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TNO report

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Real World Exhaust Gas Emissions of N2 Distribution Trucks

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Contents

1 Introduction

1.1 Background

Commissioned by the Dutch Ministry of Environment (VROM) TNO regularly performs measurements to determine the emissions performance and durability of vehicles in-use in the Netherlands. The aim of this measurement programme is, amongst others, to gain insight into trends in real-world emissions of heavy duty vehicles, under the usage conditions relevant for the Dutch situation.

In the past decade, vehicle emissions in general have been reduced substantially as a result of the European exhaust emissions legislation. Air quality problems have been reduced to specific hot-spots, which are mainly situated in urban areas. Therefore, the emission performance of vehicles under urban conditions is of increasing importance for air quality improvement.

In the past two years, TNO has performed a series of emission measurements on Euro V trucks. These measurements were performed using a Portable Emission Measurement System (PEMS). Parts of these results have been reported earlier [Ligterink et al, 2009]. During the mentioned test programme only one light distribution truck of category N2 (~12 tonne) was measured. This truck, typically deployed in an urban environment, had relatively high NO_x-emissions. So far, the existing dataset did not contain sufficient information to draw conclusions on emission behaviour of light trucks. However, light trucks have an important share in the urban fleet and the emission of this class of trucks is specifically relevant in the context of reaching the NO_2 air quality limits in urban areas, as imposed by European legislation. This gave the Dutch Ministry of Environment (VROM) reason for assigning TNO for a follow-up study to investigate the on-road NO_x-emission of trucks in the light distribution segment.

PEMS is also used for the procedure currently being developed for the future In-Service Conformity legislation. This procedure uses a special data-evaluation tool EMROAD to calculate the Conformity Factor for a regulated emission component of a given engine type in a vehicle by means of a specially developed pass fail method. The emissions were also evaluated according to this In-service Conformity. Some additional tests were added to the programme where the on-road trips were varied in composition to investigate this effect on the results of the EMROAD tool.

This report gives an overview of the results from the on-road emission tests performed with the three N2 distribution trucks. The results of the measurements on the three distribution trucks in combination with the earlier tested trucks are discussed in a separate report [Verbeek et al, 2010] dealing with the emission performance of all tested heavy duty vehicles so far.

1.2 Aim and approach

The aim of the research was to improve insights in the emission performance of relatively new light distribution trucks in real world operation.

The aim of the program was threefold:

- to assess the real world emission performance with a focus on the NO_x emission. In particular at urban or low speed driving conditions and with different payloads;
- to collect information to establish emission factors, in particular at urban or low speed driving conditions and with different payloads;
- to assess the the emissions this type of trucks according to the In-Service Conformity procedure.

Measurements on the road were performed with three distribution trucks from category N2, using a Portable Emission Measurement System (PEMS).

The data was analysed in three ways:

- using the EMROAD tool in combination with a binning method in order to obtain real-world NO_x emissions as a function of vehicle speed;
- using EMROAD to determine the In-Service Conformity Factors;
- using EMROAD to determine distance and mass-distance specific emissions.

1.3 Structure of the report

The research method is described in Chapter 2. The research results obtained for each vehicle are presented in Chapter 3.

2 Emission measurement programme

The exhaust gas emissions of three distribution trucks (category N2) were measured with a Portable Emission Measurement System (PEMS) on the road. This chapter describes the set-up of the programme, consisting of the selection of the three vehicles, the selection of on-road trips and the methods to process and analyse the data.

2.1 Measuring real world emissions with PEMS

European type approval for emissions of truck engines is obtained from tests performed on prescribed engine cycles on an engine test bed under laboratory conditions. For the determination of real world emissions of in-use vehicles, execution of engine tests on an engine test bed is not effective and not representative. With the introduction of PEMS, or Portable Emission Measurement System, it has become possible to monitor real-world emissions of vehicles in normal traffic situations.

PEMS is a system to measure exhaust gas emissions of a vehicle. The measurements can take place on the road in normal traffic. PEMS yields estimates for real-world emissions performance of the investigated vehicle. The system is meant to become part of the Euro VI heavy duty engine emission legislation for determination of 'In-Service-Conformity' [DG-ENTR, 2010]. For Euro V it is proposed to use PEMS as an alternative test method for 'In-Service-Conformity'; the engine test may remain decisive.
For this investigation, TNO used a PEMS for determination of the real-world truck emissions. The measured exhaust gas components are NO_x, NO_2, CO_2, CO and HC. The fuel consumption can be calculated from the emissions using the carbon balance method. For further specifications of the PEMS equipment, see Appendix A.

2.2 Test procedure representing typical Dutch driving conditions

Using the PEMS, a total of three N2 distribution trucks in the 12 tonne segment were tested by driving a set of specified trips under comparable circumstances.

Aim of the specified trips was to meet the following requirements:
- represent typical Dutch urban, rural and motorway conditions;
- demonstrate the effect of vehicle loading ratio on emissions;
- yield results that are comparable with the results that were obtained during the previous PEMS measurement programme [Ligterink et al, 2009];
- assess the effectiveness and robustness of the procedures currently being developed for the future In-Service Conformity legislation and assess its relation with real-world emissions for typical Dutch driving conditions.

Based on the research requirements, the test procedure consisted of at least three days of testing on the road, driving five different trips. There are shown in table 2 and explained further below.

Table 1; overview of the trips performed.

Trip name	Payload [%]	Remarks
Reference trip	10	A trip covering nearly all driving situations relevant for Netherlands HD operation. Urban/rural/motorway= 48/26/26 %
Reference trip	55	"
Reference trip	100	"
Euro VI trip	55	A trip according the proposed Euro VI specifications for N2 vehicles. Urban/rural/motorway= 45/25/30 %
Euro VI x 5 trip	55	Urban/rural/motorway= 45/25/30 % 5 short trips

Set of three reference trips

A set of three reference trips was driven with each a different payload (10%, 55% and 100% payload). The reference trip, displayed in Figure 1 and Figure 2, contains most typical relevant Dutch traffic situations.

The trip roughly consists of urban, rural and motorway conditions with respective sub trip durations of 48%, 26% and 26%. The reference trip is the same trip that was used for the previous PEMS programme where mainly category N3 trucks were tested [Ligterink et al, 2009], and therefore yields results that are comparable with the previous research. All reference trips were started with a hot engine. The 55% payload reference trip was also partially performed with a cold engine (starting with the coolant temperature at ambient temperature, driving the trip until the engine coolant reaches a stable working temperature).

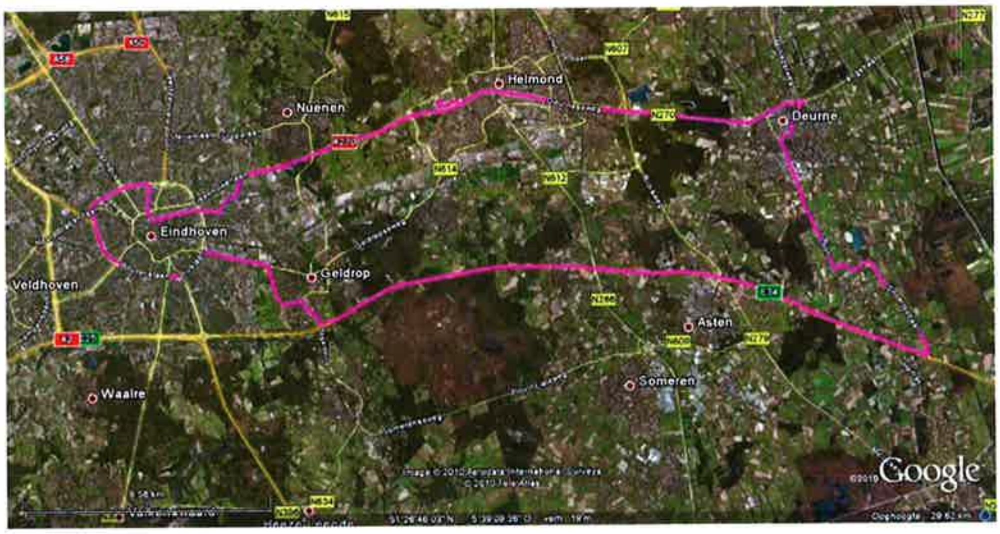


Figure 1: the reference trip displayed on the map, started at the TNO laboratory in Helmond and driven clockwise

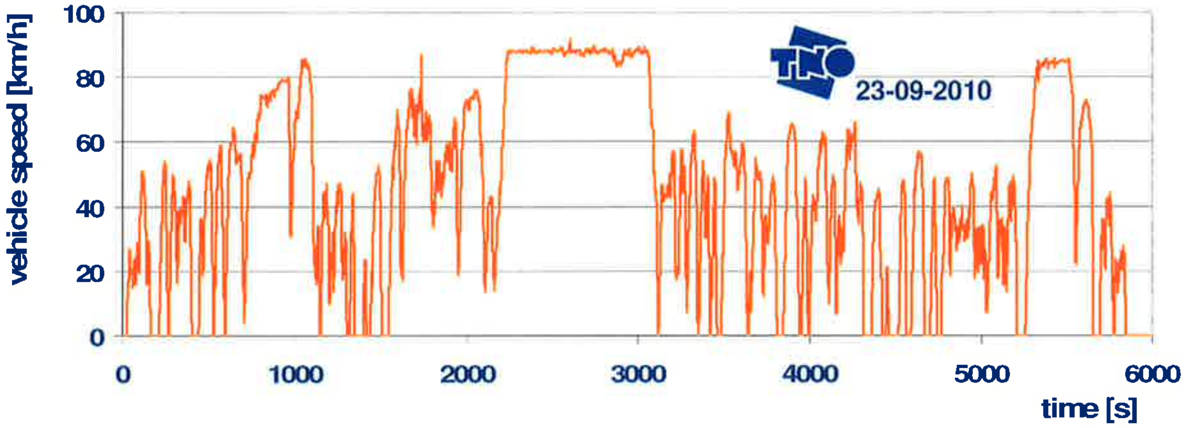


Figure 2: the vehicle speed trace of the reference trip

Trip according to the Euro-VI In-Service-Conformity procedure
One trip according to the current status of the future Euro-VI In-Service-Conformity procedure [DG-ENTR, 2010] was driven with 55% payload. According the procedure, the trip should have a length that represents at least the total work of five WHTC cycles. Also the shares of different trips are prescribed by the procedure.

The trip shares are displayed in Table 2 and take into account the following characterisations:

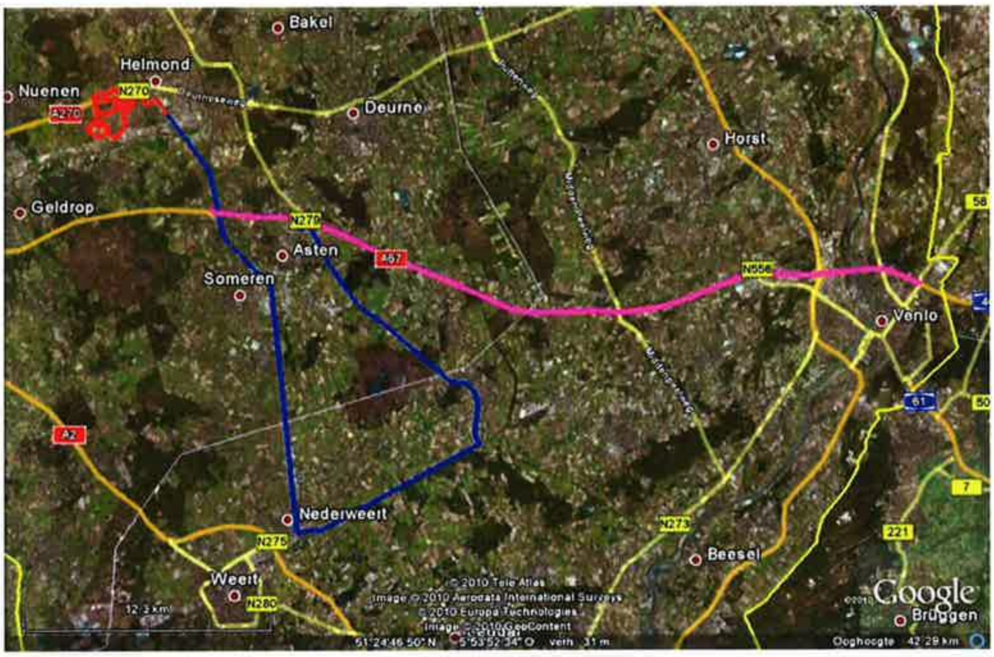
- Urban operation is characterized by vehicle speeds between 0 and 50 km/h;
- Rural operation is characterized by vehicle speeds between 50 and 75 km/h;
- Motorway operation is characterized by vehicle speeds above 75 km/h.

The trip is driven in two ways. This was done to investigate the effect of the trip on the Conformity Factor as calculated by EMROAD. The first trip is driven in the prescribed sequence, namely urban->rural->highway. The second trip has been driven with the same trip composition according to Euro VI specifications, but now the trip contains five small sequences of urban->rural->highway (Figure 4). An overview of the trips is given in Table 2.

Table 2: Euro-VI In-Service-Conformity trip duration divisions for the different vehicle categories.

Vehicle category	**Trip duration percentage (± 5%)**		
	urban	**rural**	**motorway**
M1 and N1	45	25	30
N2	**45**	**25**	**30**
N3	20	25	55
M2 / M3	45	25	30
M2 / M3 M3 of Class I, II or Class A	70	30	0

Figure 3; GPS and speed trace of the trip according Euro VI specifications. Red is urban, blue is rural, pink is motorway.



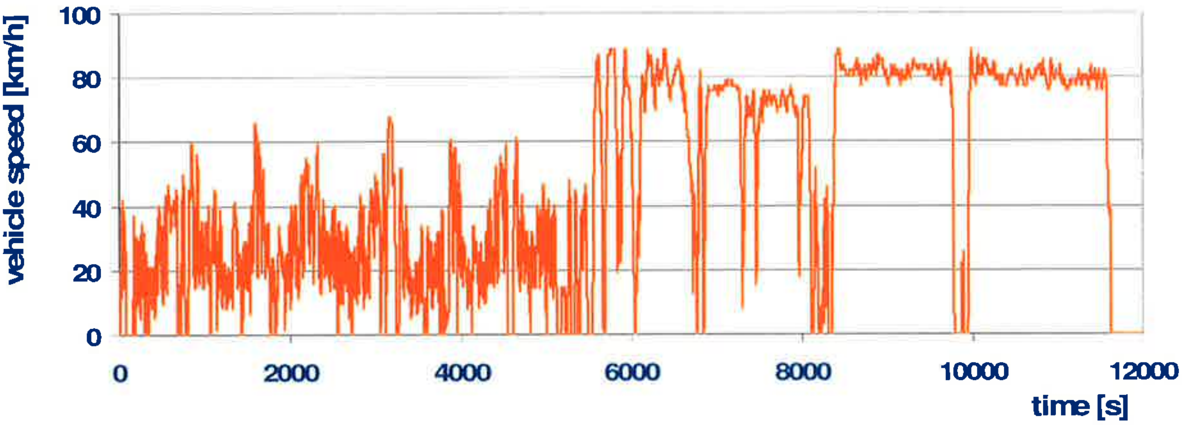
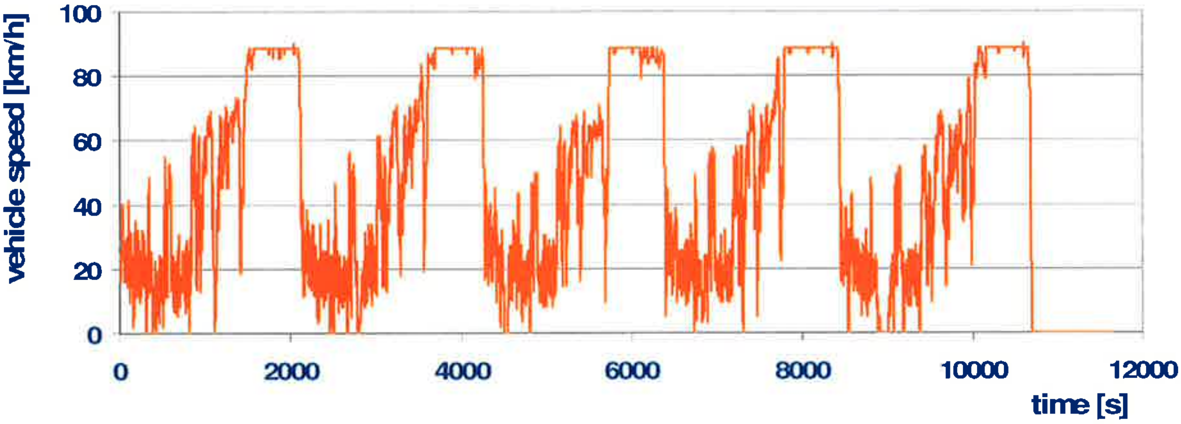


Figure 4; GPS and speed trace of the alternative trip according Euro VI specifications.



2.3 Test vehicles; category N2 distribution trucks

The first Euro V real world measurement programme [Ligterink 2009] was focussed on heavy “heavy-duty” trucks. This did not lead to enough information for the category light “heavy duty” trucks (N2) in the 12t range.

Until 2009 the newest distribution vehicles were mainly Euro IV. Euro V N2 trucks are now entering the market according to the latest Euro V requirements equipped with OBD Stage II and NO_x measures. These vehicles will thus become an important share of near future urban distribution traffic. Therefore the vehicle selection of the test programme mainly aims at the latest generation Euro V N2 truck. One Euro IV truck with EGR technology is selected because these vehicles have a large share in current urban distribution traffic and in environmental zones.

For the selection of the most representative brand and type, the vehicle and engine sales were used as a basis. The analyses of this sales data resulted in a rating of brands and engine types in the N2 segment. Three brands were selected, excluding one brand which was tested in the earlier programme. Of the engine types the best sold power rating in a certain truck type was selected. One truck was selected with a Euro IV engine for reasons stated in the paragraph above.

Table 3; vehicle specifications

Vehicle	Legislative category	Vehicle category	Vehicle type	Model year	Engine power [kW]	Test weight @ 55% [tonne]	Emission reduction technology
Vehicle I	V B2(G)	N2	Rigid	2009	130	9.6	SCR
Vehicle J	IV B1(C)	N2	Rigid	2008	132	9.7	EGR
Vehicle K	V B2(G)	N2	Rigid	2010	181	9.4	SCR

2.4 Data processing with EMROAD and the binning method

This paragraph deals with the processing methods of the PEMS data; the binning method and the currently proposed In-Service Conformity checking methodology [DG-ENTR, 2010], using the EMROAD tool.

2.4.1 Binning method

> The primary purpose of the binning method is to facilitate the use of large amounts of PEMS data as input to calculate emission factors for urban, rural and motorway conditions and to gain insight into the emission behavior over the speed range of a vehicle. The method collects all emission data belonging to a defined speed interval and determines the average emissions for every interval over the complete speed range of a truck.

As preparation for the binning method PEMS data of the trips were pre-processed with EMROAD. EMROAD performs a data quality check and aligns the test signals. Some data was excluded; only data points were used where the coolant temperature was above or equal to 70°C. This was done to ascertain that only data with a warm engine data is used for the binning exercise. There were no big altitude differences during and between the trips.
Vehicle speed bins with a width of 5 km per hour were selected to distinguish emission data for low, intermediate and high vehicle speeds easily. In each bin of vehicle speed, the emissions [g/s] and CO_2 [kg/s] or engine power [kW] from the data points belonging to that speed bin are collected. In the end the average speed within a bin, the average emissions in [g/kg CO_2] or [g/kWh] and the amount of data points within a bin are calculated.

The binning method can also be used to calculate brake specific emissions in gram per kilowatt-hour. This was not done because the data necessary to calculate work from parameters from the CAN bus (Engine Torque, Friction Torque and Engine Speed) was not available for all vehicles.

In the box below a calculation example is given to explain the binning method;

Example binning method calculation:

$$gNOx\ per\ kgCO2 = \frac{\sum_{v=vi}^{v=vi+5} NOx[g/s]}{\sum_{v=vi}^{v=vi+5} CO2[kg/s]}$$

Data points in a bin: 1 g/s NO_x, 10 kg/s CO_2
1 g/s NO_x, 0.1 kg/s CO_2
(In reality many more data points are needed)

Weighing of the contribution to the total emission in a bin:
Sum of the emissions / sum of the CO_2
=> (1+1) / (10+0. 1) = 0.2 [gNO_x/kg CO_2]

And not: Arithmetic average of the specific emissions
(1/10+1/0.1) / 2 = (0.1+10)/2 = 5.1 [g/kg CO_2]

2.4.2 *Method used for ISC*

The pass-fail evaluation method has been applied, using the EMROAD tool (version 4 build 8). This tool can upload emission data from PEMS and CAN data from the vehicle in an Excel workbook to calculate the conformity factors (CF) according to the draft In-Service Conformity rules. A Conformity Factor (CF) is the fraction of the calculated emission value, according to the given data-evaluation method, of the ETC limit value. A CF of 1.5 for NO_x means that an equivalent of 1.5 times 2.0 g/kWh = 3.0 g/kWh is calculated by the tool for a given regulated emission component. At the moment this factor of 1.5 is the proposed upper limit for the outcome of the pass-fail evaluation method of EMROAD. In other words, vehicles are allowed to emit no more than 1.5 times the ETC limit value under the for the ISC procedure prescribed conditions and data-evaluation rules.
Generally for ISC checking, more than one vehicle should be analysed to be able to arrive to the conclusion whether an engine/vehicle type is or is not in conformity in-service. This programme did only test one vehicle per type and therefore it cannot be formally judged whether the vehicle types are compliant with the in-service conformity requirements. The results are indicative only.

The next table shows the settings as used for the pass-fail data evaluation with EMROAD. For the data-evaluation the CO_2 averaging window method was used. This method calculates the average emissions over windows as large as the CO_2 mass that would have been emitted during an ETC test. Criteria are defined to exclude windows from the dataset, see the table below. Cold engine operation and high altitudes are excluded from the pass-fail analyses. Furthermore, windows with a very long duration are excluded. This is an alternative for the power threshold as used for the work window method; a power threshold excludes windows where the average power in a window is below a certain percentage of the rated power (at the moment 20% is proposed). A maximum for the window duration also excludes windows with a very

low average power because at a low average power it takes a long time before the CO_2 reference mass is reached.
What remains after exclusion of data is a set of 'valid windows' of which the single window with the largest value of 90 percentile of the data is taken to calculate the CF for each emission component.

The CO_2 method was used instead of the work window method because from most vehicles the specific CAN data was not available to estimate the work from a calculation of the ECU torque and engine speed signal. In one case no CAN signal was available at all. In all cases a complete set of required torque signals was lacking (mostly reference torque and friction torque were lacking). There is no need to rely on the availability of torque data from the ECU, because instead of the Work based window method, the CO_2 window method can formally be used to calculate the Conformity Factor [DG ENTR, 2010].

Table 4: EMROAD data evaluation settings for the calculation of the Conformity Factor according to the proposed pass fail method.

EMROAD version	**4.0 build 8**
Reference quantity	CO_2 mass
Reference cycle	ETC (average cycle power 34%)
CO_2 estimation	Brake specific fuel consumption; 200 g/kWh
Data exclusion	Engine coolant temperature < 70 ºC, Altitudes > 1500 m, 10^{th} percentile of the maximum values of the valid windows, Maximum window duration 3060 s
Time-alignment	On
Fuel density	0.84 kg/litre
Vehicles speed	GPS ground speed
Conformity Factor	1.5

3 Results

In this chapter the results of the test programme are presented. Results are presented per vehicle in the first paragraphs and for all vehicles together in the last paragraph of this chapter. The results are presented;

- in tables as emissions per component per (sub-) trip in g/km;
- binned in speed intervals for CO_2 specific NO_x emission;
- calculated as Conformity Factor by EMROAD, according the proposed In-Service Conformity procedure and rules.

3.1 Vehicle I

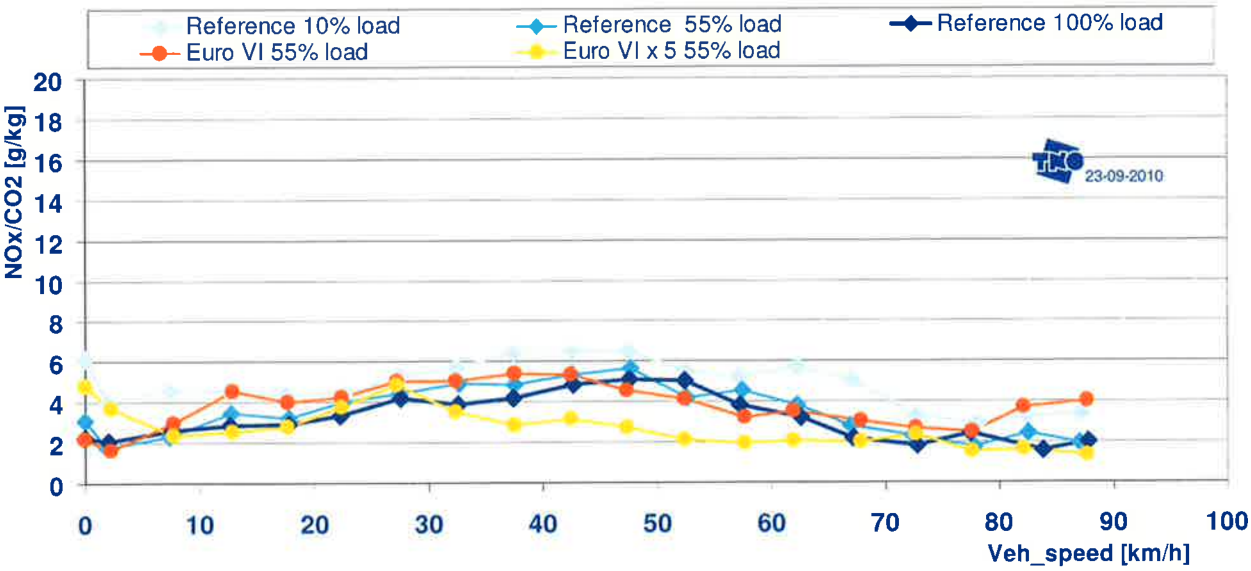
The next table shows the emission results over all trips and sub trips, the CO_2 specific NO_x emission and some basic characteristics of each trip.

Table 5; emission results in g/km over all trips and trip parts, vehicle I.

Trip ID	CO_2	CO	NO	NO_2	NO_x	HC	NO_x/CO_2	Dist	Avg Speed	Trip time share
[Trip name, payload, subtrip]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/kg]	[km]	[km/h]	[%]
Reference trip, 10%	471	1.6	2.03	0.17	2.20	0.04	4.7	77.512	38.5	
Reference trip, 55%	466	1.4	1.46	0.20	1.66	0.03	3.6	74.593	43.2	
Reference trip, 100%	588	1.1	1.53	0.32	1.85	0.01	3.1	75.078	46.1	
Euro VI trip, 55%	483	0.9	1.50	0.28	1.79	0.02	3.7	172.747	51.6	100%
Euro VI trip, 55%, urban	561	2.2	2.15	0.36	2.51	1.98	4.5	44.992	29.1	46%
Euro VI trip, 55%, rural	460	0.4	0.96	0.25	1.22	0.89	2.6	49.135	62.3	24%
Euro VI trip, 55%, motorway	452	0.5	1.47	0.26	1.73	1.35	3.8	78.620	77.6	30%
Euro VI X5 trip, 55%	531	1.3	1.04	0.12	1.16	0.02	2.2	148.703	49.7	100%
Euro VI X5 trip, 55%, #1	558	1.2	1.42	0.12	1.53	0.02	2.7	29.569	48.9	20%
Euro VI X5 trip, 55%, #2	519	1.1	0.88	0.10	0.99	0.01	1.9	29.497	50.7	20%
Euro VI X5 trip, 55%, #3	500	1.0	0.87	0.10	0.98	0.01	1.9	29.470	49.8	20%
Euro VI X5 trip, 55%, #4	532	1.6	1.26	0.14	1.40	0.03	2.6	29.662	48.8	20%
Euro VI X5 trip, 55%, #5	540	1.7	0.76	0.15	0.91	0.01	1.7	29.789	51.1	20%

The graph below shows a reasonably consistent CO_2 specific NO_x emission over the speed range. The results vary from somewhat less than 2 to about 6 g/kg. The highest CO_2 specific NO_x emission is reached at intermediate speed levels. Both load and trip have an influence on the level of the CO_2 specific NO_x emission.

Figure 5; CO_2 specific NO_x emissions averaged per speed interval of 5 km/h over the speed range; vehicle I. Both payload and trip have an effect on the CO_2 specific NO_x emission.



In the graph below the Conformity Factors are presented. The Conformity factors vary per trip and per payload. All trips except one are below the CF of 1,5. The Euro VI trip with 55% payload has the highest CF, even higher than the Reference trip with 10% payload and also substantially higher than the Euro VI trip with 55% payload which was driven in 5 short urban->rural->motorway sequences. Officially, the trips with 10% payload should not be used for the checking of In-Service Conformity.

Figure 6; NO_x Conformity Factors calculated with EMROAD; performance of the Euro V N2 distribution truck I and the influence of payload and trip.

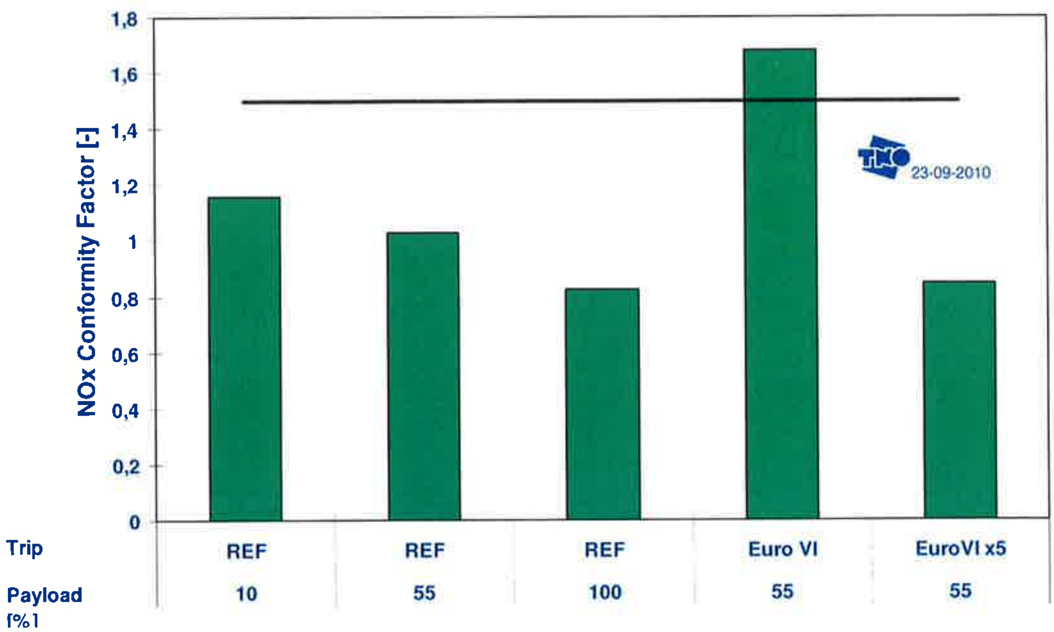


Table 6; overview of NOx Conformity Factors and EMROAD parameters qualifying the pass-fail evaluation.

Trip ID [Trip name, payload]	NO_x Conformity Factor [-]	NO_x max [-]	Window maximum duration [s]	Window minimum duration [s]	Number of valid windows	Percentage of valid windows [%]	Data coverage index
Reference, 10%	1.16	1.30	3060	1694	3219	66	77
Reference, 55%	1.03	1.16	3060	1751	3969	100	100
Reference, 100%	0.82	1.41	2313	1322	3923	100	100
Euro VI, 55%	1.68	1.75	3060	1225	8223	91	100
Euro VI x5, 55%	0.84	0.89	2110	1531	8874	100	100

3.2 Vehicle J

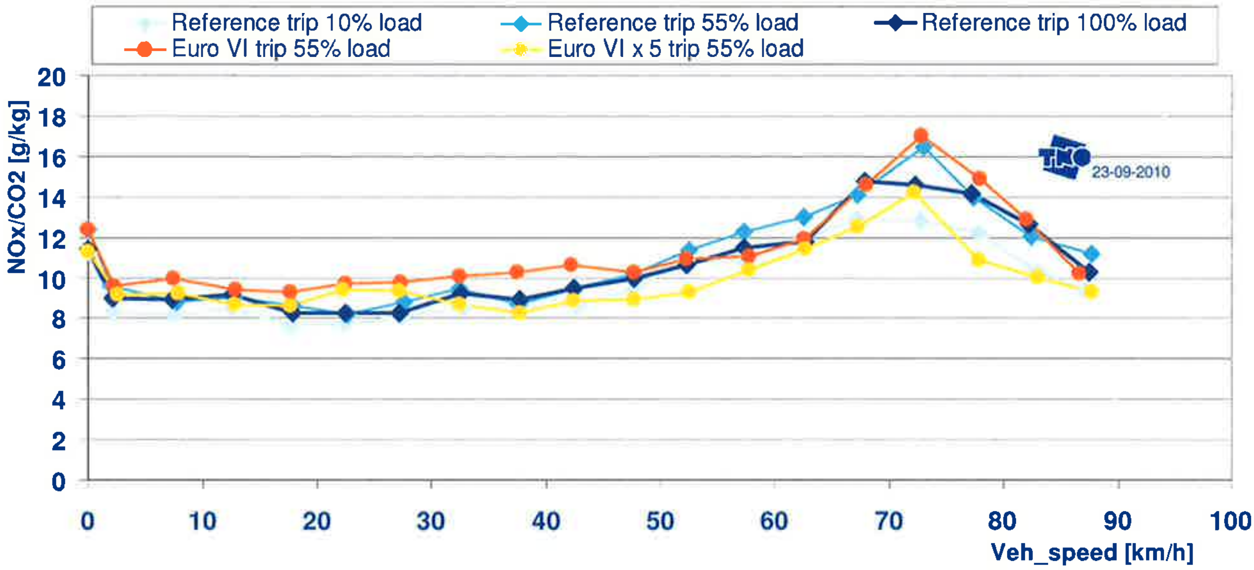
The next table shows the emission results over all trips and sub trips, the CO_2 specific NO_x emission and some basic characteristics of each trip.

Table 7; emission results in g/km over all trips and trip parts, vehicle J.

Trip ID	CO_2	CO	NO	NO_2	NO_x	HC	NO_x/CO_2	Dist	Avg Speed	Trip share
[Trip name, payload, subtrip]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/kg]	[km]	[km/h]	[%]
Reference trip, 10%	520	0.8	4.83	0.37	5.19	0.16	10.0	74.756	42.0	
Reference trip, 55%	528	0.5	5.39	0.52	5.90	0.06	11.2	75.149	47.2	
Reference trip, 100%	613	0.7	5.95	0.61	6.56	0.07	10.7	74.171	39.8	
Euro VI trip, 55%	535	0.5	5.91	0.70	6.62	0.09	12.4	155.315	48.1	100%
Euro VI trip, 55%, urban	701	1.1	6.71	0.48	7.19	6.16	10.3	38.017	24.7	48%
Euro VI trip, 55%, rural	526	0.4	6.42	0.76	7.19	5.87	13.7	48.332	62.3	24%
Euro VI trip, 55%, motorway	449	0.3	5.11	0.79	5.90	4.67	13.1	68.966	75.4	28%
Euro VI X5 trip, 55%	563	0.5	4.93	0.46	5.39	0.04	9.6	149.241	50.2	100%
Euro VI X5 trip, 55%, #1	560	0.6	4.98	0.48	5.46	0.05	9.8	29.867	49.8	20%
Euro VI X5 trip, 55%, #2	560	0.6	4.98	0.47	5.44	0.05	9.7	29.678	50.4	20%
Euro VI X5 trip, 55%, #3	552	0.5	4.94	0.46	5.40	0.04	9.8	29.708	50.8	20%
Euro VI X5 trip, 55%, #4	573	0.5	4.99	0.47	5.46	0.03	9.5	29.856	52.4	20%
Euro VI X5 trip, 55%, #5	567	0.5	4.76	0.42	5.18	0.04	9.1	29.937	47.9	20%

The emissions of vehicle J vary, but there is no very clear relation with payload; at higher speeds the higher loads of 55 and 100% seem to have a somewhat elevated CO_2 specific NO_x emission over the trip with 10% payload. Over the speed range the emissions increase from about 8 to 12 g/kg at low speeds to about 12 to 17 g/kg reached at around 75 km/h. At higher speeds the emissions decrease again to about 10 g/kg.

Figure 7; CO_2 specific NO_x emissions averaged per speed interval of 5 km/h over the speed range; vehicle J. Both payload and trip have some effect on the CO_2 specific NO_x emission.



For the vehicle with the Euro IV engine the Conformity factors vary little per payload and somewhat per trip. Especially the Euro VI trip is substantially higher than the rest of the trips.

Figure 8; NO_x Conformity Factors calculated with EMROAD; performance of the Euro IV N2 distribution truck J and the influence of payload and trip.

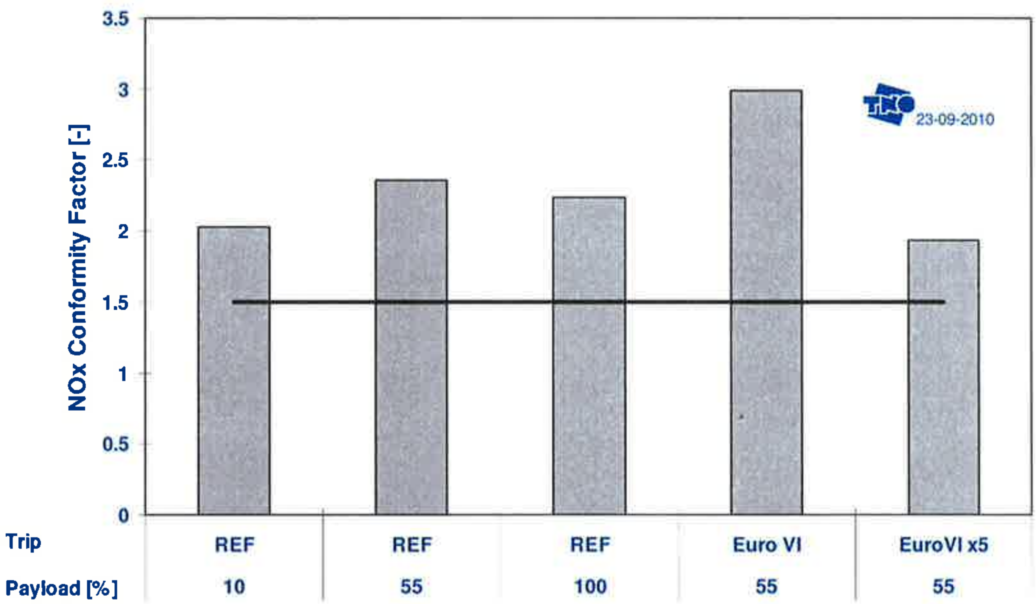


Table 8; overview of NOx Conformity Factors and EMROAD parameters qualifying the pass-fail evaluation.

Trip ID [Trip name, payload]	NO_x Conformity Factor [-]	NO_x max [-]	Window maximum duration [s]	Window minimum duration [s]	Number of valid windows	Percentage of valid windows [%]	Data coverage index
Reference trip, 10%	2.03	2.10	2893	1325	4078	100	100
Reference trip, 55%	2.35	2.40	2432	1610	3828	100	100
Reference trip, 100%	2.23	2.29	2255	1265	4059	100	100
Euro VI trip, 55%	2.99	3.18	2795	1215	8905	100	100
Euro VI x5 trip, 55%	1.93	1.95	2021	1356	8832	100	100

3.3 Vehicle K

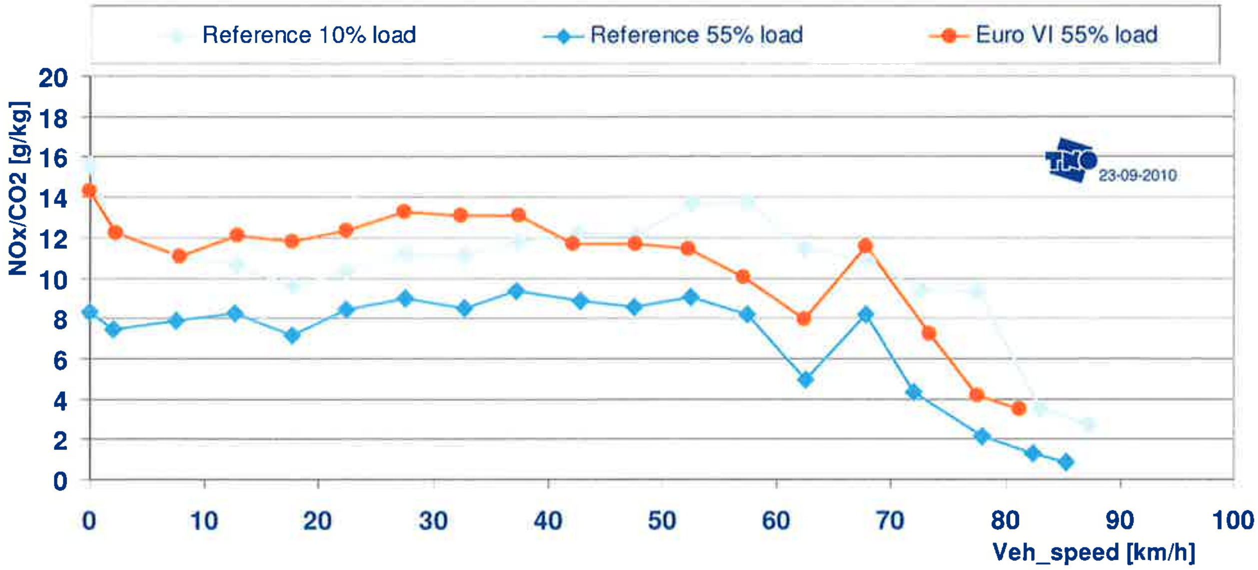
The next table shows the emission results over all trips and sub trips, the CO_2 specific NO_x emission and some basic characteristics of each trip.

Table 9; emission results in g/km over all trips and trip parts, vehicle K.

Trip ID	CO_2	CO	NO	NO_2	NO_x	HC	NOx/CO_2	Dist	Avg Speed	Trip share
Trip name, payload, subtrip	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/kg]	[km]	[km/h]	[%]
Reference trip, 10%	411	0.8	3.80	0.00	3.80	0.037	9.2	75.152	47.0	
Reference trip, 55%	474	1.1	2.90	0.00	2.90	0.060	6.1	75.180	44.3	
Euro VI trip, 55%	434	0.9	3.48	0.01	3.49	0.051	8.0	157.873	47.6	100%
Euro VI trip, 55%, urban	549	1.6	7.59	0.03	7.62	7.300	13.9	39.828	25.4	47%
Euro VI trip, 55%, rural	420	0.8	2.56	0.01	2.57	2.475	6.1	47.823	61.9	23%
Euro VI trip, 55%, motorway	377	0.7	1.77	0.01	1.78	1.675	4.7	70.223	72.4	29%

Figure 9 shows that the CO_2 specific NO_x emission is between 8 and 12 g/kg from low speeds onwards until about 70 km/h. Above 70 km/h the emission drops rapidly to around 2 to 4 g/kg. There is a clear effect of payload. Note the large difference between the Reference trips with 10 and 55% payload respectively. But there is also a large effect of the trip. The Euro VI trip with 55% payload lies around the same level as the Reference trip with 10% payload.

Figure 9; CO_2 specific NO_x emissions averaged per speed interval of 5 km/h over the speed range; vehicle K. Both payload and trip have a substantial effect on the CO_2 specific NO_x emission.



In the graph below the Conformity Factors are presented. Two trips are higher than the proposed limit of 1.5, but officially, the trips with 10% payload should not be regarded for the checking of In-Service Conformity. There is a clear difference between the same trips with different payloads, but also between different trips with the same payload. This is also observed for the binned CO_2 specific NO_x emission (Figure 9)

Figure 10; NO_x Conformity Factors calculated with EMROAD; performance of the Euro V N2 distribution truck K and the influence of payload and trip.

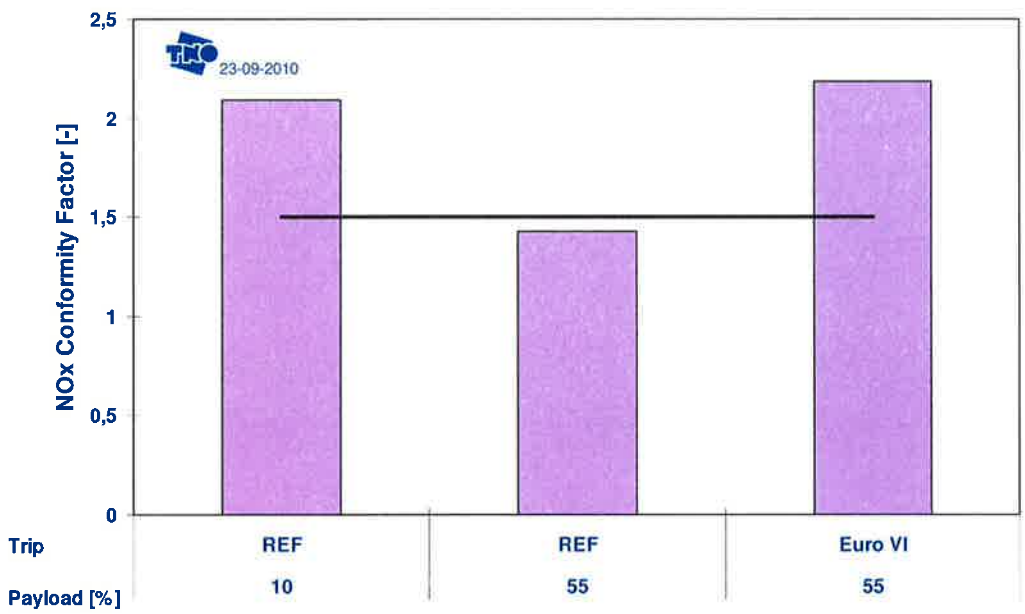


Table 10; overview of NOx Conformity Factors and EMROAD parameters qualifying the pass-fail evaluation.

Trip ID [Trip name, payload]	NO_x Conformity Factor [-]	NO_x max [-]	Window maximum duration [s]	Window minimum duration [s]	Number of valid windows	Percentage of valid windows [%]	Data coverage index
Reference trip, 10%	2.09	2.11	3221	2740	1881	65	83
Reference trip, 55%	1.43	1.61	3060	2622	2155	68	83
Euro VI trip, 55%	2.18	2.60	3060	2327	4595	62	100

3.4 Conformity factors of the three vehicles

In the graphs below the Conformity Factors as calculated by EMROAD are presented for all three vehicles and for three exhaust gas components; NO_x, CO (Carbon Monoxide) and HC (Hydro Carbons). For NO_x the Euro V vehicle I performs below 1.5, with exception of one trip, whereas vehicle K performs more critical against the CF of 1.5 and above 1.5. Officially, the trips with 10% and 100% payload should not be regarded for the checking of In-Service Conformity.

The conformity factors for CO and HC of all the vehicles are well below 1.5.

Figure 11; NO_x Conformity Factors calculated with EMROAD; performance of the three N2 distribution trucks over different trips and with different payloads.

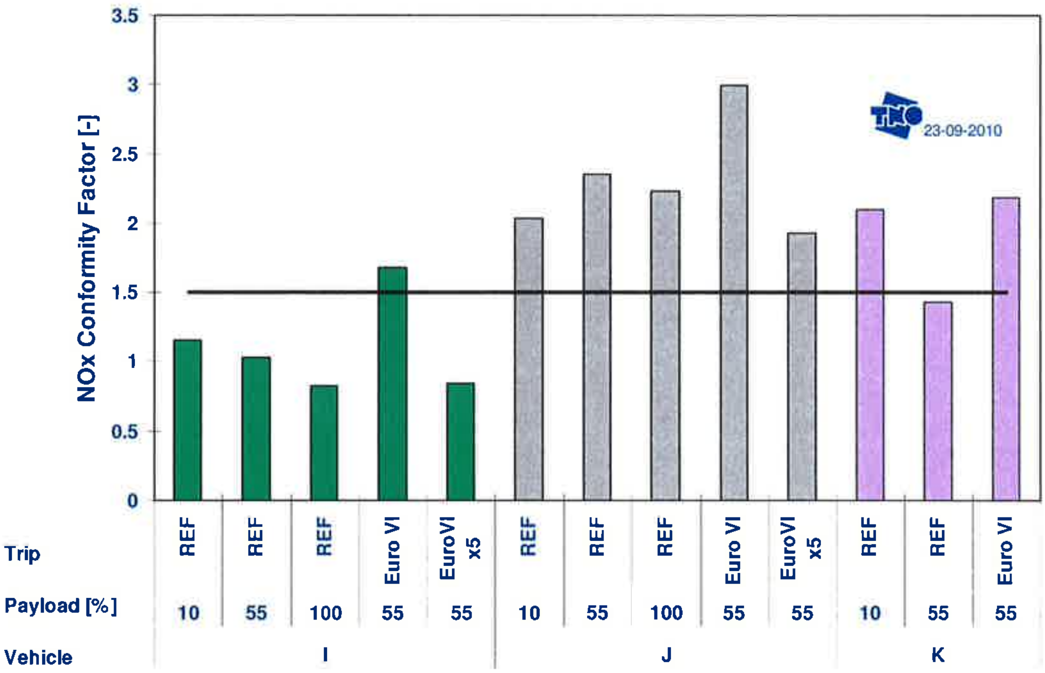


Figure 12; CO Conformity Factors calculated with EMROAD; performance of the three N2 distribution trucks over different trips and with different payloads.

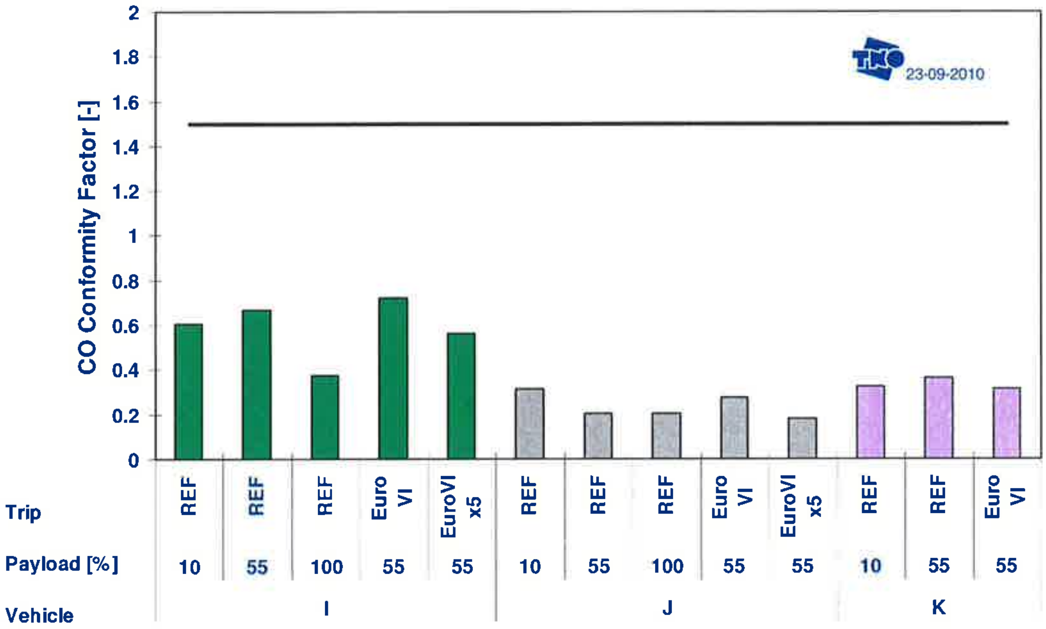
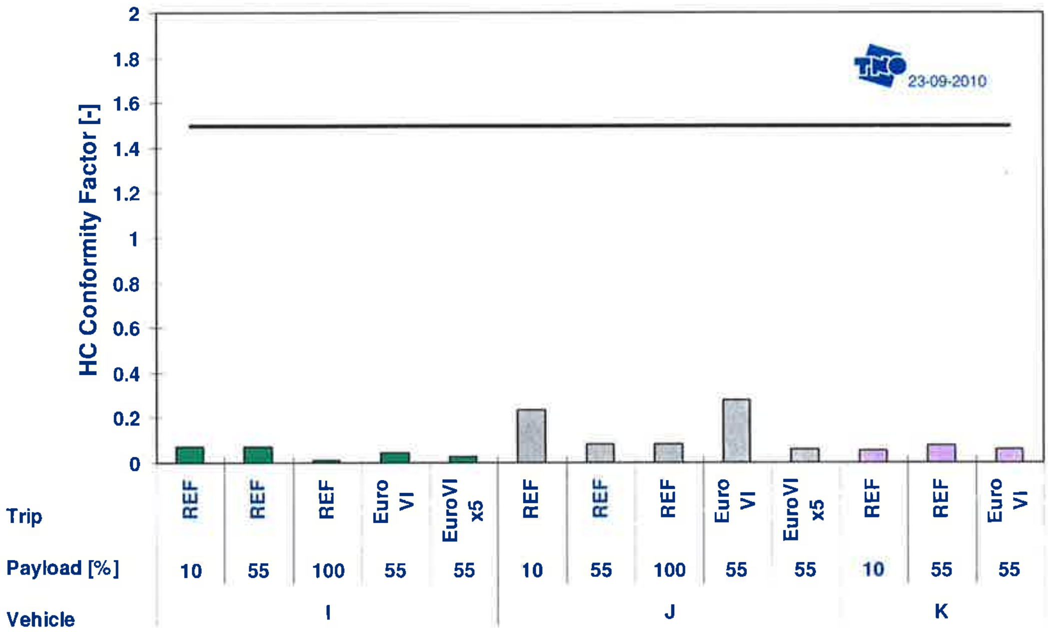


Figure 13; HC Conformity Factors calculated with EMROAD; performance of the three N2 distribution trucks over different trips and with different payloads.



4 References

[2005/78/EC]	Directive 2005/78/EC of 14 November 2005 implementing Directive 2005/55/EC of the European Parliament and …relating to the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines for use in vehicles, and the emission of gaseous pollutants from positive ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles
[Verbeek et al, 2010]	Real world NO_x emissions of Euro V vehicles, Report to be published
[DG-ENTR, 2010]	F1 7808 PE EURO VI - Draft Commission Regulation (EC) No …/.. of […] implementing and amending Regulation (EC) No 595/2009
[Ligterink et al, 2009]	Ligterink, N.E., Lange, R., Vermeulen, R.J., Dekker, H.J., "On-road NOx emissions of Euro-V trucks", TNO Science and Industry, Report number MON-RPT-033-DTS-2009-03840, Delft, 2 December 2009

5 Signature

Delft, 29 October 2010

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Authors

A Specifications of the Portable Emission Measurement System (PEMS)

PEMS (Portable Emission Measurement System)	
Brand	Sensors
Type	Semtech DS
Exhaust flow meter	Sensors EFM II, 4"tube
Emissions	CO_2, THC, O_2, NO, NO_2, NO_x
Fuel Consumption	Carbon balance
Engine and vehicle parameters	CAN (SAE J1939)
GPS	Longitude. Latitude, Altitude, Vehicle Ground Speed
Weather station	Ambient temperature, pressure and humidity
PSU	Honda 20i (2kW)

Emission component	Analyzer	Range	Accuracy (whichever is greater)	Resolution
CO	NDIR	0 - 8%	± 3.0 % or 50 ppm	10 ppm
CO2	NDIR	0 - 20%	± 3.0 % or ± 0.1 %	0.01%
NO	NDUV	0 - 2500 ppm	± 3.0 % or 15 ppm	1.0 ppm
NO2	NDUV	0 - 500 ppm	± 3.0 % or 10 ppm	1.0 ppm
THC	Heated FID	0 - 100 ppmC	± 2.0 % or 5 ppmC	0.1 ppmC
		0 - 1000 ppmC	± 2.0 % or 5 ppmC	1.0 ppmC
		0 - 10000 ppmC	± 2.0 % or 25 ppmC	1.0 ppmC
		0 - 40000 ppmC	± 2.0 % or 100 ppmC	10.0 ppmC