TNO Science and Industry

Schoemakerstraat 97
P.O. Box 6030
2600 JA Delft
The Netherlands

www.tno.nl

T +31 15 269 63 62
F +31 15 261 23 41

TNO report

06.OR.PT.047/HJD

Evaluation of the suitability to European conditions of the WNTE control zone concept as set out in the OCE GTR – Executive Summary

Performed under the Framework Service Contract No. ENTR/05/18

Date	April 27, 2007
Author(s)	Henk Dekker, Iddo Riemersma - TNO Stefan Hausberger, Martin Rexeis - TUG Patrik Soltic - EMPA Heinz Steven - TUEV Nord
Assignor	European Commission DG Enterprise
Project number	033.13362/01.04
Classification report	
Title	
Abstract	
Report text	
Appendices	
Number of pages	12
Number of appendices	

All rights reserved. No part of this report may be reproduced and/or published in any form by print, photoprint, microfilm or any other means without the previous written permission from TNO.

All information which is classified according to Dutch regulations shall be treated by the recipient in the same way as classified information of corresponding value in his own country. No part of this information will be disclosed to any third party.

In case this report was drafted on instructions, the rights and obligations of contracting parties are subject to either the Standard Conditions for Research Instructions given to TNO, or the relevant agreement concluded between the contracting parties. Submitting the report for inspection to parties who have a direct interest is permitted.

© 2007 TNO

Executive Summary

As part of the development of worldwide harmonisation of vehicle regulation, Global Technical Regulations (GTR's) are being developed under the auspices of the UN/ECE in Geneva. The Off –Cycle Emission (OCE) Working Group is currently developing a GTR that will apply to heavy duty vehicles. All documents associated with the draft OCE GTR can be found at the following web site: http://www.oica.net/htdocs/Main.htm under the 'WWH' section.

The objective of the OCE GTR is to establish a harmonised regulation which ensures that off-cycle emissions from heavy duty engines and vehicles are appropriately controlled over a broad range of engine and ambient operating conditions. The key concepts at the heart of the GTR are (implied) emissions limits and harmonised test requirements in the World harmonised Not To Exceed (WNTE) concept. The WNTE concept shall cover a range of engine operating conditions that are broader than those covered by type approval test cycles.

Work on the draft GTR is developing steadily, with many of the important concepts in the documents in the process of being defined or still under discussion. The objective of this project is to evaluate the current definition of the WNTE control area from a European perspective. The aim is to assess its effectiveness in controlling off-cycle emissions and advise on improvements and alternative methods that could be considered.

Parallel work appraising the WNTE zone was carried out by the European Commission's Joint Research Centre. This work reviewed the data collected from in use tests conducted using Portable Emissions Measurement Systems (PEMS). The PEMS data currently only includes the gaseous pollutants and does not include particulate matter. The concepts considered by the JRC in analysis of the the PEMS data such as the WNTE control area, alternatives approaches and hybrid approaches were also evaluated in this study. In addition, other alternative approaches were taken into account. The work of JRC concentrated on the use of PEMS for in use compliance testing and the role of the WNTE control area concept for these tests. Whilst this study concentrated on whether the WNTE control zone approach or alternative approaches will provide effective control of off-cycle emissions in a European context

1. Applicability of the OCE GTR in the European context

Most GTR's contain technical requirements and/or test cycles. The OCE GTR is rather special in that it does not include technical requirements and test procedures but describes the general principles of Off-Cycle Emissions and in particular the WNTE concept.

The OCE GTR is focussed on regulatory principles to be applied at type-approval or certification of a new heavy duty vehicle or engine. However, it is apparent that the linkage with in-use testing of vehicles such as with in-service conformity requirements is an important consideration. For example, the OCE draft GTR states the following:

"One of the key issues discussed during the development of the OCE GTR was the scope of the GTR with respect to in-use, on-vehicle emissions testing. After considerable debate by the OCE working group, it was decided the OCE GTR would not include specifications for in-use, on-vehicle emission measurement equipment. However, it was

also decided that the OCE GTR was developed with the specific intent to enable the testing of compliance with the WNTE during in-use, on the road operation of the engine. It may be appropriate in the future to consider the development of a GTR which would include harmonized test procedures for in-use on vehicle emission measurement."
According to an editorial comment there was no formal consensus regarding this issue from the working group.

At the moment there is no legal requirement in Europe with respect to in-use, on vehicle emissions testing for type approval. In Europe the heavy duty vehicle and engine type approval procedures only require engine tests on an engine test bench. In this context, implementation of the OCE GTR as a European type approval requirement would result in it being set up as a laboratory based procedure.

If the OCE GTR were to be implemented as a laboratory procedure, there are certain aspects of the current GTR that are not relevant to type approval. For example:

- The WNTE ambient conditions requirements are not applicable for tests on an engine test bench as these conditions are already prescribed in the description of the engine test procedure.
- The WNTE control area is used to exclude certain engine operating conditions which may occur during in-use on the road operation. The minimum sampling time of 30 seconds for a valid WNTE event is used to ensure an averaging period of at least 30 seconds. This period also reduces the sensitivity to sampling and measurement delays. These restrictions have some rationale for in-use testing programmes but have no additional value for type approval tests on an engine test bench.

In some cases, aspects of the WNTE concept are already reflected in EU legislation. Current European requirements are contained in Regulation No. 49, which requires a NO_x control check which ensures the effectiveness of the emission control of the engine within the typical engine operating range. For this check three random points within a control area between the engine speeds A and C and between 25 to 100 per cent load are selected. It is easy to envisage a replacement of this control area by the WNTE control area that would not result in significant changes to this procedure. The 30 seconds rule is always fulfilled as the measurement time is 2 minutes per point with 3 minutes preconditioning in mode 13 before the start of the NOx check. In addition, the GTR also requires a prohibition of defeat devices, such requirements already exist in European legislation.

One option for implementation of the GTR in the EU would be to replace the random points requirements with a random engine bench test cycle using the WNTE control area. With this approach, there seems to be no need at all for a 30 second sampling rule.

A further possibility would be to introduce a WNTE test on complete vehicles as part of the type approval process. In this case, the ambient conditions requirements and 30s sampling period would have a rationale. The main issues for the procedure in this case are similar to those associated with use of the WNTE for in-use testing.

Overall the development of the OCE GTR seems to have little immediate benefit for the current European laboratory based type approval procedure. However, the need for an OCE GTR and the implementation of a requirement for in-use on-vehicle emissions testing in future legislation has become more important with the introduction of exhaust after treatment and advanced electronic control systems. Therefore, a key issue for European legislation will be the application of such a concept to in-use, on-vehicle testing programmes.

2. Analysis of the WHDC driving behaviour database with respect to the WNTE concept

A key part of the project was to examine the relationship between the WNTE concept and European driving conditions. Therefore, the European part of the WHDC in-use driving behaviour database was used to provide data to evaluate whether the current WNTE concept would cover off-cycle driving conditions and engine operation conditions representative of the European situation.

The WHDC in-use driving behaviour database consists of a wide range of vehicles and operation conditions and formed the basis for the development of the WHTC cycle (world harmonised transient engine test cycle).

According to the requirements of the Commission the analysis was carried out for all vehicles of the database and the full set of driving patterns, but distinguished between urban, rural and motorway operation.

The WNTE control zone concept is intended to supplement the emission tests performed during the WHDC certification procedure, therefore a comparison between the coverage of the engine map for the in-use data and the WHTC was also carried out within the frame of this study. These observations are no criticism of the WHTC and several are probably valid for any predefined test cycle.

The results of this comparison can be summarized as follows:

- The level of coincidence between in-use data and WHTC depends on the individual design of the engine and drive train of a heavy duty vehicle and of the specific behaviour of the driver.
- Due to having a time duration of only 1800 s, the WHTC has a limited capability to reflect extensively in-use driving conditions.
- For some cases the in-use data showed a trend to higher engine speeds in comparison to the WHTC. For vehicles with low or medium power to mass ratios these in-use data points at higher engine speeds fall predominantly into the WNTE zone. But with increasing power to mass ratio an increasing number of these data points are located in an area of low normalized engine power (below 30%). This area is outside the current WNTE zone and can represent up to 40% of the whole NOx emissions for vehicles with EURO III engines.
- Low engine speeds (below n_min_WNTE) and high engine load is another area which occurs in real world driving but is outside both the WNTE zone and also the WHTC. This area is of less importance to heavy duty vehicles such as trucks than the operating points mentioned in the previous bullet point, However it is of equivalent importance to emissions for vehicles with significant urban operation like urban buses and garbage trucks.

From the analysis of the data from the in-use driving database it can be concluded that the current WNTE concept with the 30s time window works quite well for motorway operation. However, as the acceleration phases for rural and urban operation are typically shorter, much of this type of driving is excluded by the WNTE approach. In order to include urban operation, which is very important in Europe for the air quality in urban areas, the duration of the sampling period of a WNTE-event needs to be reduced.

The minimum engine speed of the WNTE-zone (n_min_NTE) was found to be suitable for rural and motorway operation. However, this was not the case for all urban operation, especially for vehicles like urban buses and garbage trucks with a high percentage of start/stop events. For these vehicles, a lower n_min_NTE would increase the operating time within the WNTE control zone, but the increase of the number of WNTE events would still be very small, even with a reduced 10 second sampling rule.

3. Evaluation of OCE monitoring approaches for in-use testing

To understand the performance of the WNTE concept, a number of different OCE monitoring approaches were analysed with regard to the standard operating conditions of European heavy duty vehicles. The OCE approaches reviewed were as follows:

1. Three control-area based concepts, including:
    a. the current WNTE proposal;
    b. a version with reduced sampling period; and
    c. a version with reduced sampling period and enlarged control area
2. Work-window based concepts (using different window definitions)
3. “Hybrid” concept (OCE approach based on a combination of 1. and 2.)
4. “Compliance factor” approach based on CO_2 specific emission values

Five vehicles representing five different classes of heavy duty vehicles (a rigid delivery truck, a 30 t trailer truck, a 40 t long haulage semi trailer truck, an urban bus and a garbage truck) were selected from the WHDC database for the simulation of the exhaust emissions so as to evaluate the WNTE approaches and their alternatives. The whole set of real world driving patterns were used for each vehicle, but the calculations were made separately for urban, rural and motorway operation. For the various combinations of vehicles and cycles, the resulting emissions were simulated for EURO III and for EURO V engines using the emission model PHEM which was developed in an earlier (EU 5th Framework Programme) project. The model results in data on engine power, engine speed, NO_x, PM, CO, CO_2, HC and fuel consumption in 1 Hz resolution. The different OCE monitoring approaches were then applied on the resulting emission curves. For one EURO V vehicle, directly measured emission curves were also used, as high influences were observed of the dynamics of the driving cycle on the overall level of emissions. These effects are not yet implemented in the model. It is not certain that such effects are common to all EURO V and VI engines, but because of this complex emission behaviour, the measured EURO V engine proved to be a good test case for the evaluation of the different OCE monitoring approaches. This is because the emissions level reached in the type approval cycle was significantly exceeded in several relevant real world driving conditions.

The analysis included: the coverage of the engine map by the OCE monitoring approach; the number of recorded emission events; the maximum, the minimum and the average emission values of the registered emission events; and the histogram of all emission events. The values calculated were compared with the emissions which occurred over the total driving time. A number of criteria were developed to appraise the different approaches suitability as an in-use testing procedure; these criteria included fulfilling the following aspects:

1. The monitoring approach should include all relevant operating conditions, so including those conditions which give an important share of the total HDV emissions. This was assessed either by measuring the total driving time with sufficient averaging periods, or by only measuring emissions in a defined area of the engine map where high brake specific emission values are avoidable.
2. The monitoring approach should be able to detect engine operation modes with technically avoidable increases in emission levels ("defeat strategies"). Whilst at the same time, unavoidable increases in emission levels should not lead to failure of the OCE limit (e.g. high brake specific PM levels at low engine loads and high engine speeds)
3. The monitoring approach should be feasible with the use of PEMS instrumentation for the purpose of in-use vehicle emission testing. The main challenges in the practical implementation of the OCE monitoring are the correct alignment of torque, correct alignment of measured emissions, and in particular modal particulate mass measurement (i.e. with continuous emission values in 1Hz or higher).

The findings for each OCE monitoring approach are as follows:

Control-area based concepts:

The current WNTE proposal with a 30 second sampling period does not cover low loads and low engine speeds. This is because these operating conditions usually occur in transient driving and are excluded to a large extent by the 30 second rule. Thus highway driving is controlled to some extent (but with decreasing coverage for increasing power to mass ratio), whilst urban driving is not controlled at all by this approach. The analysis suggests that only 30% of the total emissions of the European heavy duty vehicle fleet would be covered by the current WNTE approach. The remaining 70% of emissions occur in engine operating conditions which would not be captured by the WNTE. The "PM carve-out" rule excludes PM emissions at low engine loads and high engine speeds. This 'carve-out' has nearly no effect on the WNTE coverage as hardly any real life engine operation points fall into this zone. The rationale for the PM carve-out are the increased brake specific PM emissions in these engine operation conditions, which can be seen independently from the emission standard. However, it is not clear that it is in practice necessary.

Despite the rather poor coverage of the current WNTE approach, the measured EURO V vehicle still did not meet the WNTE NO_x limits for each emission event within the control area. This SCR equipped vehicle showed highest NO_x emissions on the dynamic part of the cycle. Short emission peaks were observed which highly influence the 30 second average of the corresponding emission event. Of course it should be recognised that this EURO V vehicle was not designed to the meet the draft WNTE regulations. It was only designed to fulfil the ESC and ETC emission limits, and the overall emissions of the vehicle were clearly below the EURO V type approval limit in hot conditions.

Reducing the minimum sampling time to 10 seconds, while leaving the control area unchanged, clearly increases the amount of operating conditions covered. In total approximately 45% of the total emissions of the European heavy duty vehicle fleet would be covered by such a version of the WNTE. A 10 second sampling period should be sufficient to largely exclude the effects of incorrect time alignments between engine load and measured emissions, assuming a proper set up of the measurement equipment. For this reason, 10 seconds is considered the shortest feasible sampling time with the current technology.

Even with the 10s sampling period, urban driving would be covered only to a small extent. This is because only 20% to 40% of the driving time in urban areas falls into the WNTE control zone. Furthermore, less than 50% of this time in the control zone would be covered by a minimum sampling time of 10 seconds for the majority of the analysed vehicles. Thus urban buses and urban driving trucks would only deliver very few emission events within the control area. This situation could make the repeatability of the OCE testing in urban conditions very poor. For the measured EURO V vehicle, the maximum recorded 10 second NO_x emission event within the control area was 7.5 g/kWh. This result compares poorly to a limit of 2.7 g/kWh according to the current WNTE draft and a limit of 2.5 g/kWh for the proposed WNTE NOx limit (OICA, June 2006).

The third variant of the WNTE analysed, extended the control area to 20% engine torque and 20% engine power. This compares with 30% torque and 30% power in the original proposal. In this scenario, the 10 second minimum sampling period was retained. This option increases the share of the total real world HDV driving covered up to 55%. Even so, between 60% (for 30t truck trailer) and 95% (for urban bus) of the urban emissions are not covered by the modified WNTE approach. The maximum 10 second NO_x emission event measured within the enlarged control area was 8.6 g/kWh, so was considerably above the implied emission limit as currently defined.

It can be concluded that short sampling periods with an enlarged control area increase the efficiency of the OCE test; this is because such OCE test methods provide better coverage of the relevant HDV operation conditions. But it has to be considered, that a shortening of the minimum sampling period, and an enlargement of the control area, generally cause an increase in the scattering of the measured emission events. This effect makes interpretation of the test results more difficult, because the risk is increased, that an engine fails the OCE test due to disadvantageous driving conditions even though no defeat strategies have been applied. Therefore the requirement that all single WNTE events have to be below the prescribed limit values could be too stringent for such a monitoring approach. One solution to this problem would be to apply OCE limits to the average of all events (or to an x% percentile of all events) possibly combined with a (higher) not to exceed emission limit.

A crucial factor for all control area based approaches is the measurement of particulate mass emissions. The filter based method for particulate mass measurement defined in type approval needs a continuous sampling period of several minutes. Since such a system can not foresee if the next time period will be completely within the control area, a filter based measurement is not feasible for control area based approaches. An alternative measurement method would be to provide instantaneous signals. However, these have not yet proven conformity with the type approval method so could result in intensive discussions and research demand. Recent PEMS particulate mass measurement developments in the US seem promising, but further evaluation of this equipment is necessary.

Work-window based concepts:

To assess whether an emission event, complies with a work window OCE test limit, the instantaneous emissions and engine power data are averaged over certain time periods. The time period will vary and will correspond to when the cumulative positive engine power amounts to a certain value (the "work-window"). Compared to an averaging over a fixed time window, a fixed work window has the advantage that periods with low load engine operation have a smaller influence on the averaged emission events.

The version of the work-window approach discussed here covers the complete vehicle operating time. Due to the averaging of the emissions over a reasonable number of kWh's, the effect of driving partially in engine load operations with unavoidably high brake specific emission levels (e.g. idling) is reduced. However, special driving conditions like garbage truck operation, still lead to very high emission results. All other vehicle/cycle combinations result in fairly constant levels of the emission events during typical operation conditions. Thus boundary conditions for the test driving would have to be defined for the work window approach to be used as a test procedure. For example, defining the maximum share of idling and a minimum average speed for urban driving for a test trip could be a feasible strategy.

If any detected emission event from the work window approach had to be below the limit values proposed in the current WNTE draft, the measured EURO V vehicle would also fail this OCE test. The maximum NO_x emission event for a work window equivalent to the size of the WHTC was 4 g/kWh in trips with an active SCR system. The minimum value was 0.5 g/kWh. On trips with inactive SCR (slow urban cycles) the maximum NO_x event was 7 g/kWh. A reason for the high emissions for driving conditions with active SCR is the large and long term influence of transient engine loads on the level of NO_x emissions. Since the traffic situations that lead to the high specific NO_x emission levels are most likely to occur in predominantly urban locations, there is a need in Europe to improve the emission behaviour in such driving conditions to reduce local air pollution. A work window based OCE monitoring approach would be a feasible instrument to fulfil this task.

To obtain a work window test procedure where the limits can be fulfilled with reasonable effort for EURO V vehicles (2008/09) onwards would require further specification. For example, a rather large work window may be needed for the purpose of longer averaging emissions events, (e.g. the amount of work during the WHTC). Alternatively, the earlier mentioned approach to apply OCE limits to the average of all events (or e.g. to an x% percentile of all events) could be considered. This could be combined with a higher not to exceed emission limit.

Hybrid" concept:

A hybrid concept combines a work window and a control area concept. As discussed already in the control area based concepts, short sampling times need an averaging of the results before comparing against limit values. A work window could be used to define the averaging method, i.e. single emission events are averaged until the total work is larger than the work performed by the engine in the type approval cycle. The issues with window sizes were discussed in the previous section. The conclusions are also valid here.

An alternative "hybrid concept" could be an approach, which replaces the minimum sampling period by a work window. Such a method seems to have only disadvantages, since it will cause difficulties in obtaining a correct time alignment between engine load and measured emissions for events where the engine enters the control area for only a few seconds.

CO_2-based compliance factor concept:

The basic idea of the CO_2 specific compliance factor concept is to measure emissions during the total driving time and relate the total emissions to the total CO_2 emissions (alternatively to the total fuel consumption). For the assessment whether the OCE test is passed or failed, the CO_2 specific emissions are compared with a reference value based on the emission limits of the type approval cycle. If this ratio (the "compliance factor") exceeds a given limit value, the OCE test is failed.

There are a number of benefits to the CO_2 compliance factor approach. First, using reference values [$g_{Emissions}/kg_{CO2}$] causes less sensitivity to low load or idling conditions during the driving cycle than dividing the emissions by the engine work [g/kWh]. A second crucial benefit of this approach, when a PEMS system is used, is the fact that no engine load data is required for the calculation of the emission events. Therefore this kind of monitoring approach can be performed independently from the support of the manufacturer. This may be a clear advantage compared to the other approaches since it is not guaranteed to get an exact and time-aligned signal for engine power and engine speed from the engine control unit. The CO_2 based approach is also less sensitive to possible flow measurement errors in the PEMS system, as the emissions are divided by the CO_2 emissions. Additionally, the evaluation of the on-road measured emission data from a Euro III vehicle indicated that the CO_2-based concept was less sensitive to the ambient conditions than the window-based approach.

Like in the work-window approach, the "compliance factor" approach covers the complete driving time. Due to the averaging of the emissions over a reasonable amount of CO_2-emissions, the effect of driving partially in engine load operations with high CO_2- specific emission levels is reduced. While relating the emissions to brake specific values [g/kWh] always gives infinite values in idling conditions, this problem does not exist if the emissions are related to the CO_2 emission value [$g_{emission}/kg_{CO2}$].

However, special driving conditions like with the garbage truck analysed here, still lead to very high emission results. Thus, the boundary conditions for the test driving would have to be defined like in the work window approach.

General remarks on OCE monitoring approaches:

A robust approach for effective OCE monitoring should cover all relevant HDV operating conditions and not only 'off test cycle' engine and vehicle operation. This is because even if both a real world HDV engine operating pattern and the type approval /certification cycle show a similar distribution in the engine map, due to the high sensitivity of modern engine designs to transient load changes and thermal conditions, it can not be guaranteed that the emission levels are comparable.

All OCE monitoring approaches reviewed in this report have specific advantages and disadvantages. However, the "compliance factor" approach seems to be the most robust approach for the near future.

Further development of the techniques and procedures will have to be considered to develop an effective OCE monitoring tool irrespective of which approach is adopted. These issues include:

- The definition of the test driving. This could include a certain number of hours urban driving and hours of highway driving which would be evaluated separately. In addition, specification of the maximum and minimum vehicle speeds for a valid test. This would prevent manufacturers from having disadvantageous driving conditions on one hand and on the other hand guarantee that relevant traffic situations are covered.
- A more specific definition of the vehicle pre-conditioning is necessary in order to include low load urban driving, but this should also protect manufacturers against tests with cold start conditions. It needs to be discussed if the OCE test procedure should be a tool to regulate the thermal management of the exhaust gas after-

treatment systems. The temperature of a catalyst strongly depends on the location in the vehicle; therefore it would be reasonable to include an OCE monitoring test involving the complete vehicle in the type approval/certification procedure in addition to engine bench tests.

- The final definition of the OCE test limit values. These limit values will depend on the final boundaries of each specific OCE test approach.
- The definition of the vehicle load during the emission testing.

Despite the remaining issues to be addressed before an OCE test could be included in the European type approval legislation, there is a clear need for such a test A procedure should guarantee that a reduction of emission levels in the type approval cycle will also result in lower emission levels in real world driving conditions.

The specific advantages and disadvantages of the OCE monitoring approaches analysed are summarised in the following table:

OCE monitoring approach		coverage of all relevant operating conditions	ability for classification of increased emission levels to “unavoidable” or “defeat strategies”	feasibility with PEMS incl. measurement of PM emissions	**Remarks**
Control area	draft WNTE	- -	+ +	- -	ECU data required → support from manufacturer needed
	WNTE + 10s minimum sampling period	-	-	- -	
	WNTE + enlarged control area + 10s minimum sampling period	o	-	- -	
Work window		+	+	+ +	
Hybrid approach	control area + minimum sampling time and work window for averaging of emission events	o	+	- -	
	control area + work window instead of minimum sampling time	Not recommended due to restrictions from the measurement equipment			
“Compliance factor” based on CO_2 specific emissions		+	+ +	+ +	no ECU data necessary → independence from manufacturer

A condensed explanation of the different scores can be found in the summary of the analysis of each OCE monitoring approach

<u>Legend:</u>

+ +	fulfilled
+	reasonably fulfilled
o	partially fulfilled
-	poorly fulfilled
- -	not fulfilled

The evaluation showed that both the Work-window and the CO_2-based Compliance Factor approach can be seen as the most promising versions for an OCE monitoring approach in the nearer future. Both cover the total driving time and the measurement of PM mass with the filter method is feasible for in-use testing.
Additional advantages of the CO_2-based compliance factor approach are an even more stable evaluation quality for low load engine operation and the fact, that opposite to all previous discussed approaches, the monitoring can be performed independent from the manufacturer, as no ECU data is needed for the emission evaluation. The influence of possible PEMS flow measurement errors is also reduced.

4. Review of WNTE temperature and altitude boundaries

In the current WNTE proposal the WNTE emission limits apply in certain ambient conditions (temperature, humidity, altitude). For operating conditions outside of these boundaries, either the WNTE limits do not apply, or correction factors for PM and NOx have to be used, depending on the actual conditions and the ambient conditions option selected at the time of certification or type-approval of an engine.

A review of the European situation shows that the proposed WNTE ambient conditions zone covers the altitudes well, but that the ambient temperature and humidity conditions are covered only weakly. Using the current definition, the European ambient conditions are covered during only about 20% of the year without the use of correction factors.

The analysis of the year 2005 weather data shows, that the maximum temperature concepts for options A and B of the current proposal are equivalent from a European perspective. The maximum daily temperatures of all analyzed weather stations are above the maximum temperature defined by both options for far less than 1% of the time.

However, if a substantial part of real European ambient conditions should be covered without the use of correction factors, the minimum temperature and the ambient humidity range should be widened.

The current WNTE proposal counts emissions on a "per work" base (i.e. g/kWh) as normal type-approval regulations do for emissions measured on engine dynamometers. Because it is rather complicated to measure the engine work precisely on the road, there are good reasons to limit the emissions in a fuel- or CO_2 specific manner. Looking at NOx and THC emissions of a Euro III engine measured in a vehicle with a PEMS system, the CO_2 specific emissions clearly show a reduced sensitivity to the ambient conditions when compared with the brake specific emissions.

5. Conclusions

The objective of this project was to evaluate the current definition of the WNTE control area from a European perspective. The study showed that the WNTE control area approach as defined in the OCE GTR is suitable for highway operations. The method is not suitable for city driving conditions.

The study also showed that very low emission levels recorded during the European type approval test do not guarantee low emission levels during real world driving conditions. The need for an OCE procedure and in-use, on-vehicle, measurements was confirmed.

The work-window approach and the CO_2-based compliance factor approach showed the highest potential for monitoring all relevant driving conditions. The latter method is less sensitive to driving situations with low engine loads and does not need ECU data from the vehicle for engine power and engine speed. The influence of possible PEMS flow measurement errors is also reduced. Thus from the current point of view, the CO_2-based compliance factor approach can be seen as the most promising approach for an OCE monitoring implementation.

The WNTE concept could be integrated into the European type approval process by replacing the ‘random points’ concept or even providing a new test for whole vehicles. However, it is apparent that for in-use testing programmes alternative OCE approaches are more desirable for the operating conditions of European Vehicles. The European Commission has a programme (PEMS Programme) to develop in-use procedures, so requirements in this area will begin to develop. A key question is therefore whether there is additional benefit from having a WNTE procedure at type approval and a different approach for in-use testing.