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A. Statement of Technical Rationale and Justification

1. Introduction

The objective of this Global Technical Regulation (GTR) is to establish a harmonized regulation which ensures off-cycle emissions from heavy-duty engines and vehicles are appropriately controlled over a broad range of engine and ambient operating conditions encountered during normal in-use vehicle operation. The GTR is intended to complement emission limits established under the test procedures of the World-Harmonized Heavy-duty Certification (WHDC) GTR.

To that purpose, this Off-cycle Emissions (OCE) GTR includes provisions that prohibit the use of defeat strategies. This OCE GTR also adopts new harmonized emissions limits and test requirements which cover a broad range of engine and ambient operating conditions, the World-Harmonized Not-to-Exceed requirements (“WNTE”). The WNTE requires the control of emissions during engine and ambient operating conditions that are not covered in emissions testing during the two components of the WHDC, the World-Harmonized Transient Cycle and the World-Harmonized Steady-state Cycle.

2. Background on Off-cycle Emissions

The basic regulatory approach historically utilized by a number of countries to reduce exhaust emissions from heavy-duty engines was to use a combination of an emissions certification test cycle with an emissions limit (or standard) and a prohibition against the use of defeat strategies.

The test cycle for heavy-duty engines, while different among various countries, had a number of common characteristics. The test cycle was based on an engine test, performed in a laboratory, under a limited range of ambient conditions, and the test cycle contained a pre-defined set of speed and load point always run in the same order. The prohibition against the use of defeat strategies generally required that the engine could not be designed to operate in-use in a manner which reduced the effectiveness of the engine’s emission control system relative to its emission performance over the certification test cycle. Emissions which occur under conditions not well represented by the laboratory-based test cycle are typically called off-cycle emissions.

Heavy-duty vehicles are driven over a wide variety of operating conditions, including starts, stops, accelerations, decelerations, steady cruises, and under varying ambient conditions (e.g., temperature, humidity and barometric pressure). While the establishment of the WHDC GTR will result in a laboratory-based test cycle which reflects world-wide on-road

heavy-duty engine operation, a substantial portion of the wide variety of real world driving conditions are not incorporated in the procedures.

Heavy-duty engines have progressed over the past decade to become a very sophisticated electronic and mechanical system. The system is capable of controlling the performance of heavy-duty engines over a wide variety of driving conditions. A central aspect of this sophisticated engineering is the capability to continuously monitor a wide range of operating parameters, including engine rotational speed, vehicle ground speed, and intake manifold pressure and temperature, and to modify the performance of the engine and its emission control systems in real-time in response to the monitored data.

The defeat strategy provisions do not provide a quantified numerical emissions limit and associated test procedure for conditions not encountered on the regulatory test cycles. This has generally resulted in the need for case-by-case decision making during the certification and type-approval process regarding whether a particular element of design constitutes a defeat strategy. These design-based reviews have become increasingly difficult as the engines and the emission control technologies have grown more complex.

The approach contained in this GTR reduces the reliance on case-by-case design reviews by requiring compliance with the WNTE provisions in addition to meeting emission limits based on a laboratory-based test cycle. The WNTE is intended to allow for a more efficient and objective performance-based means of evaluating off-cycle emissions behavior in addition to the prohibition against defeat strategies. The WNTE provisions accomplish this by substantially increasing the range of engine and ambient operating conditions which are subject to an emission limit.

The GTR does not specify obligations or requirements for in-use testing by manufacturers or certification agencies. Rather, by specifying emission limits under a wide range of engine and ambient operating conditions, the GTR provides a framework to enable in-use testing as a means of verifying that engines are designed and manufactured to comply with emission limits when operated under such conditions.

When considered as a whole, the WHDC GTR and this OCE GTR provide the opportunity for a globally harmonized set of regulations to effectively reduce air pollution from heavy-duty vehicles and engines.

3. Procedural Background and Development of GTR

This GTR was developed by the GRPE informal working group on Off-cycle Emissions (the OCE Informal group). A full report of the work of

the OCE Informal group, its deliberations and conclusions is provided in the group's Technical Report, TRANS/WP.29/GRPE/xxxxx.

The work to develop this GTR began in XXX 2001 with the establishment of the OCE Informal group. The OCE Informal group had its first meeting in December 2001.

As required by the 1998 Global Agreement, a formal proposal for the establishment of a GTR was proposed to the Executive Committee for the 1998 Agreement (AC3) by the United States. At its session on 13th March 2005, the proposal from the United States was approved as a GTR project by AC.3 ((TRANS/WP.29/AC.3/13).

[Include a discussion of any key issues discussed and resolved by the OCE Informal group or by GRPE in the development of the GTR]

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 requirements for in-use testing or specifications for on-vehicle emission measurement equipment. It was decided that at this time, regulations concerning such testing and equipment could be developed by individual countries and regional authorities. However, it was clearly recognized that the OCE GTR was developed with the specific intent to allow for testing of compliance with the WNTe during in-use, on the road operation of the engine. As such, individual countries and regional authorities may specify their own provisions in this regard in order to enforce this GTR, and such enforcement provisions could include requirements for in-use, on-vehicle emissions testing of heavy-duty engines.

4. Technical and Economic Feasibility

[Draft and insert text at a later date]

5. Anticipated Benefits

This GTR can result in a number of benefits, including: improved emissions control; more efficient certification or type approval methods, and reduced costs for engine and vehicle manufacturers.

The addition of harmonized defeat strategy provisions and WNTe requirements to the certification testing regime (e.g., the WHDC test cycles) will better ensure that an appropriate control of emissions is achieved in-use, under a wide range of operating conditions. As a result, it

can be expected that the application of this GTR by Contracting Parties will result in an improved level of emissions control.

The GTR can reduce the need for time consuming case-by-case design reviews and provide a more efficient and objective performance-based means for evaluating off-cycle emissions.

Finally, heavy-duty engines and vehicles are often produced for the world market. It is economically more efficient for manufacturers to design and produce models which meet emissions objectives specified in a common Global Technical Regulation rather than developing products to meet a wide array of different and potentially conflicting regulatory requirements in individual countries and regions. This in turn is expected to allow manufacturers to develop new models more effectively at a lower cost.

6. Potential Cost Effectiveness

[Develop and insert text at a later date, taking into consideration the language developed for the WMTC GTR]

B. Text of Regulations

1. Scope and Purpose

This regulation establishes performance-based emission requirements and a prohibition on the use of defeat strategies for heavy-duty engines to require effective control of emissions under a broad range of engine and ambient operating conditions.

2. Application

This regulation applies to the emission of gaseous and particulate pollutants from compression-ignition engines, natural gas engines and positive-ignition engines fuelled with LPG, generally used for propelling motor vehicles having a design speed exceeding 25 km/h and having a total mass exceeding 3.5 tonnes.

3. Definitions

Element of Design
Emission Control Strategy
Basic Emission Control Strategy
Auxiliary Emission Control Strategy
Defeat Strategy
Beer-Lambert relationship
Engine starting
Engine Family
Engine rating/configuration

Heavy-duty engine
Passive regeneration
Active regeneration
Diesel derived engines
Steady-State Engine Operation [referring to smoke requirements]
Transient Engine Operation [referring to smoke requirements]

4. General Requirements

Engines shall be designed, constructed and assembled as to enable the engine and/or vehicle in normal use to comply with the provisions of this Regulation.

4.1 Prohibition of Defeat Strategies

No engine and/or vehicle shall be equipped with a defeat strategy

4.2 WNTTE Requirement.

Emissions must not exceed specified emission limit values when measured over a broad range of engine speed and load points (the WNTTE control area) and a broad range of ambient conditions which can reasonably be expected to be encountered in normal vehicle operation and use.

5. Performance Requirements

[Note – all of Section 5.1 has been suggested by OICA and not reviewed by the Editorial Committee. The text is included here for discussion]

5.1 Emission Control Strategy

5.1.1 Any element of design and emission control strategy (ECS) liable to affect the emission of gaseous and particulate pollutants from diesel engines and the emission of gaseous pollutants from gas engines shall be so designed, constructed, assembled and installed as to enable the engine, in normal use, to comply with the provisions of this GTR. ECS consists of the base emission control strategy (BECS) and usually one or more auxiliary emission control strategies (AECS).

5.1.2. Requirements for base emission control strategy

5.1.2.1. The base emission control strategy (BECS) shall be so designed as to enable the engine, in normal use, to comply with the provisions of this GTR. Normal use is not restricted to the conditions of use as specified in section 5.1.3.4.

5.1.3. Requirements for auxiliary emission control strategy

5.1.3.1. An auxiliary emission control strategy (AECS) may be installed to an engine or on a vehicle provided that the AECS:

- operates only outside the conditions of use specified in section 5.1.3.4 for the purposes defined in paragraph 5.1.3.5 or,
- is activated only temporarily within the conditions of use specified in section 5.1.3.4 for the purposes defined in section 5.1.3.5 and not longer than is needed for these purposes.

5.1.3.2. An auxiliary emission control strategy (AECS) that operates within the conditions of use specified in section 5.1.3.4 and which results in the use of a different or modified emission control strategy (ECS) to that normally employed during the applicable emission test cycles will be permitted if, in complying with the requirements of section 5.1.4, it is fully demonstrated that the measure does not permanently reduce the effectiveness of the emission control system. In all other cases, such strategy shall be considered to be a defeat strategy.

5.1.3.3. An auxiliary emission control strategy (AECS) that operates outside the conditions of use specified in section 5.1.3.4 will be permitted if the manufacturer fully demonstrates that the measure is the minimum strategy necessary for the purposes of section 5.1.3.5 with respect to environmental protection and other technical aspects. In all other cases, such a strategy shall be considered to be a defeat strategy.

5.1.3.4. As provided for in section 5.1.3.1, the following conditions of use apply under steady state and transient engine operations:

- an altitude not exceeding 1 600 meters (or equivalent atmospheric pressure of 83.5 kPa), and,
- an ambient temperature within the range 275 K to 308 K (2°C to 35°C) and,
- engine coolant temperature within the range 343 K to 373 K (70°C to 100°C).

5.1.3.5. An auxiliary emission control strategy (AECS) may be installed to an engine, or on a vehicle, provided that:

- the operation of the AECS is substantially included in the applicable test cycle, or,
- the AECS is activated only by on-board signals for the purpose of protecting the engine system (including air-handling device protection) and/or vehicle from damage, or
- the AECS is activated for purposes such as operational safety, permanent emission default modes and limp-home strategies, or

- the AECS is activated for such purposes as excessive emissions prevention, cold start or warming-up, or
- the AECS is used to trade-off the control of one regulated pollutant under specific ambient or operating conditions in order to maintain control of all other regulated pollutants within the emission limit values that are appropriate for the engine in question. The overall effects of such an AECS is to compensate for naturally occurring phenomena and do so in a manner that provides acceptable control of all emission constituents.

5.1.4. Documentation requirements

The manufacturer shall provide a documentation package that gives access to any element of design and emission control strategy (ECS) of the engine system and the means by which it controls its output variables, whether that control is direct or indirect. The documentation shall be made available in two parts:

(a) the formal documentation package, which shall be supplied to the technical service at the time of submission of the type-approval application, shall include a full description of the ECS. This documentation may be brief, provided that it exhibits evidence that all outputs permitted by a matrix obtained from the range of control of the individual unit inputs have been identified. This information shall be attached to the documentation required in [CERTIFICATION SECTION];

(b) additional material that shows the parameters that are modified by any auxiliary emission control strategy (AECS) and the boundary conditions under which the AECS operates. The additional material shall include a description of the fuel system control logic, timing strategies and switch points during all modes of operation. The additional material shall also contain a justification for the use of any AECS and include additional material and test data to demonstrate the effect on exhaust emissions of any AECS installed to the engine or on the vehicle. The justification for the use of an AECS may be based on test data and/or sound engineering analysis.

This additional material shall remain strictly confidential, and be made available to the type-approval authority on request. The type-approval authority will keep this material confidential.

5.2 WNTTE Limits for Gaseous and Particulate Exhaust Emissions

5.2.1 Exhaust emissions of NO_x, (NM)HC, CO and PM from an engine shall not exceed the applicable WNTTE emission limits when the engine is

operated under the conditions specified in section 6.0 and emissions are determined in accordance with the procedures specified in section 7.0.

5.2.2 For the purposes of section 5.2.1, the applicable WNTe emission limits for an engine shall be determined using the following formula

$$\text{WNTe Emission Limit} = \text{WHDC Emission Limit} \times \text{WNTe Factor}$$

where

“WHDC Emission Limit” is the emission limit to which the engine is certified pursuant to the WHDC test procedures; and

“WNTe Factor” is determined by reference to Table 1 and is based on the engine’s WHDC Emission Limit

Table 1: WNTe Factors for Gaseous and Particulate Emissions

Pollutant	WHDC Emission Limit*	WNTe Factor*
NOx	= 2.0 g/kWh	1.5
	> 2.0 g/kWh	1.25
(NM)HC	= 0.6 g/kWh	1.5
	> 0.6 g/kWh	1.25
CO	= 1.0 g/kWh	1.5
	> 1.0 g/kWh	1.25
PM	= 0.05 g/kWh	1.5
	> 0.05 g/kWh	1.25

[Note – all values in Table 1 have been suggested by OICA and are included here for discussion purposes]

5.3 WNTe Smoke emissions requirements

Operation within the WNTe control area (defined in Section 7.1) must comply with either of the alternative limits in section 5.3.1 or 5.3.2. The manufacturer selects which option and must declare at the time of certification or type approval which option has been selected.

5.3.1 A filter smoke number of 1.0 under steady-state operation, or the following alternate opacity limits:

5.3.2 A 30 second transient test average opacity limit of 4% for a 5 inch path; and a 10 second steady state test average opacity limit of 4% for a 5 inch path.

5.3.1 A filter smoke number (FSN) of 1.0 under steady-state operation, or the following alternate light absorption coefficient limits:

5.3.2 A 30 second transient test average light absorption coefficient limit of 0.35 m^{-1} ; and a 10 second steady state test average light absorption coefficient limit of 0.35 m^{-1} .

5.3.3 The standards set forth in Section 5.3.1 and 5.3.2 of this section refer to exhaust smoke emissions generated under the conditions specified in Section 7.1 and 7.3 and calculated in accordance with the procedures set forth in Section 7.4.

6. Applicable Ambient Conditions

The WNTe emission limits apply over one of the two alternative ambient operating regions specified in Section 6.1 or Section 6.2. The manufacturer shall select which ambient operating region and shall declare the selected option at the time of certification or type-approval of an engine.

6.1 Option (A) The WNTe emission limits apply at all altitudes less than or equal to 5,500 feet above sea-level and at all ambient temperature and humidity conditions. Temperature and humidity ranges for which correction factors are allowed are specified in Section 7.3; or

6.2 Option (B) The WNTe emission limits apply at all altitudes less than or equal to 5,500 feet above sea-level, for temperatures less than or equal to the temperature determined by the following equation at the specified altitude:

$$T = -0.00254 \times A + 100$$

Where:

T = ambient air temperature in degrees Fahrenheit.
A = altitude in feet above sea-level (A is negative for altitudes below sea-level).

7. WNTe Test Procedures

7.1 WNTe control area for diesel heavy-duty engines.

The WNTe Control Area for heavy-duty engines consists of the engine speed and load points defined in Sections 7.1.1 through 7.1.6. Figure 1 is an example illustration of the WNTe control area.

7.1.1 Engine speed range. The WNTE control area shall include all operating speeds greater than the speed calculated using the following formula:

$$n_{lo} + 0.15 \times (n_{hi} - n_{lo})$$

where n_{hi} and n_{lo} are determined according to the provisions in [EPA Sec. 86.1360(c)/reference to participating country's Euro Steady-State test regulation cite Preference is to refer to WHDC GTR].

7.1.2 Engine load range. The WNTE control area shall include all engine load points greater than or equal to 30% or more of the maximum torque value produced by the engine.

7.1.3 Engine power range. Notwithstanding the provisions of Sections 7.1.1 and 7.1.2, speed and load points below 30% of the maximum power value produced by the engine shall be excluded from the WNTE control area for all emissions.

7.1.4 Additional WNTE Area Requirements for Vehicles Using CVT. All operating speed and load points with brake specific fuel consumption (BSFC) values within 5% of the minimum BSFC value of the engine are included in the WNTE control area when the engine is used in a vehicle with a continuously variable transmission. BSFC must be calculated under the general test cell conditions specified in

7.1.5 Particulate matter engine speed and load carve-out. For engines certified to a PM standard greater than 0.07 g/kW-hr, speed and load points determined by using the applicable method described below shall be excluded from the WNTE Control Area for the purposes of compliance with the WNTE PM emission limits.

7.1.5.1 C speed below 2400 rpm (see Figure 1). Exclude engine speed and load points to the right of or below the line formed by connecting the two points defined by 7.1.5.1.1 and 7.1.5.1.2:

7.1.5.1.1 30% of maximum torque or 30% of maximum power, whichever is greater, at the B speed; and

7.1.5.1.2 70% of maximum power at 100% speed (n_{hi})

7.1.5.2 C speed is above 2400 rpm (see Figure 2). Exclude engine speed and load points to the right of the line formed by connecting following the two points in Section 7.1.5.2.1 and 7.1.5.2.2 and below the line formed by connecting the two points in Section **7.1.5.2.2** and **7.1.5.2.3**:

7.1.5.2.1 30% of maximum torque or 30% of maximum power, whichever is greater, at the B speed;

7.1.5.2.2 50% of maximum power at 2400 rpm;

7.1.5.2.3 70% of maximum power at 100% speed (n_{hi}).

7.1.5.3 Determining B and C engine speeds. B and C engine speeds shall be determined according to the provisions in [EPA Sec. 86.1360(c)/reference to participating country's Euro Steady-State test regulation cite Preference is to refer to WHDC GTR]:

Figure 1. Example Not-To-Exceed Control Area When C Speed < 2,400 rpm

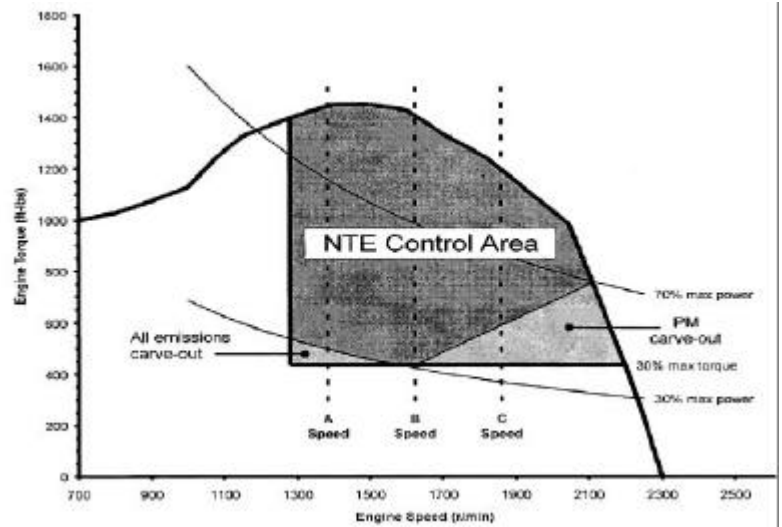
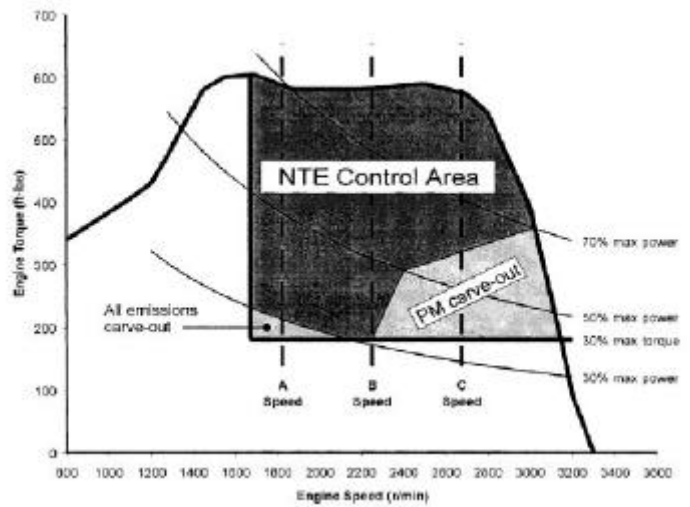


Figure 2. Example Not-To-Exceed Control Area When C Speed > 2,400 rpm



7.1.6 Compliance exclusion from certain WNTe operating points.

At the time of certification or type approval, the manufacturer may request approval of the Certification or Type Approval Authority to exclude operating points from the WNTe control area defined in Section 7.1.1 through 7.1.5 if the manufacturer can demonstrate that the engine is not capable of operating at such points when used in the specific engine-vehicle combination(s) identified by the manufacturer.

7.2 WNTe minimum sampling period.

7.2.1 When determining compliance with the emissions standards specified Section 5.0, an engine shall operate within the WNTe Control Area defined in Section 7.1 and its emissions shall be measured and averaged over any period of time greater than or equal to continuous 30 seconds, except where a longer averaging period is required by Section 7.2.2.

7.2.2 Engines equipped with emission controls that include discrete regeneration events. If a regeneration event occurs during the WNTe test, then the averaging period shall be at least as long as the time between the

events multiplied by the number of full regeneration events within the sampling period. The requirement in this Section only applies for engines that send an electronic signal indicating the start of the regeneration event-

7.2.3 WNTE Limited Testing Region Provision.

At the time of certification or type approval, manufacturers may request that the Certification or Type Approval Authority approve a limited testing region in a single defined region of speeds and loads within the WNTE control area. If approved, compliance testing would not be allowed with sampling periods in which operation within that region constitutes more than 5.0 percent of the time-weighted operation within the sampling period. The 5.0 percent is calculated on a time-weighted basis, e.g. no more than 2 seconds out of a 40 second-WNTE averaging period could be within the approved limited testing region. Such a defined region must generally be of elliptical or rectangular shape, and must share some portion of its torque/speed boundary with the torque/speed boundary of the WNTE control area. Approval of this limited testing region by the Certification or Type Approval Authority is contingent on the manufacturer satisfactorily demonstrating that operation at the speeds and loads within that region accounts for less than 5.0 percent of all in-use operation (weighted by vehicle-miles-traveled or other weightings approved by the Certification or Type Approval Authority) for the in-use engines of that configuration (or sufficiently similar engines). At a minimum, this demonstration must include operational data from representative in-use vehicles.

7.3 Ambient emissions corrections.

For engine operation within the conditions specified in Sections 6.1 or 6.2, the measured data shall be corrected based on the ambient conditions under which it was taken, as specified in this section.

7.3.1 For engines operating within the ambient conditions specified in Section 6.1.1:

7.3.1.1 NO_x emissions shall be corrected for ambient air humidity to a standard humidity level of 7.14 g/kg if the humidity of the intake air was below 7.14 g/kg, or to 10.71 g/kg if above 10.71 g/kg .

7.3.1.2 NO_x and PM emissions shall be corrected for ambient air temperature to a temperature of 12 degrees C for ambient air temperatures below 12 degrees C or to 35 degrees C if the ambient air temperature is above 35 degrees C.

7.3.1.3 No ambient air temperature or humidity correction factors shall be used within the ranges of 12 degrees C – 35 degrees C or 7.14 g/kg – 10.71 g/kg.

7.3.2 For engines operating within the ambient conditions specified in Section 6.1.2:

7.3.2.1 NO_x emissions shall be corrected for ambient air humidity to a standard humidity level of 7.14 g/kg if the humidity of the intake air was below 7.14 g/kg, or to 10.71 g/kg if above 10.71g/kg.

7.3.2.2 NO_x and PM emissions shall be corrected for ambient air temperature to a temperature of 12 degrees C for ambient air temperatures below 12 degrees C.

7.3.2.3 No ambient air temperature or humidity correction factors shall be used for temperatures greater than or equal to 12 degrees C or within the range of 7.14 g/kg – 10.71 g/kg.

7.3.3 Where test conditions require such correction factors, the manufacturer shall use good engineering judgment to determine the appropriate correction factors, subject to prior approval by the certification authority.

7.3.4 If applicable, the following correction factors shall be used:

$$\begin{aligned} - \text{ NOx: } k_{h,D} &= \frac{1}{1 - 0,0182 \times (H_a - 10,71) + 0,0045 \times (T_a - 298)} \\ - \text{ PM: } K_p &= \frac{1}{[1 + 0,0133 \times (H_a - 10,71)]} \end{aligned}$$

Other correction factors may be used if they can be justified or validated based on good engineering judgment and generally accepted engineering practice and with the prior approval of the type approval authority.

7.4 Measuring smoke emissions within the WNTE control area.

This section contains the measurement techniques to be used for determining compliance with the filter smoke limit or opacity limits in Section 5.3.

7.4.1 For steady-state or transient smoke testing using full-flow opacimeters. 10.7.1.1 Equipment meeting the requirements of *subpart I of this part or ISO/DIS-11614 "Reciprocating internal combustion compression-ignition engines--Apparatus for measurement of the opacity and for determination of the light absorption coefficient of exhaust gas"* is required. This document is incorporated by reference (*see Sec. 86.1 /reference to participating country's applicable test regulation cite*).

7.4.1.1 All full-flow opacimeter measurements shall be reported as the equivalent percent opacity for a five inch effective optical path length using the Beer-Lambert relationship.

7.4.1.2 Zero and full-scale (100 percent opacity) span shall be adjusted prior to testing.

7.4.1.3 Post test zero and full scale span checks shall be performed. For valid tests, zero and span drift between the pre-test and post-test checks shall be less than two percent of full-scale.

7.4.1.4 Opacimeter calibration and linearity checks shall be performed using manufacturer's recommendations or good engineering practice.

7.4.2 For steady-state testing using a filter-type smoke meter. Equipment meeting the requirements of *ISO/FDIS-10054* "*Internal combustion compression-ignition engines--Measurement apparatus for smoke from engines operating under steady-state conditions--Filter-type smokemeter*" is recommended. Other equipment may be used provided it is approved in advance by the Certification or Type Approval Authority.

7.4.2.1 All filter-type smoke meter results shall be reported as a filter smoke number (FSN) that is similar to the Bosch smoke number (BSN) scale.

7.4.2.2 Filter-type smoke meters shall be calibrated every 90 days using manufacturer's recommended practices or good engineering practice.

7.4.3 For steady-state testing using a partial-flow opacimeter. Equipment meeting the requirements of *ISO-8178-3* and *ISO/DIS-11614* is recommended. Other equipment may be used provided it is approved in advance by the Certification or Type Approval Authority.

7.4.3.1 All partial-flow opacimeter measurements shall be reported as the equivalent percent opacity for a five inch effective optical path length using the Beer-Lambert relationship.

7.4.3.2 Zero and full scale (100 percent opacity) span shall be adjusted prior to testing.

7.4.3.3 Post-test zero and full scale span checks shall be performed. For valid tests, zero and span drift between the pre-test and post-test checks shall be less than two percent of full scale.

7.4.3.4 Opacimeter calibration and linearity checks shall be performed using manufacturer's recommendations or good engineering practice.

7.4.4 Replicate smoke tests. Replicate tests may be run to improve confidence in a single test or stabilization. If replicate tests are run, three additional tests which confirm to this section shall be run, and the final reported test results must be the average of all the valid tests.

7.4.5 A minimum of thirty seconds sampling time shall be used for average transient smoke measurements. The opacity values used for this averaging must be collected at a minimum rate of 1 data point per second, and all data points used in the averaging must be equally spaced in time.

7.5 Calculating WNTE emissions.

WNTE emissions shall be calculated in accordance with the following formula:

$Gas_{mass} = (u_{gas} \times c_{gas} \times q_{mew})$ divided by P

$$PT_{mass} = \frac{m_f}{m_{sep}} \times \frac{q_{medf}}{1000} \times P$$

7.6 Rounding.

WNTE emissions determined under Section 7.0 shall be rounded to the same number of significant figures as the applicable cycle-based standards using the conventions described in Annex “XX”.

9. WNTE deficiencies

9.1 General.

For the first three years after an emission limit is implemented which results in a more stringent WNTE emission limit, such as a more stringent WHDC emission limit, a manufacturer may request from the Certification or Type Approval Authority at the time of certification a WNTE deficiency as described below. A WNTE deficiency allows an engine or vehicle to be certified as compliant with this GTR even though specific requirements, limited in scope, are not fully met. The Certification or Type Approval Authority has the discretion to decide the duration that the WNTE deficiency will be granted during the three year period. The WNTE deficiency provisions allow a manufacturer to apply for relief from the WNTE emission requirements under limited conditions, such as extreme ambient temperatures and/or severe operation where vehicles do not accumulate significant mileage.

9.2 Evaluation criteria.

Deficiencies will be granted only if compliance is determined to be infeasible or unreasonable considering such factors as, but not limited to: technical feasibility of the given hardware and lead time and production cycles including phase-in or phase-out of engines or vehicle designs and programmed upgrades of computers. A WNTE deficiency may be granted where unreasonable hardware or software modifications would be necessary to correct the deficiency, and the manufacturer has demonstrated an acceptable level of effort toward compliance as determined by the Certification or Type Approval Authority.

9.3 Number of deficiencies.

The number of deficiencies allowed cannot be greater than three per engine family.

10. WNTE Carve-Outs and Technology-based WNTE exclusions.

10.1 WNTE cold temperature operating exclusion.

Engines equipped with exhaust gas recirculation (EGR) are not subject to any applicable WNTE emission limits when the engine is operated during cold temperature conditions as specified using either of the following two criteria even when the engine is operated within the WNTE control area specified in Section 7.1.

10.1.1 Intake manifold temperature (IMT) less than or equal to the temperature defined by the following relationship between IMT and absolute intake manifold pressure (IMP) for the corresponding IMP:

$$P=0.0875 \times \text{IMT} - 7.75$$

Where:

P = absolute intake manifold pressure in bars.

IMT = intake manifold temperature in degrees Fahrenheit.

10.1.2 Engine coolant temperature (ECT) less than or equal to the temperature defined by the following relationship between ECT and absolute intake manifold pressure (IMP) for the corresponding IMP:

$$P = 0.0778 \times \text{ECT} - 9.8889$$

Where: P = absolute intake manifold pressure in bars.

ECT = engine coolant temperature in degrees Fahrenheit.

10.2 NOx and NMHC Aftertreatment warm-up.

For engines equipped with one or more aftertreatment devices that reduce NOx or NMHC emissions, the applicable WNTE NOx and NMHC emission limits do not apply when the exhaust gas temperature measured within 12 inches of the outlet of the aftertreatment device is less the 250 deg.C. For multi-bed systems, the temperature at the outlet of the device having the maximum flow rate shall be used to determine whether the WNTE limits apply.

11. Documentation for Application for Compliance (or Annex)

11.1 Statement of WNTe compliance.

The manufacturer shall provide a statement in the application for certification that the diesel heavy-duty engine for which certification is being requested complies with the applicable WNTe emission limits specified in Section 5.0 when operated under all conditions which may reasonably be expected to be encountered in normal vehicle operation and use.

11.1.1 Example statement of compliance.

“These engines comply with the WNTe emission limits specified in Section 5.1 when operated under all conditions which may reasonably be encountered in normal vehicle operation and use.”

11.2 Basis for WNTe compliance statement.

The manufacturer shall maintain records at the manufacturer’s facility which contain all test data, engineering analyses, and other information which provides the basis for the compliance statement, where such information exists. The manufacturer shall provide such information to the Certification or Type Approval Authority upon request.

11.3 Technology exclusion descriptions.

For engines equipped with exhaust gas recirculation, the manufacturer shall provide a detailed description of the control system the engine will use to comply with the requirements of Sections 6.2 and 10.1 for the WNTe cold temperature operating exclusion. The description shall include but is not limited to the method the manufacturer will use to access this exclusion during normal vehicle operation. Specifically, the manufacturer must describe how control system will identify the conditions described in Section 10.6 and limit access to the cold temperature exclusion during normal vehicle operation.

11.4 NO_x and NMHC Aftertreatment warm-up.

For engines equipped with one or more aftertreatment devices that reduce NO_x or NMHC emissions, the manufacturer must provide a detailed description of the control system the engine will use to comply with the requirements of Section 10.2 for the WNTe exhaust aftertreatment warm-up exclusion, including but not limited to the method the manufacturer will use to access this exclusion during normal vehicle operation. Specifically, the manufacturer must describe how control system will identify the conditions described in Section 10.2.

11.5 Deficiency Descriptions.

For each engine model and/or horsepower rating within an engine family for which a manufacturer is requesting a WNTe deficiency(ies) under the provisions of Section 8.0, the manufacturer’s application for an WNTe deficiency(ies) must include a complete description of the deficiency. The

description shall include but is not limited to: the specific description of the deficiency; the reason the deficiency is needed; the pollutant that is the subject of the deficiency; all engineering efforts made by the manufacturer to overcome the deficiency; the specific engine and ambient operating conditions for which the deficiency is being requested (i.e., temperature ranges, humidity ranges, altitude ranges, etc.); the frequency the deficiency will be used (i.e., %VMT, % operation); if applicable, the specific emissions control system parameters modulated in response to the deficiency and the purpose of that modulation; if applicable, a full description of the auxiliary emission control device(s) which will be used to maintain emissions to the lowest practical level; and identification of the lowest practical emission level .

11.6 WNTE Limited Testing Region Descriptions and Demonstrations

For each engine model and/or horsepower rating within an engine family for which a manufacturer is requesting a 5% limited testing region under the provisions of Section 7.2.3, the manufacturer's application shall include a complete description of the carve-out including but not limited to the range of engine load and speed which define the carve-out region and the methods or analyses used to arrive at the carve-out region. Manufacturers shall provide analyses of typical engine operation that reflects known or reasonably anticipated engine use patterns that may be based on in-use data from testing of representative vehicle/engine configurations, valid engineering calculations corresponding to operational data from in use vehicles, or a combination of the two.

11.7 WNTE Exclusion Descriptions and Demonstrations

For any engine family which contains an engine-vehicle combination for which a manufacturer is applying for a WNTE exclusion for certain operating points under the provisions of Section 7.1.6, the manufacturer must describe those operating points and the basis for concluding that the engine is not capable of being operated at such points when used in the specified engine-vehicle combination(s).