban Cold	Average	0,3622	0,0321	0,5789	0,0015
		Std.dev.	0,1250	0,0148	0,0597	0,0010
	ARTEMIS Urban	Average	0,0112	0,0244	0,7704	0,0022
		Std.dev.	0,0219	0,0207	0,0446	0,0017
	ARTEMIS Road	Average	0,0075	0,0071	0,4196	0,0013
		Std.dev.	0,0046	0,0011	0,0370	0,0010
	ARTEMIS Motorway	Average	0,0091	0,0076	0,7112	0,0017
		Std.dev.	0,0042	0,0006	0,1018	0,0012
Diesel Euro 4 N1 class III	NEDC	Average	0,0476	0,0164	0,3368	0,0298
		Std.dev.	0,0408	0,0062	0,0479	0,0090
	ARTEMIS Urban Cold	Average	0,0808	0,0083	0,9295	0,0886
		Std.dev.	0,0242	0,0028	0,0653	0,0330
	ARTEMIS Urban	Average	0,0366	0,0001	0,8368	0,0687
		Std.dev.	0,0083	0,0008	0,0900	0,0278
	ARTEMIS Road	Average	0,0104	0,0004	0,6785	0,0349
		Std.dev.	0,0028	0,0023	0,0633	0,0128
	ARTEMIS Motorway	Average	0,0259	0,0029	1,7593	0,0391
		Std.dev.	0,0057	0,0007	0,1326	0,0128
Euro 4 E85	NEDC	Average	0,4275	0,0515	0,0259	0,0003
		Std.dev.	0,0515	0,0071	0,0128	0,0001
	ARTEMIS Urban Cold	Average	1,4080	0,1573	0,0835	0,0010
		Std.dev.	0,1540	0,0498	0,0375	0,0005
	ARTEMIS Urban	Average	0,2469	0,0031	0,0641	0,0007
		Std.dev.	0,1494	0,0019	0,0577	0,0006
	ARTEMIS Road	Average	0,1200	0,0013	0,0179	0,0004
		Std.dev.	0,0365	0,0010	0,0099	0,0002
	ARTEMIS Motorway	Average	0,2458	0,0048	0,0135	0,0008
		Std.dev.	0,0270	0,0014	0,0080	0,0004
Euro 4 CNG	NEDC	Average	0,4662	0,0652	0,0200	0,0001
		Std.dev.	0,0620	0,0123	0,0083	0,0002
	ARTEMIS Urban Cold	Average	0,7459	0,3121	0,3045	0,0013
		Std.dev.	0,2375	0,1473	0,2397	0,0012
	ARTEMIS Urban	Average	0,1218	0,0560	0,4522	0,0010
		Std.dev.	0,1568	0,0413	0,3994	0,0006
	ARTEMIS Road	Average	0,0963	0,0157	0,2464	0,0004
		Std.dev.	0,1229	0,0063	0,2380	0,0001
	ARTEMIS Motorway	Average	0,2951	0,0128	0,0357	0,0009
		Std.dev.	0,1375	0,0065	0,0110	0,0002

Table 10: Average exhausts emissions from different vehicle types during Type I test (NEDC) and Common Artemis Driving Cycle

Figures 54 to 59 shows average CO, HC, NOx, PM emissions and also Fc during CADS for all tested vehicles compared to the average NEDC results.

For vehicles with positive ignition most of the carbon oxide emits during the UDC-phase (1^{st} part of the NEDC-cycle) and also during ARTEMIS Urban Cold cycle. In figure 54 the ARTEMIS Motorway table is very high due to that one vehicle family emitted significantly more CO on the ARTEMIS Motorway cycle than the other vehicle types. The crosshatched table for the ARTEMIS Motorway show average CO emissions without the high CO emitting vehicle family in particular.

One possible cause for the high CO emission may be that the ECU (Engine Control Unit) stops using close loop lambda control. To protect the catalytic converter from overheating, during accelerations/transients, it is common to run the engine at about λ 0,85.

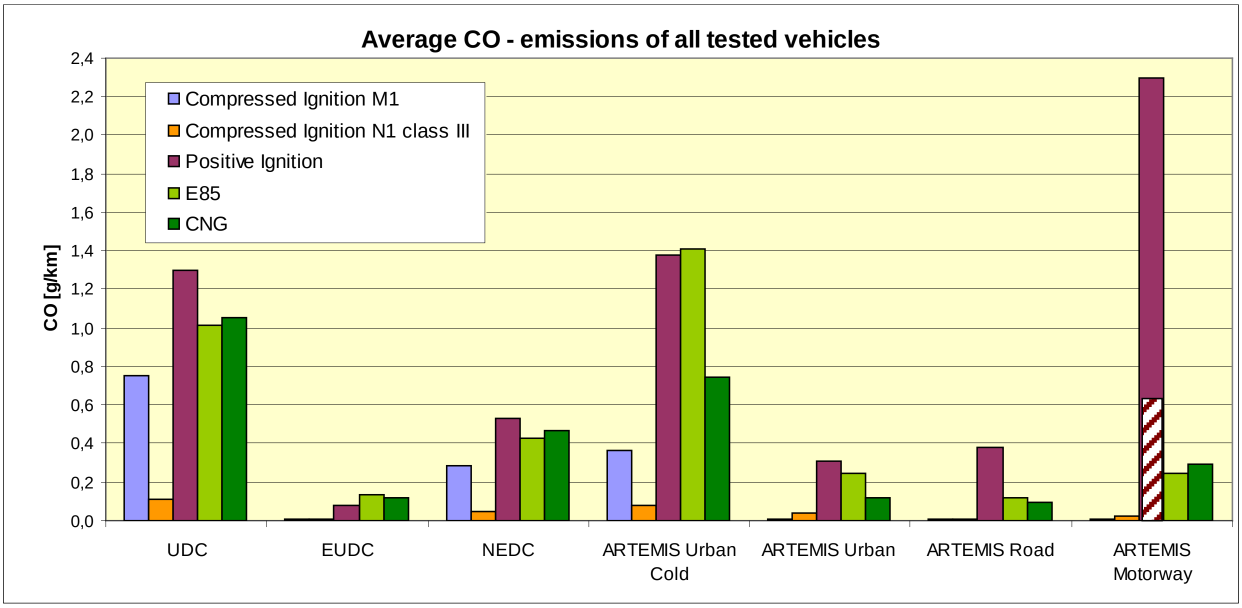


Figure 54: Average CO emissions of all tested vehicles during CADS

Figure 55 show the HC emissions from fore different cycles. The ARTEMIS Urban Cold Cycle has quite an impact on CNG vehicles were the HC emissions are higher than the rest of the vehicle types. One possible reason could be that the catalyst demands roughly 150 °C higher exhaust temperature for methane than for gasoline to reach high conversion rates.

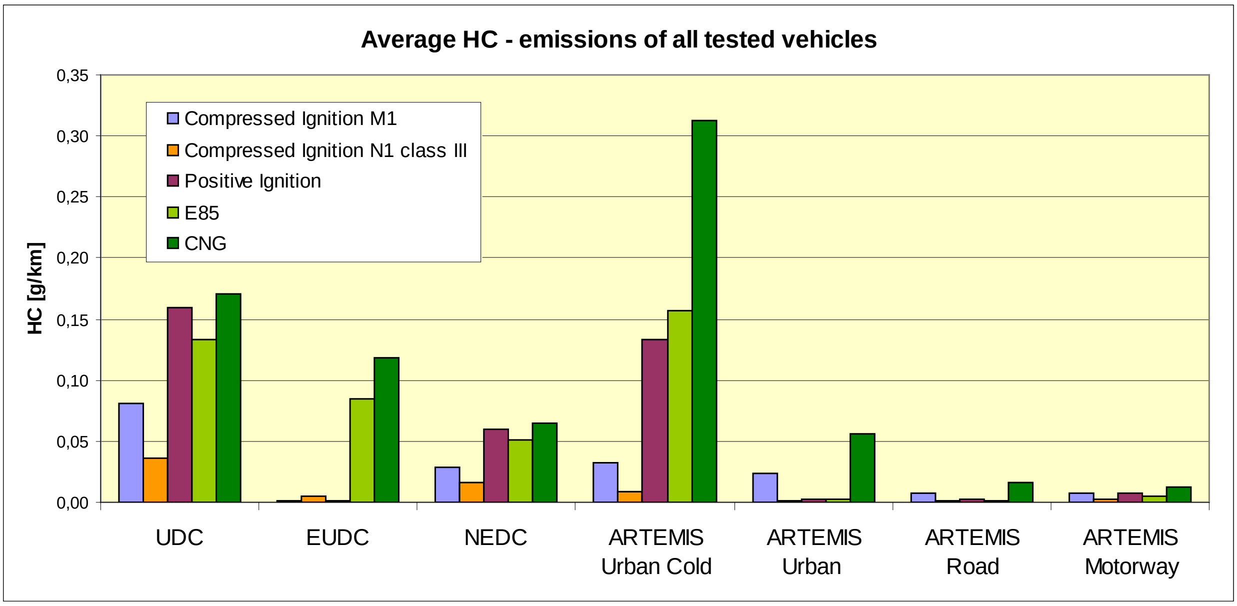


Figure 55: Average HC emissions of all tested vehicles during CADS

In figure 56 the compression ignition vehicles shows significant higher NOx emissions than the positive ignition vehicles. Euro 4 legislation allows three times more NOx emissions for compression ignition vehicles compared with positive ignition vehicles.

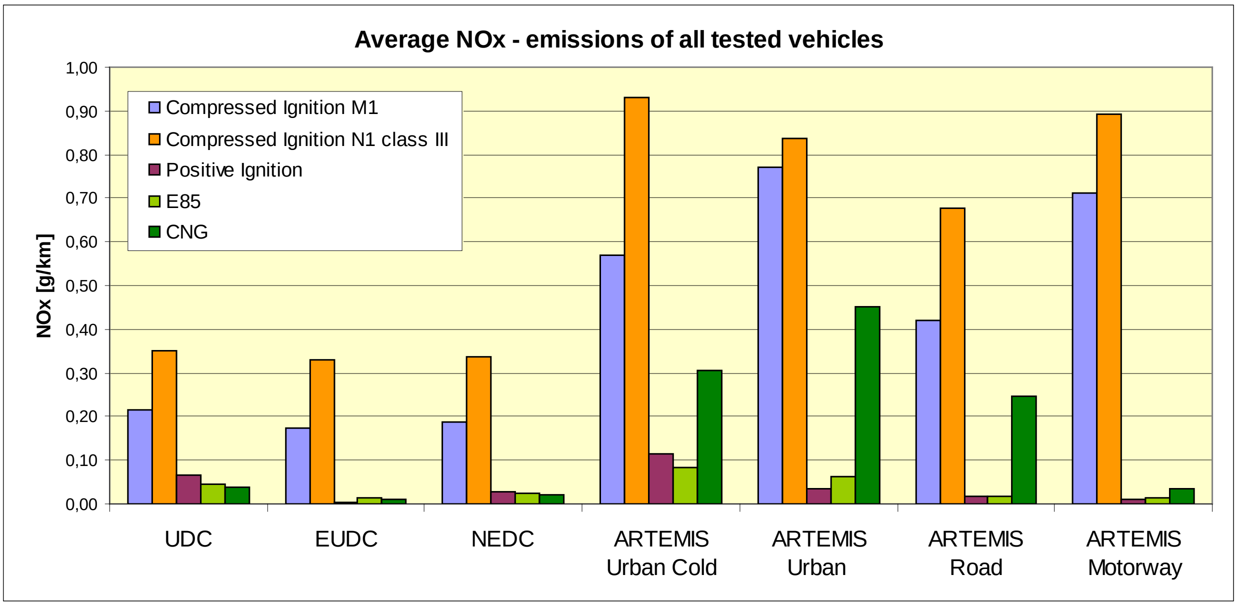
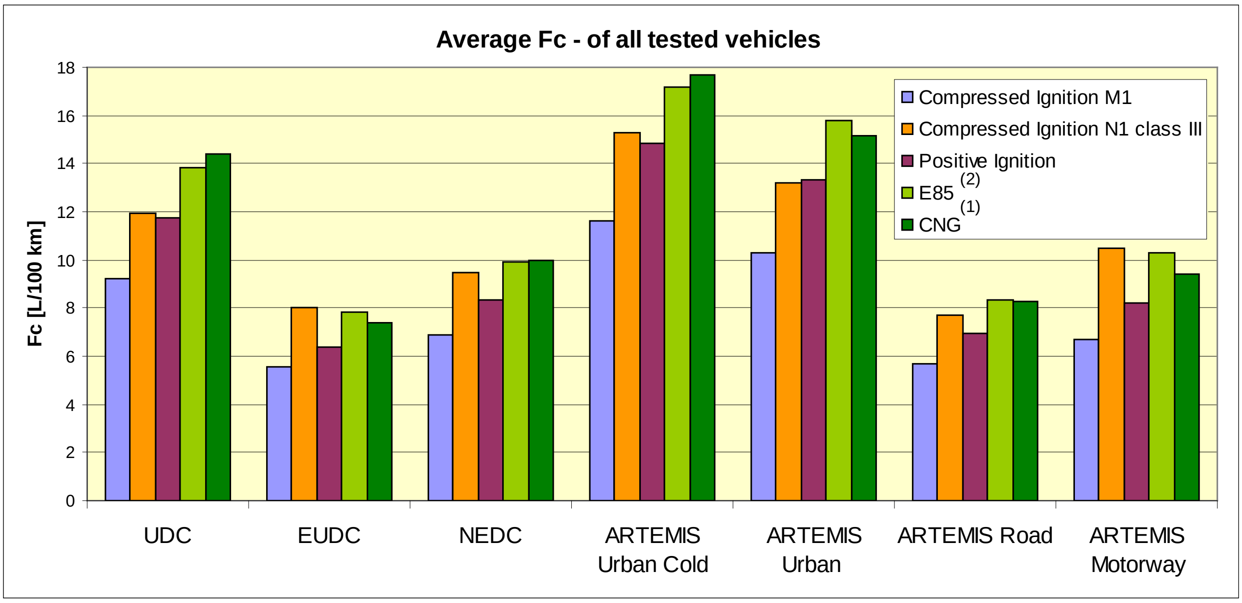


Figure 56: Average NOx emissions of all tested vehicles during CADS

Figure 57 shows the average fuel consumption for all tested vehicles. When looking at the different vehicle types it is difficult to draw conclusions due to the different weight classes and also the different energy content for different fuels.



(1) Fc for CNG vehicles = **[nm3/100km]**
(2) The E85 fuel contains less energy than diesel and gasoline

Figure 57: Average Fc of all tested vehicles during CADS

Figure 58 clearly demonstrates the N1 class III vehicles and its lack of DPF; the PM levels are very high compared to the 2005PM (M1) – vehicles.

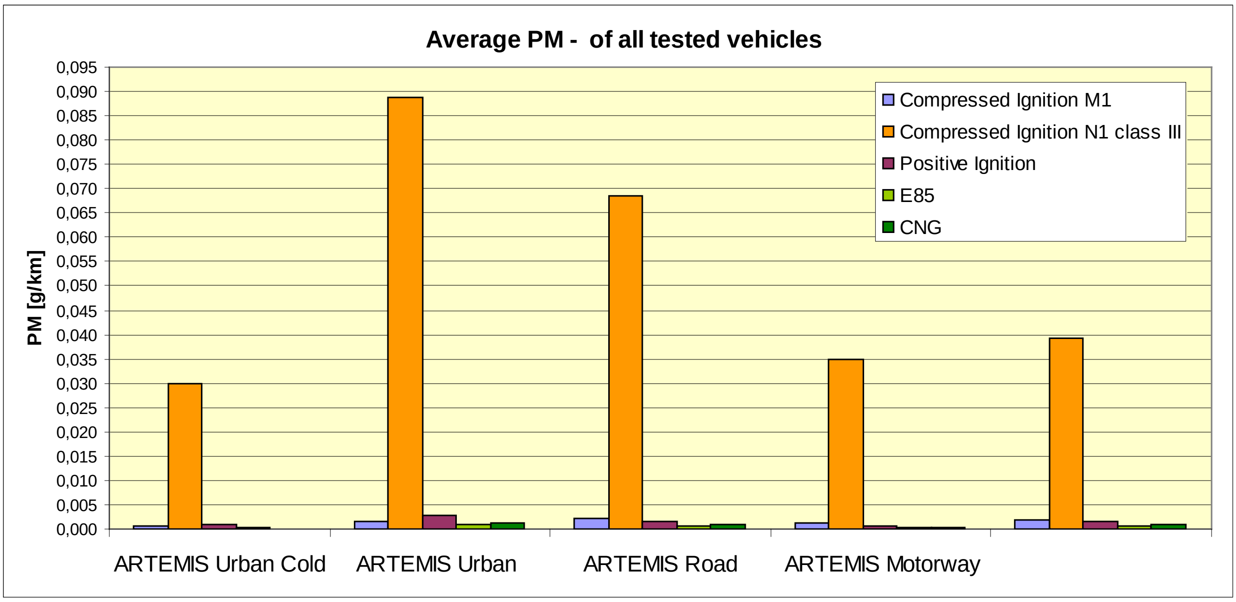


Figure 58: Average PM of all tested vehicles during CADS

Figure 59 demonstrates the difference between PM emissions when excluding Euro 4 N1 class III compression ignition vehicles from the rest of the tested vehicles. The DPF seem to work well for the compression ignition vehicles. The positive ignition vehicles seem to suffer more from cold start.

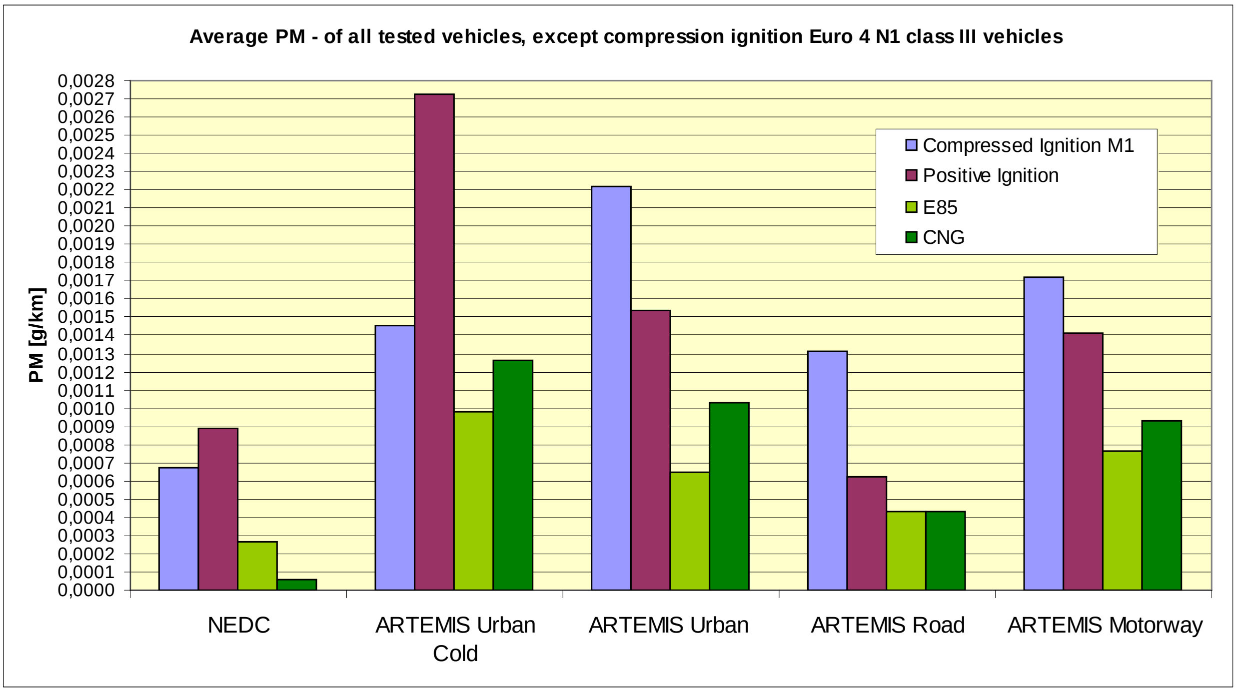


Figure 59: Average PM of all tested vehicles except compression ignition Euro 4 N1 class III vehicles during CADS

Particulate measurement according to PMP - protocol

Particle Measurement Programme (PMP) was initiated by a Working Group of the UN-ECE.

The objective of the PMP programme was to develop new particle measurement technologies to complement or replace the existing particulate mass measurement, with special consideration to measuring particle emissions at very low levels. In the PMP programme, it was concluded to measure only solid particles, since these are anticipated to have the most adverse health effects. As the PMP measurement protocol now is being finalised (ECE Regulation R83), new measurement systems have been developed fulfil the criteria set in this regulation.

For all the vehicles tested during the 2009 programme, the particulate measurement (PM) has been conducted according to the new procedure in the PMP-protocol to be implemented in the EU from the 1 September 2011 and is a part of UNECE reg.83.

The sampling system and analysing equipment are based on full flow dilution systems, i.e. the total exhaust is diluted using the CVS (Constant Volume Sampling) concept. The sampling system fulfils the requirements of the Directive 70/220/EEC including latest amendments.

For the PM measurement the particle emissions (PM) were measured gravimetrically by the use of TX40 filters. The diluted exhausts were sampled on the filters. Single filters were used.

Differences between PM and PMP can be seen in table 11.

PM according to 70/220/EEC including latest amendments	PM according to PMP protocol
HEPA Filter with 99.97% efficiency for dilution air	HEPA Filter with 99.97% efficiency for dilution air
Probe with china hat	Probe without china hat combined with cyclone
Temperature at filter pads max 52°C	Temperature at filter pads max 52°C
TA60 filterpads with 96,4% efficiency: one filter + backup filter per phase	TX40 filterpads with 99,9% efficiency: one filter without backup filter for both phases

Table 11: PM determination according to 70/220/EEC including latest amendments and to PMP protocol

Within the PMP protocol there are also requirements for particle number counting.

The measuring principle can be explained from figure 60 below.

Exhaust gas is sampled from a CVS tunnel and diluted with HEPA filtered compressed air. Inside the evaporation tube the diluted exhaust gas is heated to a degree that causes the volatile emission components to vaporize, leaving behind nothing other than solid particles. After that, the exhaust gas is diluted once again using a porous tube diluter and fed into the Condensation Particle Counter (CPC).

In the CPC, butanol is condensed on to the particles inside the exhaust gas to enlarge them so that they become visually detectable. The enlarged particles are then counted based on the scattered light pulses generated when the particles pass through the laser beam. This makes it possible to determine the number of particles per volume unit. According to PMP specifications, particles that exceed the size of 23nm are measured with an efficiency of 50±12% and particles exceeding 30nm are measured with an efficiency of 70±12%. Particles any smaller are not measured.

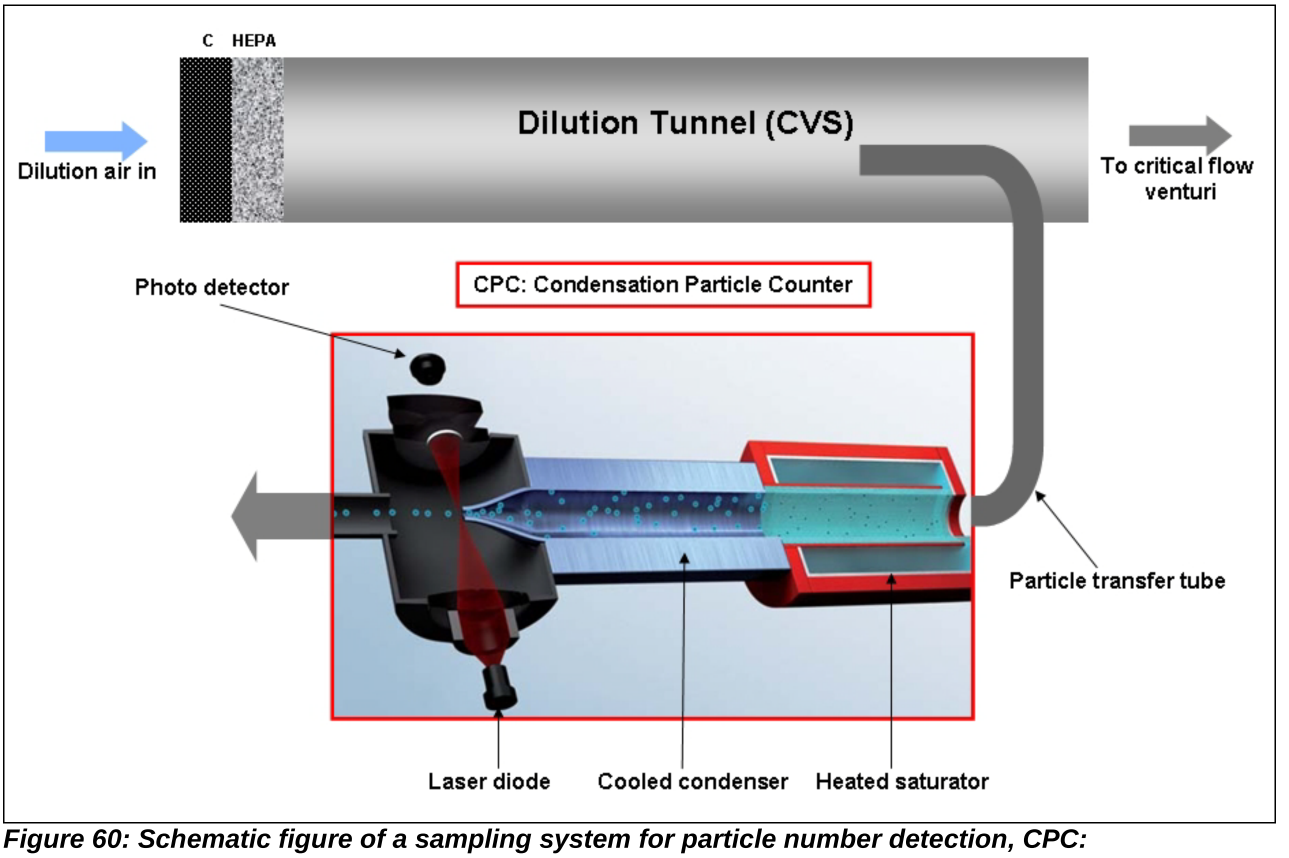


Figure 60: Schematic figure of a sampling system for particle number detection, CPC: Condensation Particle Counter

The Euro 6 limit for Particulate Matter (PM) is **4,5** mg/ and the particle number limit (6,00E+11) shall be effective from 1 September 2011 for the type-approval on new types of vehicles and from 1 January 2013 for all new vehicles sold, registered or put into service in the Community

Table 12 shows the average PM and PN# for all tested vehicles during the programme according to the PMP – protocol.

		NEDC	ARTEMIS Urban Cold	ARTEMIS Urban	ARTEMIS Road	ARTEMIS Motorway
Compression ignition vehicles Euro 4 M1	PM - PMP [mg/km]	0,7	1,5	2,2	1,3	1,7
	PN# [#/km]	1,2E+12	1,5E+12	1,9E+12	2,2E+12	1,5E+12
Compression ignition vehicles Euro 4 N1 class III	PM - PMP [mg/km]	29,8	88,6	68,7	34,9	39,1
	PN# [#/km]	1,2E+14	2,6E+14	2,2E+14	1,3E+14	2,2E+14
Positive ignition vehicles Euro 4	PM - PMP [mg/km]	0,5	1,6	1,3	0,6	1,4
	PN# [#/km]	1,2E+12	3,1E+12	6,3E+11	3,0E+11	6,6E+11
Positive ignition GDI vehicles Euro 4	PM - PMP [mg/km]	2,9	8,4	2,5	0,7	1,7
	PN# [#/km]	3,0E+12	1,3E+13	3,7E+12	1,5E+12	2,4E+12
Positive ignition vehicles E85 Euro 4	PM - PMP [mg/km]	0,3	1,0	0,7	0,4	0,8
	PN# [#/km]	2,0E+11	2,2E+12	5,5E+11	2,5E+11	9,0E+11
Positive ignition vehicles CNG Euro 4	PM - PMP [mg/km]	0,1	1,3	1,0	0,4	0,9
	PN# [#/km]	1,8E+10	6,5E+10	6,4E+10	1,9E+10	3,4E+10

Table 12: Average particle mass and particle number determined according to PMP-protocol

Figure 61 shows the PN# for each tested vehicle. The Diesel N1 class III vehicles are not equipped with DPF. The Diesel M1 vehicles are equipped with DPF.

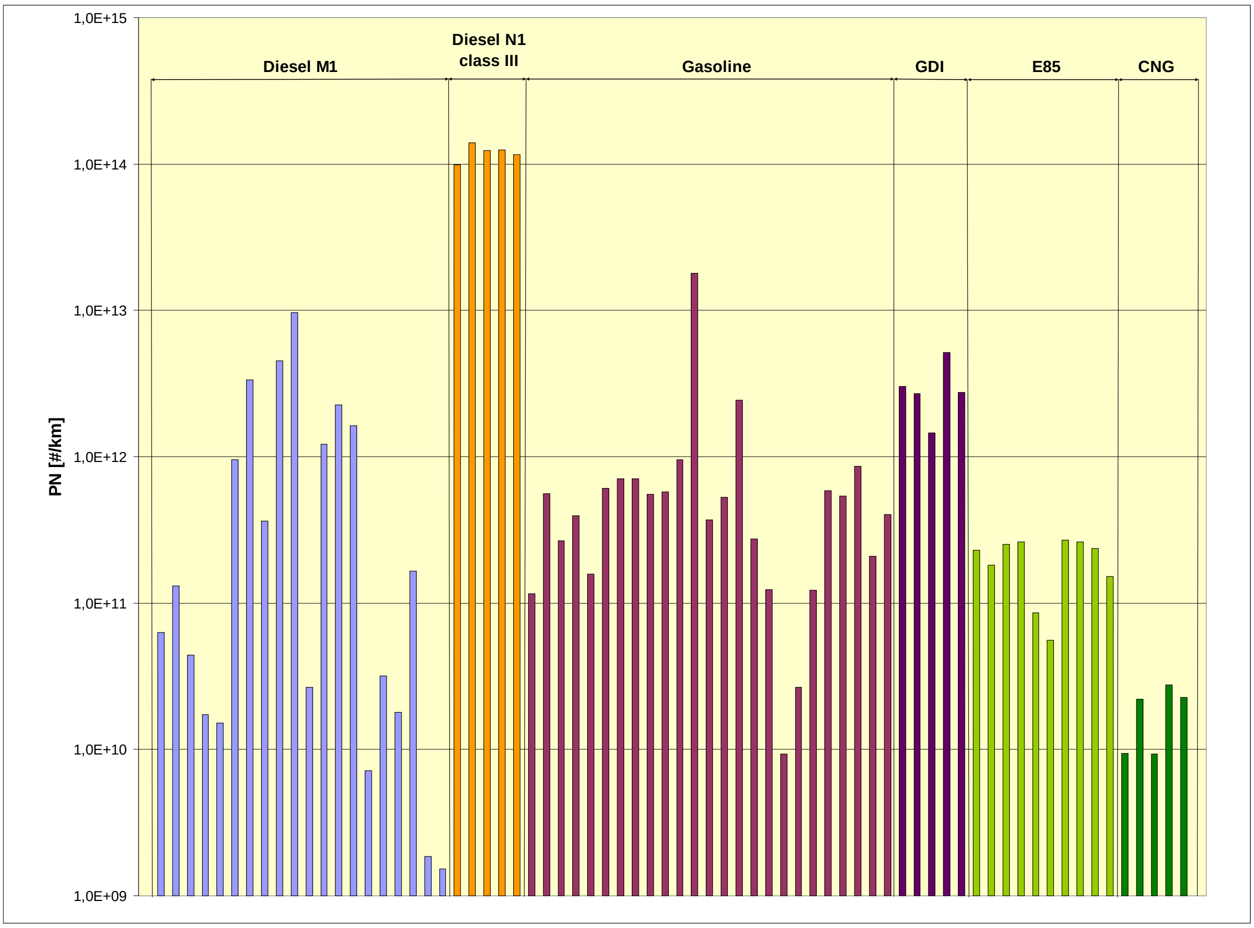


Figure 61: Particle number collection for all tested vehicles types during Type I test (NEDC)

Figure 62 and figure 63 show the difference in PN# between a positive ignition vehicle and a compression ignition vehicle, running the Type I test.

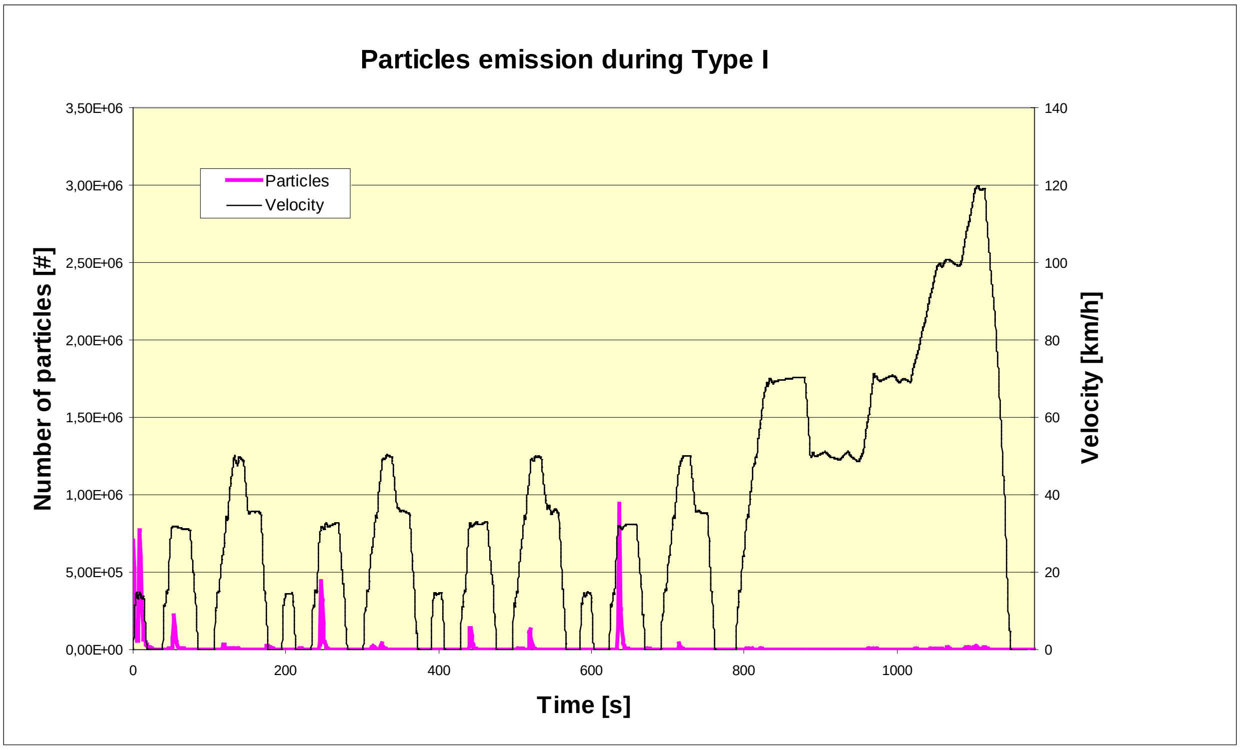


Figure 62: Particle emissions of a Euro 4 vehicle with positive ignition during Type I test (NEDC)

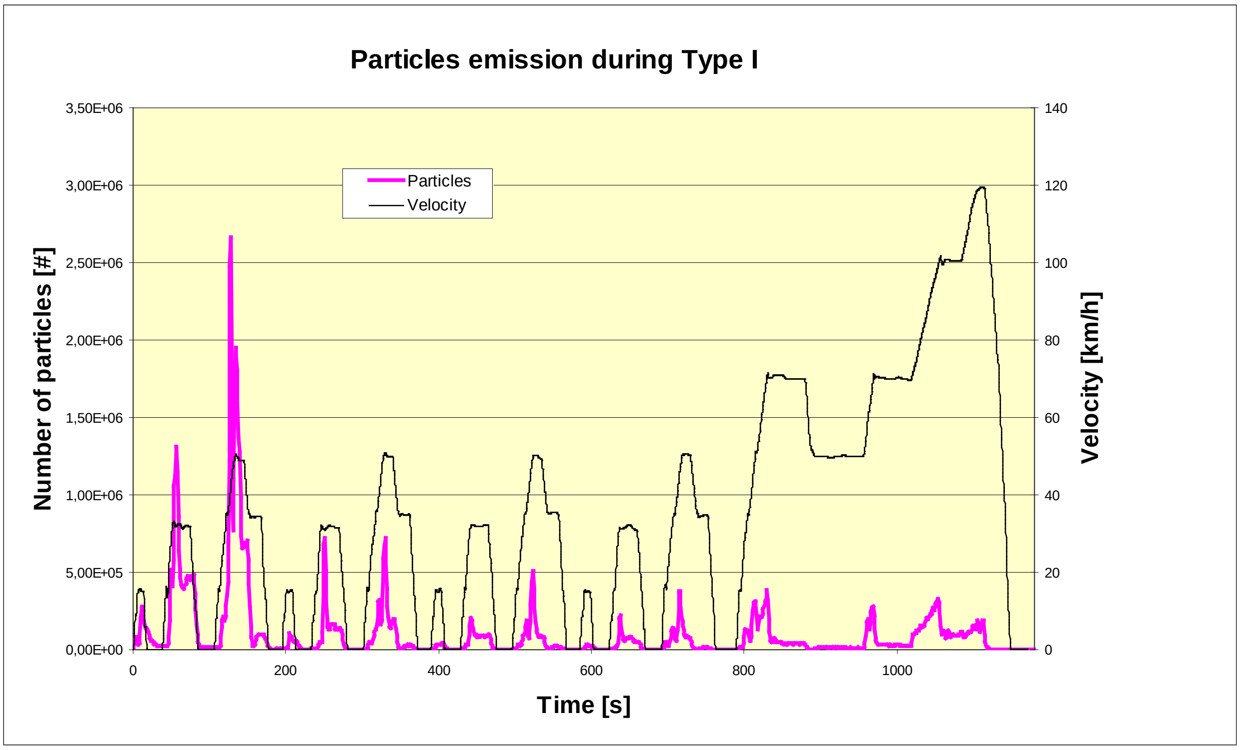


Figure 63: Particle emissions of a Euro 4 M1 vehicle with compression ignition and particle filter during Type I test (NEDC)

Figure 64 shows the PN# for a N1 class III vehicle with compression ignition and without DPF.

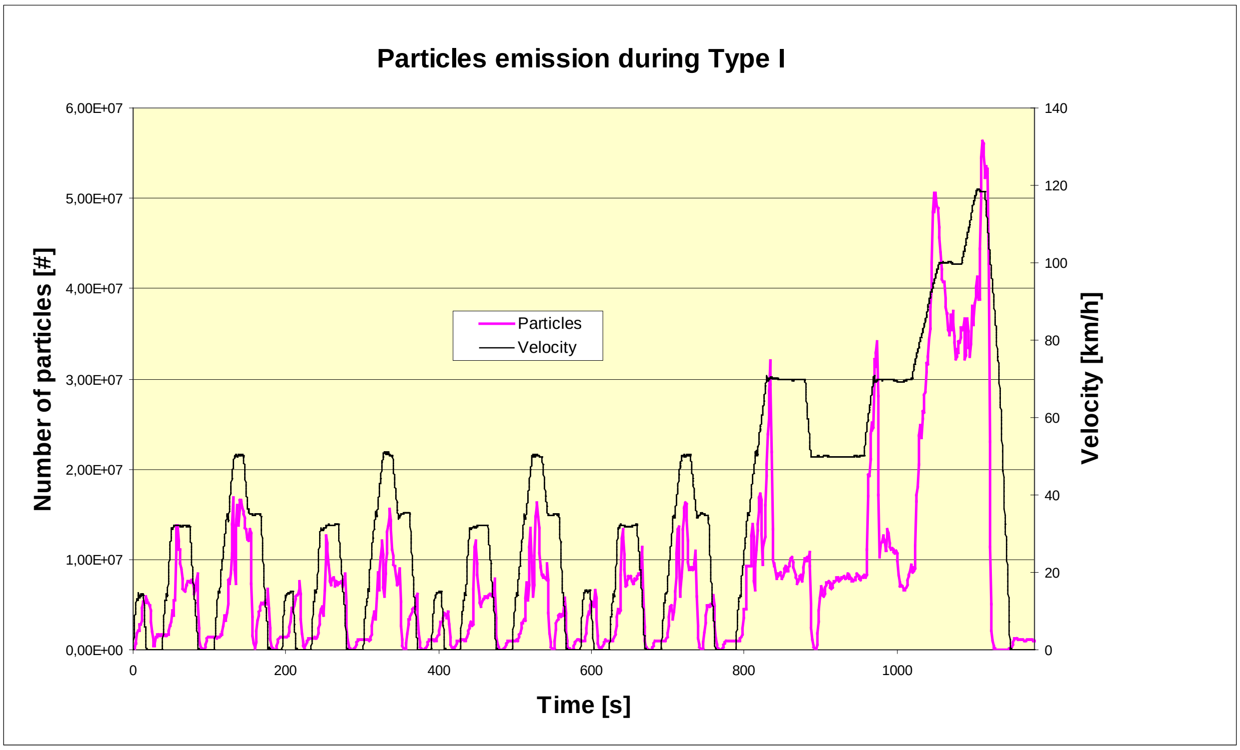


Figure 64: Particle emissions of a Euro 4 N1 class III vehicle with compression ignition during Type I test (NEDC) No DPF.

For the Artemis Urban Cold cycle the PN# is high in the beginning of the cycle and then flattens out. See comparison between a positive and compression ignition vehicle, figures 65 and 66.

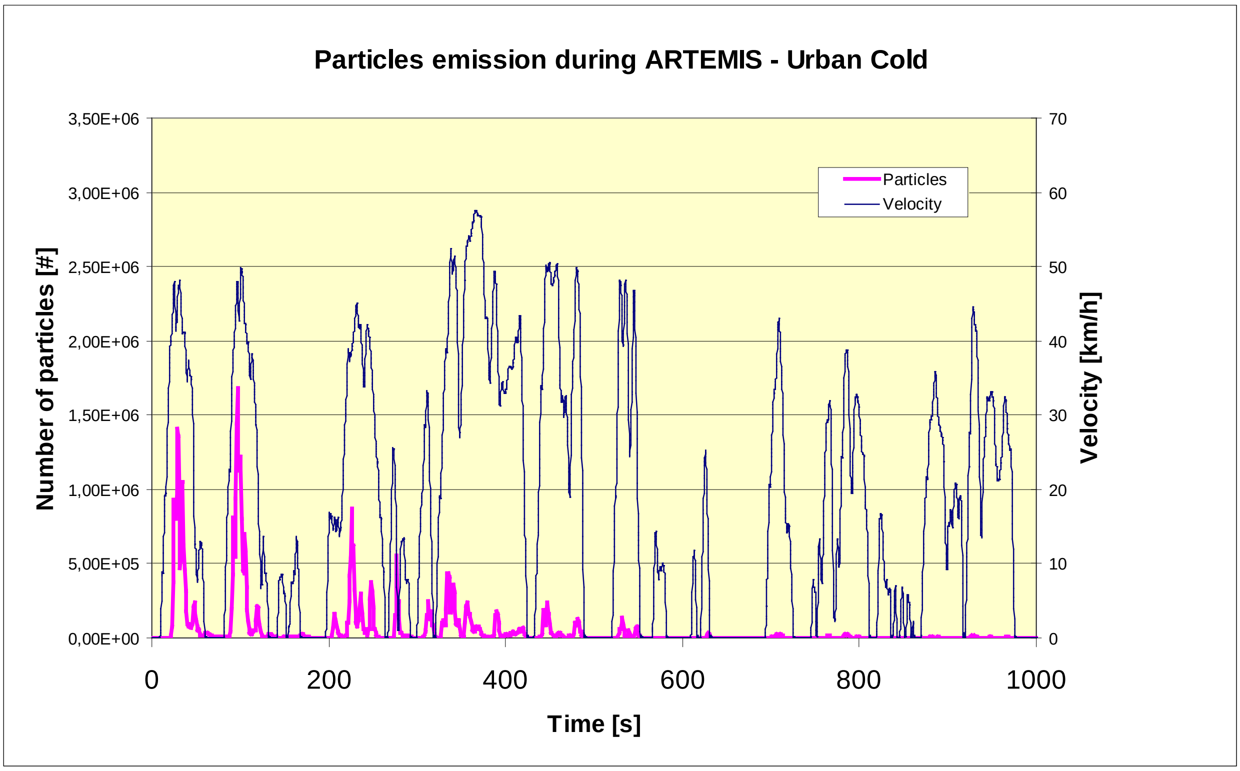


Figure 65: Particle emissions of an Euro 4 vehicle with positive ignition during ARTEMIS Urban Cold cycle

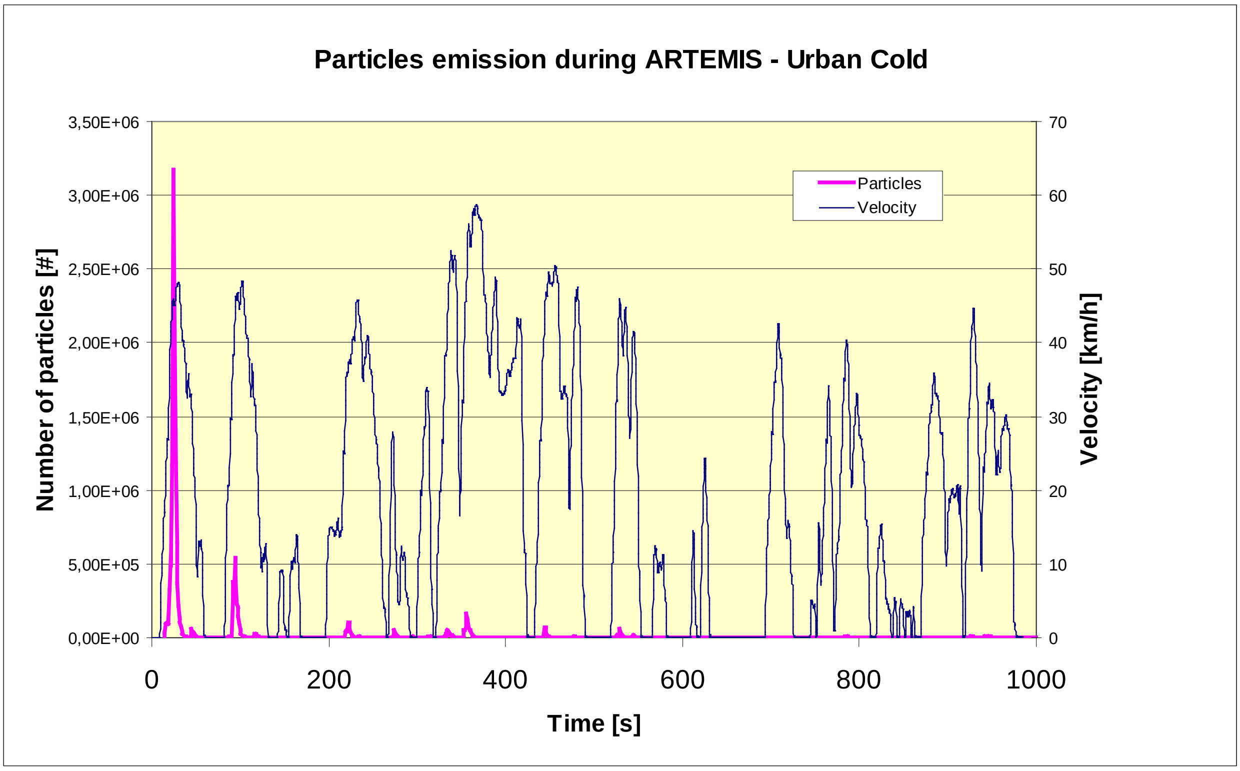


Figure 66: Particle emissions of an Euro 4 M1 vehicle with compressed ignition during ARTEMIS Urban Cold cycle

Figure 67 show the PN# during ARTEMIS Urban Cold cycle for an E85 vehicle which has approximately the same PN# as for the compressed ignition vehicle, previously shown in figure 66

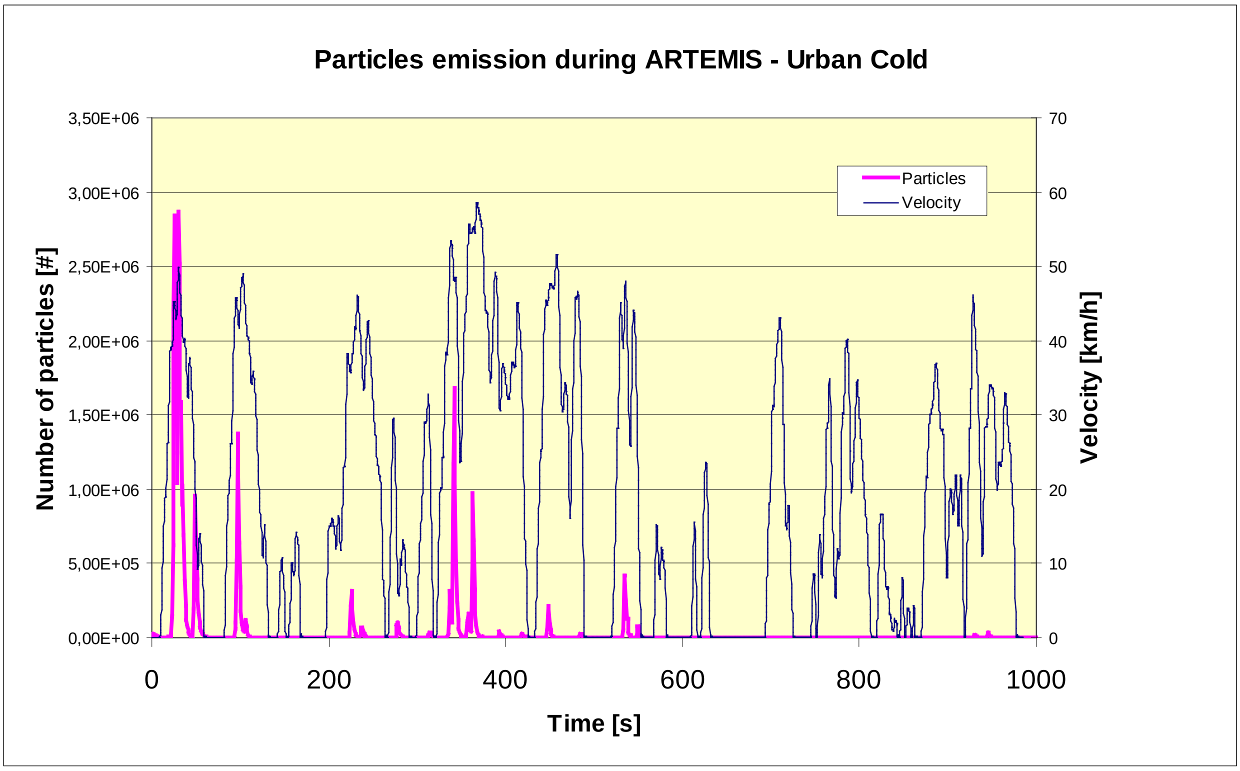


Figure 67: Particle emissions of an E85 vehicle with positive ignition during ARTEMIS Urban Cold cycle

OBD System

Directive 70/220/EEC as amended by 2003/76/EC requires that all vehicles must be equipped with an OBD system so designed, constructed and installed in a vehicle as to enable it to identify types of deterioration or malfunction over the entire life of the vehicle.

In the 2009 In Service Programme different manipulated failures such as electrical disconnections of oxygen sensor, fuel injectors, mass air flow sensor, pressure sensors etc. were made. All failures were registered and detected. All OBD-tested vehicles passed the tests according to the directive.

References

- Directive 70/220/EEC including all amendments
- Directive 80/1268/EEC including all amendments
- Euro 5/6 draft implementing legislation - Draft final version Published September 18, 2007
    - implementing and amending Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information
- Particle Measurement Programme (PMP), Light-duty Inter-laboratory Correlation Exercise (ILCE_LD) Final Report

Appendix 1

Fuel specifications

According to Directive 70/220/EEC as amended by 2003/76/EC reference fuels shall be used when performing the Type 1 and Type VI tests.

The following tables show the content of the reference fuels that have been used during testing.

CNG fuel composition:

GASEOUS FUEL:
The emissions are calculated according to directive 70/220/EEC, as last amended by directive 2003/76/EC. This means that the hydrocarbons are calculated as grams CH_4 per km when using gaseous fuel (NG).The fuel consumption is according to directive 80/1268/EEC, as last amended by directive 99/100/EC, and thus based on carbon balance method. The carbon balance uses the fixed carbon weight fraction 0.749 for both the carbon content in the hydrocarbon emissions as well for the fuel.

The fuel density used in the calculation is a fixed value for NG (natural gas) according to directive, 0.654 kg/m³. For the energy comparison a lower heating value of 31,9 MJ/m³ is applied for the gaseous fuel. This is an approximate figure valid both for biogas and natural gas. The tests are not performed using reference gaseous fuel but commercial gaseous fuel (fordonsgas) which in the Stockholm area is biogas or a biogas/natural gas mixture (compressed methane gas according to Swedish biogas standard SS 15 54 38).

Gasoline fuel composition:

GASOLINE FUEL:
The emissions are calculated according to directive 70/220/EEC, as last amended by directive 2003/76/EC. This means that the hydrocarbons are calculated as grams CH1,85 per km. The fuel consumption is according to directive 80/1268/EEC, as last amended by directive 99/100/EC, and thus based on carbon balance method. The carbon balance uses the fixed carbon weight fraction 0.866 for both the carbon content in the hydrocarbon emissions as well for the fuel.
The fuel density used in the calculation is according to certificate for the reference fuel, 0.753 kg/dm³.
For the energy comparison the lower heating value 42.75 MJ/kg is used for the gasoline fuel.

CEC Legislative Fuel RF-02-03; Batch: WG21513AC3

Property	Units	Haltermann Batch: WG21513AC3	Minimum	Maximum	Test Method
Research octane number (RON)		100,6	95	-	EN ISO 5164
Motor octane number (MON)		89	85	-	EN ISO 5163
Lead	mg/l	3	-	5	EN 237
Density @ 15°C	kg/m^3	753,2	740,0	754,0	EN ISO 12185
Sulphur content	mg/kg	2,4	-	10	ASTM D5453
Phosphorus content	mg/l	0,2	-	1,3	ASTM D3231
Oxidation stability	minutes	> 1200	480	-	EN ISO 7536
Existent gum content (solvent washed)	mg/100ml	1	-	4	EN ISO 6246
Copper strip corrosion (3 h @ 50°C)	rating	1A	-	-	EN ISO 2160
Olefins	vol %	4,5	-	10,0	ASTM D1319
Aromatics	vol %	31,8	29,0	35,0	ASTM D 1319
Benzene content	vol %	0,19	-	1,00	EN 12177
Oxygen content	mass %	< 0,1	-	0,1	EN 1601
Oxygenates content	vol %	< 0,1	-	-	EN 1601
Vapour Pressure	kPa	58,3	56,0	60,0	EN 13016-1 reported as DVPE
Distillation curve					EN ISO 3405
IBP	°C	38,5	-	-	
Dist. 10% v/v	°C	51,3	-	-	
Dist. 50% v/v	°C	91,2	-	-	
Dist. 90% v/v	°C	160,1	-	-	
E 70	vol %	34,5	24,0	40,0	
E 100	vol %	54,6	50,0	57,0	
E 150	vol %	84,4	83,0	87,0	
FBP	°C (max)	190,8	190,0	210,0	
Dist. residue	vol %	1,0	-	2,0	
Carbon	% wt	86,90	-	-	ASTM D3343
Hydrogen	% wt	13,10	-	-	ASTM D3343
C:H ratio (C=1)	-	1,800	-	-	ASTM D3343
Net Heating Value	MJ/kg	42,750	-	-	ASTM D3338
Net Heating Value	Btu/lb	18380	-	-	ASTM D3338

E10-fuel used in evaporative emission test

Property	Units	Preem Gasoline 95, E10, Batch: 2009033883	EN 228	Test Method
Research octane number (RON)		95,2	≥ 95	EN ISO 5164:2005
Motor octane number (MON)		85,0	≥ 85	EN ISO 5163:2005
Lead	mg/l	≤ 1,0	≤ 5	EN 237:2004
Density @ 15°C	kg/m^3	747,5	720-775	EN ISO 12185 T1:99
Sulphur content	mg/kg	≤ 3	≤ 10	EN ISO 20884:2004
Oxidation stability	minutes	≥ 600	≥ 360	EN ISO 7536:1996
Existent gum content (solvent washed)	mg/100ml	≤ 4	≤ 5	EN ISO 6246:1998
Copper strip corrosion (3 h @ 50°C)	rating	1A	class 1	EN ISO 2160:1998
Appearance		Bright and Clear	Bright and Clear	Visual inspection
Olefins	vol %	3,2	≤ 18,0	EN ISO 22854:2008
Aromatics	vol %	26,5	≤ 35,0	SS 15 51 20:1996
Benzene content	vol %	0,52	≤ 1,0	EN 238:1996/A1:04
Oxygen content	mass %	3,48	≤ 3,7	EN ISO 22854:2008
Oxygenates content -methanol -ethanol -iso-propyl alcohol -iso-butyl alcohol -tert-butyl alcohol -ethers (5 or more C-atoms) -other oxygenates	vol %	 0 10,0 0 0 0 0 0	 ≤ 3 ≤ 10 ≤ 12 ≤ 15 ≤ 15 ≤ 22 ≤ 15	EN ISO 22854:2008
Vapour Pressure Summer (Sweden) Winter (Sweden)	kPa	61,0	 45 - 70 65 - 95	EN 13016-1:2007 reported as DVPE
Distillation curve			Summer / Winter	EN ISO 3405:2000
% evaporated at 70°C, E70	°C	44,3	20 - 48 / 22 - 50	
% evaporated at 100°C, E100	°C	56,9	46 - 71	
% evaporated at 150°C, E150	°C	93,3	≥ 75,0	
IBP	°C	38,9	-	
Temp. at 10% V/V evap.	°C	53,1	-	
Temp. at 50% V/V evap.	°C	84,9	-	
Temp. at 90% V/V evap.	°C	143,4	-	
FBP	°C	185,0	210	

E85/75 fuel composition:

ALCOHOL FUEL E85:
Since the directive 70/220/EEC does not describe how to handle emission and fuel consumption measurements for alcohol fuels AVL MTC have chosen to handle it the following way.(please note that the tested vehicles are Euro 4 spec,) The emissions are calculated according to directive 70/220/EEC, as last amended by directive 2003/76/EC, with the following exception: The "Fs" (the denominator in the formula for DF) is changed from 13.4 to 12.5 because of the change in stoichiometry using E85 (an influence that though is negligible in this case). The hydrocarbons are here also calculated as grams CH1,85 per km, even if the composition of the hydrocarbon emissions using E85 fuel definitely will differ from the ones emitted by gasoline fuel.

The FID instrument used for the HC analysis is still calibrated using propane gas and the response factor is set to 1 (same as for gasoline fuel).
The same formula is used to calculate KH for the NOx correction as in the gasoline fuel case. The carbon balance is used to calculate the fuel consumption for the alcohol fuel also. The carbon balance uses the fixed carbon weight fraction 0.866 for the carbon content in the hydrocarbon emissions as a consequence of the assumed hydrocarbon composition. For the fuel, the carbon weight fraction 0.564 is used. The fuel density used in the calculation is calculated according to composition for the E85 fuel used, that is 0.782 kg/dm^3.

Summer and winter E85 at A60 testing 2009:

Property	Units	SEKAB Summer E85	SEKAB Winter E85	Minimum	Maximum	Test Method
Research octane number* (RON)		Not analyzed	Not analyzed	95	-	EN ISO 5164
Motor octane number* (MON)		Not analyzed	Not analyzed	85	-	EN ISO 5163
Sulphur content	mg/kg	<10	<10	-	10	EN ISO 20846 EN ISO 20884
Oxidation stability*	minutes	Not analyzed	Not analyzed	360	-	EN ISO 7536
Existent gum content* (solvent washed)	mg/100 ml	Not analyzed	Not analyzed	-	5	EN ISO 6246
Ethanol	% (v/v)	85	77	75 (summer) 70 (winter)	86	EN 1601 EN 13132
Higher alcohols (C3 – C8)	% (v/v)	0,2	0,2	-	2,0	
Methanol	% (v/v)	0,4	0,4	-	1,0	
Ethers (5 or more C)	% (v/v)	1,3	2,1	-	5,2	
Phosphorus content	mg/l	Not analyzed	Not analyzed	Not detectable		ASTM D3231
Water content	% (v/v)	0,13	0,05	-	0,3	ASTM E 1064
Inorganic chloride content	mg/l	< 0,1	< 0,1	-	1	ISO 6227
pHe		9	6,7	6,5	9,0	ASTM D 6423
Copper strip corrosion* (3 h @ 50°C)	rating	Not analyzed	Not analyzed	-	Class 1	EN ISO 2160
Acidity, (as acetic acid)	% (m/m)	0,002	0,002	-	0,005	ASTM D1613
Vapour Pressure	kPa	41,2	52,2	35 (summer) 50 (winter)	70 (summer) 95 (winter)	EN 13016-1 reported as DVPE
FBP	°C (max)	80	150	-	205,0	EN ISO 3405 ASTM D3710
Dist. Residue	vol %	1,0	0,8	-	2,0	
Density @ 20°C	kg/m^3	782,0	776,2	-	-	EN ISO 12185

*) Solvent washed gum, Octane number, oxidation stability and copper strip corrosion not analyzed but guarantied by supplier to be within specification.

Diesel fuel composition:

CEC Legislative Fuel RF-06-03; Batch: WE05513AB5

Property	Units	Haltermann Batch: WE05513AB5	Minimum	Maximum	Test Method
Cetane number (CFR)		52,9	52	54	EN ISO 5165
Density @ 15°C	kg/m^3	833,6	833	837	EN ISO 3675 EN ISO 12185
Distillation curve					EN ISO 3405
IBP	vol %	204,0	-	-	EN ISO 3405
Dist. 10%	vol %	233,7	-	-	EN ISO 3405
Dist 50%	vol %	275,3	245,0	-	EN ISO 3405
Dist 90%	vol %	322,3	-	-	EN ISO 3405
Dist 95%	vol %	348,4	345,0	350,0	EN ISO 3405
FBP	°C	357,7	-	370,0	EN ISO 3405
Flash Point	°C	88	55	-	EN ISO 2719
CFPP	°C	-20	-	- 5	EN 116
Cloud Point	°C	-19	-	-	ISO 3015
Viscosity @ 40°C	cSt	2,930	2,300	3,300	EN ISO 3104
Aromatics, total	mass %	23,4	-	-	IP 391
Aromatics, mono	mass %	19,0	-	-	IP 391
Aromatics, Di	mass %	4,3	-	-	IP 391
Aromatics, Tri+	mass %	< 0,1	-	-	IP 391
Aromatics, Poly (2+)	mass %	4,4	3,0	6,0	IP 391
Suphur	mg/kg	1,6	-	10,0	EN ISO 6246
Copper strip corrosion (3 h @ 50°C)	rating	1A	-	Max. 1	EN ISO 2160
Carbon Residue	mass %	< 0,01	-	0,20	EN ISO 10370
Ash Content	mass %	0,002	-	0,010	EN 13132 EN 14517
Water	mass %	0,0026	-	0,0200	EN ISO 12937
Strong Acid Number (KOH/g)	mg	< 0,02	-	0,02	ASTM D974
Oxidation stability	mg/ml	<0,001	-	0,025	EN ISO 7536
Carbon	mass %	86,35	-	-	ASTM D3343
Hydrogen	mass %	13,65	-	-	ASTM D3343
C:H ratio (H=1)	-	6,33	-	-	ASTM D3343
H:C ratio (C=1)	-	0,158	-	-	ASTM D3343
Net Heating Value	MJ/kg	43,199	-	-	ASTM D3338
Net Heating Value	Btu/lb	18570	-	-	ASTM D3338
HFRR	µm	207	-	400	EN ISO 12156-1
FAME	vol %	Passes	-	Non added	Local

Appendix 2

On-road testing - PEMS

In Table 2, section test programme vehicles, all tested cars with spark ignition are presented. These vehicles were tested on chassis dynamometer according to Directive 70/220/EEC as amended by 2003/76/EC. In addition, vehicle family no 4, SAAB 9-3 Aero (see Table 2), was tested with a Portable Emission Measurement System (PEMS). The instrument is an on-board emission analyzer that enables tailpipe emissions to be measured and recorded simultaneously while the vehicle is in operation.

The instrument, Semtech-DS, is developed by Sensors for testing all classes of diesel, gasoline and natural gas powered vehicles, both light as well as heavy duty vehicles and the instrument measures under real-world operating conditions.
The following measurement subsystems are included in the Semtech-DS emission analyzer:

- Heated Flame Ionization Detector (HFID) for total hydrocarbon (THC) measurement.
- Non-Dispersive Ultraviolet (NDUV) analyzer for nitric oxide (NO) and nitrogen dioxide (NO_2) measurement.
- Non-Dispersive Infrared (NDIR) analyzer for carbon monoxide (CO) and carbon dioxide (CO_2) measurement.
- Electrochemical sensor for oxygen (O_2) measurement.

The instruments are operated in combination with an electronic vehicle exhaust flow meter, Semtech E_xFM. The Semtech-DS instrument uses the flow data together with exhaust component concentrations to calculate instantaneous and total mass emissions. The flow meter is available in different sizes depending on engine size. A 2.5" flow meter was used, which is suitable for the engine size of the tested vehicles.
The program for emission calculation was supplied by Joint Research Centre (JRC).

The on-road testing and calculation has been performed in accordance with the PEMS protocol. According to the PEMS protocol the driving routes should include urban, suburban, and highway driving. Where possible, the trips should include:

- Hill climbs;
- Segments with cruising at constant speed and segments that is highly transient in their character;
- Different altitudes.
- Typical driving for the vehicle type

The test rout used was a part of the PEMS route used for the heavy duty pilot programme.

Test route description*:*
Below are the test routes presented with data in Table 1 and a plot speed vs. time in Figure 1.

Trip duration (s)	1200
Trip distance (km)	13.9
Average speed (km/h)	42

Table 1: Total test route data, PEMS test route.

In order to compare the PEMS route results with chassis dynamometer testing, emissions from 20 minutes of driving were calculated i.e. the same duration as NEDC.

Prior testing, the vehicles were prepared and soaked according to the standard test procedure i.e. 22 °C. The test route was carried out at an ambient temperature of -2 °C and studded tyres were used.

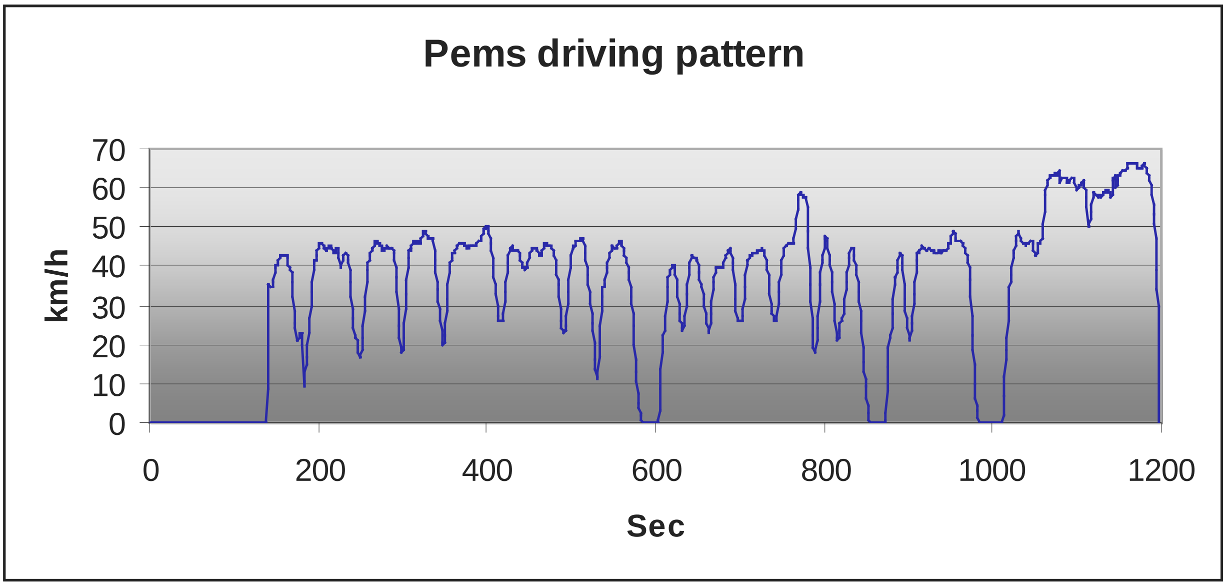


Figure 1: The light duty PEMS test route

Results

From the results in Table 2 it can be seen that the emission results when comparing chassis dynamometer testing and on road measurements differs in the rage of 10 to 60 % for the different vehicles except NOx, vehicle no 2. The fuel consumption is 10 % higher on road mainly due to tires and road surface (snow). Vehicle no 3 were tested on dry roads.

	CO g/km	HC g/km	NOx g/km	Fc l/100km
SAAB 1 CD	0,31	0,07	0,04	10,4
SAAB 1 PEMS	0,19	0,04	0,04	11,8
SAAB 2 CD	0,21	0,05	0,04	10,4
SAAB 2 PEMS	0,51	0,04	0,10	11,9
SAAB 3 CD	0,27	0,05	0,03	10,3
SAAB 3 PEMS	0,35	0,03	0,06	9,7
Euro 4 Limit	**1**	**0,1**	**0,08**	**-**

Table 2: Emissions and fuel consumption from on-board (PEMS) measurements and chassis dynamometer (CD) testing.