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Item [X] of the provisional agenda

Retrofit Emission Control devices (REC)

**Draft new Regulation on uniform requirements for Retrofit Emission Control devices (REC) for heavy duty vehicles, agricultural tractors and non-road mobile machinery (NRMM) equipped with Compression Ignition engines, type approved according to Regulation No. 49 and NRMM and tractors with engines type approved according to Regulation No. 96.**

Submitted by the expert from [ ]

The text reproduced below was prepared by the expert from [ ] as a result of the discussion of the informal group on retrofit emission control devices (REC) regarding a proposal for a new Regulation on REC.

Draft Version 2 dated 11.08.2011

Remarks are highlighted in green. Sections not yet reviewed are highlighted in blue

[Values], [dates], [provisions] and [parameter] not fixed yet are indicated in [square brackets], indicated in [red] and [highlighted in yellow].

## I. Proposal

### Draft new Regulation on uniform requirements for Retrofit Emission Control devices (REC) for heavy duty vehicles, agricultural tractors and non-road mobile machinery (NRMM) equipped with Compression Ignition engines.

### ~~Draft new Regulation on uniform requirements for retrofit emission control devices for heavy duty vehicles equipped with engines type approved according to Regulation No. 49 and NRMM and tractors with engines type approved according to Regulation No. 96.~~

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## 1. Purpose

This regulation ~~is intended to provide~~ provides a harmonized method for the ~~classification, evaluation and approval and classification~~ of retrofit emission control systems (REC) for ~~oxides of nitrogen (NO<sub>x</sub>), particulate matter (and/or PM mass and PM number) or for both NO<sub>x</sub> and PM,~~ and for the determination of the levels of emissions from compression-ignition (C.I.) engines used in ~~applications, vehicles and non-road mobile machinery~~ within the scope indicated in paragraph 2. ~~It provides, for this purpose, a harmonised method for the determination of the levels of emissions from engines and from engines fitted with REC. The procedures and classifications may be used as the basis for the regulation of retrofit emission control systems within regional type approval and certification procedures.~~

## 2. Scope

This Regulation applies to retrofit emission control systems (REC) to be installed:

- 2.1 ~~on category M<sub>2</sub>, M<sub>3</sub> > 3.5t and N vehicles<sup>1</sup> and their C.I. engines, engines approved in accordance with Regulation No. 49~~
- 2.2 ~~on C.I. engines used in non-road mobile machinery<sup>1</sup> having an installed net power higher than 18 kW but not more than 560 kW, operated under variable speed,~~
- 2.3 ~~on C.I. engines used in non-road mobile machinery<sup>1</sup> having an installed net power higher than 18 kW, but not more than 560 kW, operated under constant speed,~~
- 2.4 ~~on C.I. engines used in category T vehicles<sup>1</sup> having an installed net power higher than 18 kW but not more than 560 kW,~~
- 2.4 ~~on C.I. engines operated under variable speed and having an installed net power higher than 18 kW but not more than 560 kW and used in non-road mobile machinery<sup>1</sup>, or~~
- 2.5 ~~on C.I. engines operated under constant speed having an installed net power higher than 18 kW but not more than 560 kW, and used in non-road mobile machinery<sup>1</sup>,~~  
not approved in accordance to Reg.96.
- 2.6 ~~Contracting parties may choose to recognise other regulations as being equivalent to this regulation.~~

## 3. Definitions

For the purpose of this Regulation:

<sup>1</sup> As defined in Annex 7 to the Consolidated Resolution on the Construction of Vehicles (R.E.3), (document TRANS/WP.29/78/Rev.1/Amend.2, as last amended by Amend.4).

- 3.1. "Adjustment factors" means additive upward adjustment factor and downward adjustment factor or multiplicative factors to be considered during periodic regeneration;
- 3.2. "Application range" means the range of vehicles to which a retrofit emission control device (REC) approved according to this regulation can be applied;
- 3.3. "Retrofit emission control device (REC)" means any particulate reduction system, NO<sub>x</sub>-reduction system or combination of both which is used for retrofit purposes. This includes any sensors and software essential to the operation of the device. Systems that only modify the existing engine system controls are not considered to be RECs;
- ~~"Particulate reduction REC" means a particulate reduction system that has a gravimetric particulate reduction or particle number reduction efficiency, determined in accordance with the procedure in Section 9, which meets one of the reduction levels indicated in Section 3;~~
- 3.4. "Particulate reduction REC" means a REC that has a particulate mass or number emission reduction efficiency which qualifies it to be certified as meeting one of the classification type levels as defined in this Regulation. The regeneration system and strategy are part of the particulate reduction REC;
- ~~3.5. "NO<sub>x</sub>-reduction REC" means a REC that has a NO<sub>x</sub> mass emission reduction efficiency which qualifies it to be certified as meeting one of the classification type levels as defined in this Regulation;~~
- ~~3.6. "Type I Category A" retrofit emission control device (REC)" means a retrofit emission control device which is intended to control particulate matter emissions only, and which does not increase the direct NO<sub>2</sub> emissions;~~
- 3.7. "Type II Category B" retrofit emission control device (REC)" means a retrofit emission control device which is intended to control particulate matter emissions only, and which does not increase the direct NO<sub>2</sub> emissions by more than the percentage specified in paragraph 3.7.1 based on the engine baseline emission NO<sub>2</sub> level;
- 3.8. "Engine baseline emission" means the tailpipe-emissions of a given engine or engine system without any retrofit emission control device. For engines without after-treatment the engine baseline emissions are equal to the engine out tailpipe raw emissions. For engines with after-treatment the engine baseline emissions are equal to the after-treated tailpipe emissions downstream of the after-treatment system;
- 3.9. "Type III Category C" retrofit emission control device (REC)" means a retrofit emission control device which is intended to control NO<sub>x</sub> emissions only;
- 3.10. "Type IV Category D" retrofit emission control device (REC)" means a retrofit emission control device which is intended to control both particulate matter emissions and NO<sub>x</sub> emissions, and thus NO<sub>2</sub> emissions;
- 3.11. "Reduction level" means a reduction efficiency in percent to be met by the retrofit emission control device (REC) in order to be certified as meeting one of the reduction levels specified in Section 3;

- 3.10. ~~"Combined deNOx particulate filter" means an exhaust aftertreatment system designed to simultaneously reduce emissions of oxides of nitrogen (NO<sub>x</sub>) and particulate pollutants;~~
- 3.12. "Continuous regeneration" means the regeneration process of an exhaust after-treatment system that occurs either permanently or at least once per applicable test cycle;
- 3.13. "deNOx system" means an exhaust after-treatment system designed to reduce emissions of oxides of nitrogen (NO<sub>x</sub>) (for example, passive and active lean NO<sub>x</sub> catalysts, NO<sub>x</sub> adsorbers, and selective catalytic reduction (SCR) systems);
- 3.14. "Emission control monitoring system" means the system that monitors ensures correct operation the operation of the emission control measures implemented in the engine and/or REC system in accordance with the requirements of paragraph [---];
- 3.15. "ESC test" means a test cycle consisting of 13 steady state modes to be applied in accordance with the relevant series of amendments to Regulation No.49;
- 3.16. "ETC test" means a test cycle consisting of 1800 second-by-second transient modes defined in, and to be applied in accordance with the relevant series of amendments to Regulation No.49;
- 3.17. "Reduction efficiency" means the ratio between the engine baseline mass emissions and the emissions downstream of the REC system, both measured in accordance with the procedures defined in this Regulation;
- 3.18. "Gaseous pollutants" means carbon monoxide, hydrocarbons (assuming a ratio of CH<sub>1.85</sub> for diesel), ~~and~~ oxides of nitrogen (NO<sub>x</sub>, the last named being expressed in as nitrogen dioxide (NO<sub>2</sub> equivalent) and nitrogen dioxide (NO<sub>2</sub>););
- 3.19. "Load condition" means the loading of particulate matter being stored at any moment in a particulate reduction system (such as a filter) expressed as a proportion of the maximum loading of particulate matter that may be stored in the system under specific driving conditions without external regeneration measures being initiated;
- ~~3.19. "Nitrogen dioxide (NO<sub>2</sub>)" to be discussed;~~
- ~~3.20. "NOx reduction system" means a deNO<sub>x</sub> system that has a mass emission reduction efficiency, determined in accordance with paragraph number [---] or number [---], which qualifies it to be certified as meeting one of the classification levels indicated in paragraph [---];~~
- 3.20. "NRSC cycle" means a test cycle consisting of steady state modes which is defined in, ~~and is to be applied in accordance with the relevant series of amendments to , paragraph [---] of [which regulation to be used, not yet inside Regulation No.96;~~
- 3.21. "NRTC cycle" means a test cycle consisting of 1173 second-by-second transient modes defined in, ~~[ ] and to be applied in accordance with the~~

**Comment [JM1]:** Correct referencing to be discussed with GRPE secretariat.

relevant series of amendments to paragraph [---] of [which regulation to be used, not yet inside Regulation No.96;

- 3.23. ~~“Particulate reduction system” means an exhaust gas after-treatment system for reducing particulate emissions by means such as chemical reaction, mechanical and /or aerodynamic separation, or by diffusion and /or inertial or electrostatic separation, or by any combination of these processes. The definition includes any sensors essential to the operation of the device. The regeneration system and strategy are part of the particulate reduction system. Engine-specific modifications to structural components of the engine or the vehicle, electronic control elements and electronic components are not considered part of the particulate reduction system;~~
- 
- 3.22. “Particulate matter ~~/(PM)-mass~~” means the mass of any material collected on a specified filter medium which is defined in the relevant series of amendments to Regulations No.49 or 96 as defined in this Regulation in accordance with the procedure set out in [---] after diluting C.I. engine exhaust gas with clean filtered air so that the temperature does not exceed 325K (52 °C);
- 3.23. “PM number” means the number of particles which is defined in the relevant series of amendments to Regulation No.49; any material counted with an instrument as defined in this Regulation in accordance with the procedure defined in paragraph number [---] after diluting C.I. engine exhaust gas with clean filtered air.;
- 
- 3.24. “Particulate reduction ~~system~~ REC family” means a family of particulate reduction systems that are technically identical with respect to their functioning in accordance with when compared in accordance with the harmonisation criteria for system families in paragraph number [---];
- 3.25. ~~“NOx reduction system~~ REC family” means a family of NOx reduction systems that are technically identical with respect to their functioning in accordance with when compared in accordance with the harmonisation criteria for system families in paragraph number [---];
- 3.26. “Periodic regeneration” means the regeneration process of an emission control device that occurs periodically in typically less than 100 hours of normal engine operation. During cycles where regeneration occurs, emission standards can be exceeded;
- 3.27. “Reagent” means any medium that is stored on-board the vehicle in a tank and provided to the exhaust after-treatment system (if required) upon request of the emission control system;
- 3.28. “WHSC cycle” means a test cycle consisting of 13 steady state modes defined in, and to be applied in accordance with the relevant series of amendments to Regulation No.49, paragraph [---] of [Global technical regulation No.4];
- 3.29. “WHTC cycle” means a test cycle consisting of 1800 second-by-second transient modes defined in, and to be applied in accordance with the relevant series of amendments to Regulation No.49, paragraph [---] of [Global technical regulation No. 4];

- 3.30 “Active regeneration” means any additional measure to force regeneration either on a periodic or continuously regenerating REC.

Insert to relevant Annex a paragraph that if a continuous regeneration system has active regeneration under some circumstances then KI factors must be applied.

**Comment [JM2]:** (based on R.115 and 582/2011/EU)

#### **4. Application for approval**

- 4.1. The application for approval of an REC shall be submitted by the manufacturer or by his duly accredited representative,
- 4.2. Each REC shall be accompanied by the following information:
- (a) the manufacturer’s name or trade mark;
- (b) the make and identifying part number of the REC as recorded in the information document issued in accordance with the model set out in [Annex XX];
- (c) the application including year of manufacture for which the REC is approved, including, where applicable, a marking to identify if the REC is suitable for fitting to a vehicle that is equipped with an on-board diagnostic (OBD) system as defined in [Application Range];
- (d) the instruction manual for the retrofit installation;
- (e) the end-user service manual including maintenance instructions.
- 4.3. The applicant shall provide sample(s) of the REC to be tested and to be retained by the Technical Service.

**Comment [JM3]:** (based on R.115 and 582/2011/EU)

#### **5. Markings**

- 5.1. All REC shall be marked with the trade name or mark of the retrofit manufacturer, the type [and reduction level] as indicated in [annexes ...] and the identifying part number as recorded in the information document issued in accordance with the model set out in [Annex XX].
- 5.2. All REC shall be identified by a label, in which the approval number, and the technical specifications, as required in [annexes ...] shall be placed. This label has to be permanently fixed to the REC, shall be indelible, and shall be clearly readable after installation of the REC.
- 5.3. REC samples for approval testing have to be clearly identified with at least the applicant’s name and the application.
- 5.4. An international approval mark shall be affixed to the REC as indicated in [annexes ...], conforming to a type approved under this Regulation, in addition to the mark prescribed in paragraphs 5.1 and 5.2 This approval mark shall consist of:
- 5.4.1. A circle surrounding the letter "E" followed by the distinguishing number of the country which has granted the approval<sup>2</sup>.

<sup>2/</sup> 1 for Germany, 2 for France, 3 for Italy, 4 for the Netherlands, 5 for Sweden, 6 for Belgium, 7 for Hungary, 8 for the Czech Republic, 9 for Spain, 10 for Serbia and Montenegro, 11 for the United Kingdom, 12 for Austria, 13 for Luxembourg, 14 for Switzerland, 15 (vacant), 16 for Norway, 17 for



- 5.4.2. The number of this Regulation, followed by the letter "R", a dash and the approval number to the right of the circle defined in [paragraph ....]. The approval number consists of the REC type approval number, which appears in the communication form for this type (see [paragraph 5.2. and annexes ...]) preceded by two figures indicating the latest series of amendments to this Regulation.
- 5.5. The approval mark shall be clearly readable and be indelible.
- 5.6. [Annexes ...] to this Regulation give examples of the arrangement of the aforesaid label with approval mark.

**Comment [JM4]:** (based on R.115)

## **6. Approval**

- 6.1. Type approval shall be granted if the REC meets the requirements of this Regulation.
- 6.2. An approval number shall be assigned to each REC approved. Its first two digits (at present 00 according to the Regulation in its original form) shall indicate the series of amendments incorporating the most recent major technical amendments made to the Regulation at the time of issue of the approval. The same type approval number shall not be assigned to another REC.
- 6.3. Notice of approval or of refusal or of extension of approval of a REC pursuant to this Regulation shall be communicated to the Parties to the Agreement applying this Regulation, by means of a form conforming to the model in [annexes ...] to this Regulation.

## **7. General requirements**

- 7.1. The REC shall be designed, constructed and capable of being mounted so as to enable the application to comply with the rules set out in this Regulation throughout the normal life of the REC under normal conditions of use.
- 7.2. The REC shall be durable. That is it shall be designed, constructed and capable of being mounted so that reasonable resistance is obtained to phenomena such as the corrosion, oxidation, vibration and mechanical stress to which it will be exposed under normal conditions of use.
- 7.3. For REC requiring a reagent, each separate reagent tank installed on a vehicle or machine shall include means for taking a sample of any fluid inside the

Finland, 18 for Denmark, 19 for Romania, 20 for Poland, 21 for Portugal, 22 for Russian Federation, 23 for Greece, 24 for Ireland, 25 for Croatia, 26 for Slovenia, 27 for Slovakia, 28 for Belarus, 29 for Estonia, 30 (vacant), 31 for Bosnia and Herzegovina, 32 for Latvia, 33 (vacant), 34 for Bulgaria, 35 (vacant), 36 for Lithuania, 37 for Turkey, 38 (vacant), 39 for Azerbaijan, 40 for The former Yugoslav Republic of Macedonia, 41 (vacant), 42 for the European Community (Approvals are granted by its Member States using their respective ECE symbol), 43 for Japan, 44 (vacant), 45 for Australia, 46 for Ukraine, 47 for South Africa and 48 for New Zealand. Subsequent numbers shall be assigned to other countries in the chronological order in which they ratify the Agreement Concerning the Adoption for Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts which can be fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approval Granted on the Basis of these Prescriptions, and the numbers, and the numbers thus assigned shall be communicated by the Secretary-General of the United Nations to the Contracting Parties to the Agreement.

tank. The sampling point shall be easily accessible without the use of any specialised tool or device.

7.4. Where a REC requires the use of a reagent, the driver or machine operator shall be informed of the level of reagent in the reagent storage tank on the vehicle or machine through a specific mechanical or electronic indication. This indication shall include a specific warning (such as a warning lamp or clear mechanical indication) when the level of reagent goes either:

(a) Below 10 per cent of the tank or a higher percentage at the choice of the manufacturer, or;

(b) Below a level corresponding to 12 hours of usage of the vehicle or machine under average conditions of operation.

The reagent level indicator and the warning indicator shall both be placed in close proximity to the fuel level indicator.

7.5. Devices that by-pass or reduce the efficiency of the REC are not permitted.

**Comment [LES5]:** Aligned with wording of other ECE Regs.

## 8. Reduction levels Performance requirements

8.1. REC approved under this regulation shall meet both of the following criteria

- the reduction levels as specified in paragraph 8.2 and
- the emission limit values as specified in paragraph 8.3

receive certification for an REC, the reduction levels indicated in table 4.1 the appropriate annex of this Regulation must be achieved. Those levels are to be applied to the engine raw baseline emissions of the test engine as defined in paragraph 4.1. Table 8.1:

**Comment [JM6]:** Reduction levels to be specified in the Annexes

### Reduction levels

	Reduction efficiency (%)	
	NO <sub>x</sub>	PM mass
Reduction Level 1	50 – [as specified in Annex III]	50 – [as specified in Annex I] 50
Reduction Level 2	70 – [as specified in Annex IV]	90 – [as specified in Annex II.] / [PM Number, see separate Euro VI Annex]

8.2. Reduction levels

8.2.1. The reduction level efficiency as measured using the test procedure(s) associated with the limit values to be achieved shall not be lower than the amounts specified in the respective Annexes I to IV of this Regulation and shown in Table 8.1. Those levels are to be applied to the engine baseline emissions of the test engine as defined in paragraph 4.1.

8.2.2. For the purpose of this regulation the reduction level efficiency for NO<sub>x</sub> shall be applicable to systems which are intended to reduce only NO<sub>x</sub>, and the PM reduction level to systems intended to reduce only PM particulate. For Combined-Type IV REC systems, which are intended to reduce emissions of both NO<sub>x</sub> and particulate matter are permitted to have any combination of the reduction levels for these two pollutants shown in the Annexes I

to IV of this Regulation is permitted. There is no requirement for a system to have the same reduction level for both pollutants.

- 8.2.3. A Type I, Type II, Type III or Type IV REC system Category A, Category B, Category C or Category D REC can may be approved to any reduction level applicable to its performance with respect to each of the pollutants, as indicated in Table 8.2.

Table 8.2:

**REC Categories Types and Reduction levels**

	Reduction level applicable	
	NOx	PM mass
<del>Category A</del> Type I	-	1 or 2
<del>Category B</del> Type II	-	1 or 2
<del>Category C</del> Type III	1 or 2	-
<del>Category D</del> Type IV	1 or 2	1 or 2

- 8.3. Limit values

The engine or engine system shall meet the next higher emission stage with respect to the limits of Regulation No. 49 and No. 96 based on the engine baseline emissions, as measured using the test procedure(s) associated with the limit values to be achieved.

- 8.3.1. The minimum requirements for each type category of REC are illustrated in table 8.3, table 8.4., table 8.5. and table 8.6.

Table 8.3:

**REC Matrix for Regulation No. 49**

Baseline	Component	Type I / II	Type III		Type IV	
A		to B1 / B2 / C	to B1	to B2	to B1	to B2 / C
	NOx	-	3,5 g/kWh	2,0 g/kWh	3,5 g/kWh	2,0 g/kWh
	PM	0,02 <sup>1)</sup> / 0,03 <sup>2)</sup> g/kWh	-		0,02 <sup>1)</sup> / 0,03 <sup>2)</sup> g/kWh	
Baseline	Component	Type I / II	Type III		Type IV	
B1		to C	to B2		to B2 / C	
	NOx	-	2,0 g/kWh		2,0 g/kWh	
	PM	0,02 g/kWh	-		0,02 g/kWh	

**Comment [JM7]:** Baseline A, Type IV: EEV (Row C)\_ requirement for PM is 0.02g/kWh on both cycles.

<sup>1)</sup> for the ESC cycle

<sup>2)</sup> for the ETC cycle

where the baseline identifiers correspond to those in Tables 1 and 2 of Regulation No. 49 revision 5.

For retrofit to Euro VI see separate Annex

Table 8.4:

REC Matrix for Regulation No. 96 / REC [Category A/B](#) Type I / II

Baseline	net. Power	Component g / kWh	Type I / II									
			H	I	J	K	L	M	N	P	Q	R
E	$130 \leq P \leq 560$	PM	-	-	-	-	0,025	-	-	-	0,025	-
F	$75 \leq P \leq 130$	PM	-	-	-	-	-	0,025	-	-	-	0,025
G	$37 \leq P \leq 75$	PM	-	-	-	-	-	-	0,025 <sup>(1)</sup>	-	-	0,025 <sup>(1)</sup>
D	$18 \leq P \leq 37$	PM	-	-	-	0,6 <sup>(2)</sup>	-	-	-	-	-	-
H	$130 \leq P \leq 560$	PM	-	-	-	-	0,025	-	-	-	0,025	-
I	$75 \leq P \leq 130$	PM	-	-	-	-	-	0,025	-	-	-	0,025
J	$37 \leq P \leq 75$	PM	-	-	-	-	-	-	0,025 <sup>(1)</sup>	-	-	0,025 <sup>(1)</sup>
K	$19 \leq P \leq 37$	PM	-	-	-	-	-	-	-	-	-	-
L	$130 \leq P \leq 560$	PM	-	-	-	-	-	-	-	-	-	-
M	$75 \leq P \leq 130$	PM	-	-	-	-	-	-	-	-	-	-
N	$56 \leq P \leq 75$	PM	-	-	-	-	-	-	-	-	-	-
P	$37 \leq P \leq 56$	PM	-	-	-	-	-	-	-	-	-	-

(1) only for engines with net power > 56 kW

(2) only for engines with net power > 19 kW

where the baseline identifiers correspond to those in Regulation No96 revision II.

Table 8.5:

## REC Matrix for Regulation No. 96 / REC Category C Type III

Baseline	net. Power	Component g / kWh	Type III										
			H	I	J	K	L	M	N	P	Q	R	
E	$130 \leq P \leq 560$	NO <sub>x</sub>	4,0 <sup>(3)</sup>	-	-	-	-	2,0	-	-	-	0,4	-
F	$75 \leq P \leq 130$	NO <sub>x</sub>	-	4,0 <sup>(3)</sup>	-	-	-	-	3,3	-	-	-	0,4 <sup>(1)</sup>
G	$37 \leq P \leq 75$	NO <sub>x</sub>	-	-	4,7 <sup>(3)</sup>	-	-	-	-	3,3 <sup>(1)</sup>	-	-	-
D	$18 \leq P \leq 37$	NO <sub>x</sub>	-	-	-	7,5 <sup>(2)</sup>	-	-	-	-	-	-	-
H	$130 \leq P \leq 560$	NO <sub>x</sub> <sup>(3)</sup>	-	-	-	-	-	2,0	-	-	-	0,4	-
I	$75 \leq P \leq 130$	NO <sub>x</sub> <sup>(3)</sup>	-	-	-	-	-	-	3,3	-	-	-	0,4 <sup>(1)</sup>
J	$37 \leq P \leq 75$	NO <sub>x</sub> <sup>(3)</sup>	-	-	-	-	-	-	-	3,3 <sup>(1)</sup>	-	-	0,4 <sup>(1)</sup>
K	$19 \leq P \leq 37$	NO <sub>x</sub> <sup>(3)</sup>	-	-	-	-	-	-	-	-	-	-	-
L	$130 \leq P \leq 560$	NO <sub>x</sub>	-	-	-	-	-	-	-	-	-	0,4	-
M	$75 \leq P \leq 130$	NO <sub>x</sub>	-	-	-	-	-	-	-	-	-	-	0,4
N	$56 \leq P \leq 75$	NO <sub>x</sub>	-	-	-	-	-	-	-	-	-	-	0,4
P	$37 \leq P \leq 56$	NO <sub>x</sub>	-	-	-	-	-	-	-	-	-	-	-

(1) only for engines with net power > 56 kW

(2) only for engines with net power > 19 kW

(3) sum of hydro-carbons and oxides of nitrogen

where the baseline identifiers correspond to those in Regulation No.96 revision 1.

Table 8.6:

**REC Matrix for Regulation No. 96 / REC Category-D Type IV**

Baseline	net. Power	Component g / kWh	Type IV										
			H	I	J	K	L	M	N	P	Q	R	
E	130 ≤ P ≤ 560	PM	-	-	-	-	0,025	-	-	-	-	0,025	-
		NOx	4,0 <sup>(3)</sup>	-	-	-	2,0	-	-	-	-	0,4	-
F	75 ≤ P ≤ 130	PM	-	-	-	-	-	0,025	-	-	-	-	0,025
		NOx	-	4,0 <sup>(3)</sup>	-	-	-	3,3	-	-	-	-	0,4 <sup>(1)</sup>
G	37 ≤ P ≤ 75	PM	-	-	-	-	-	-	0,025 <sup>(1)</sup>	-	-	-	0,025 <sup>(1)</sup>
		NOx	-	-	4,7 <sup>(3)</sup>	-	-	-	3,3 <sup>(1)</sup>	-	-	-	-
D	18 ≤ P ≤ 37	PM	-	-	-	0,6 <sup>(2)</sup>	-	-	-	-	-	-	-
		NOx	-	-	-	7,5 <sup>(2)</sup>	-	-	-	-	-	-	-
H	130 ≤ P ≤ 560	PM	-	-	-	-	0,025	-	-	-	-	0,025	-
		NOx <sup>(3)</sup>	-	-	-	-	2,0	-	-	-	-	0,4	-
I	75 ≤ P ≤ 130	PM	-	-	-	-	-	0,025	-	-	-	-	0,025
		NOx <sup>(3)</sup>	-	-	-	-	-	3,3	-	-	-	-	0,4 <sup>(1)</sup>
J	37 ≤ P ≤ 75	PM	-	-	-	-	-	-	0,025 <sup>(1)</sup>	-	-	-	0,025 <sup>(1)</sup>
		NOx <sup>(3)</sup>	-	-	-	-	-	-	3,3 <sup>(1)</sup>	-	-	-	0,4 <sup>(1)</sup>
K	19 ≤ P ≤ 37	PM	-	-	-	-	-	-	-	-	-	-	-
		NOx <sup>(3)</sup>	-	-	-	-	-	-	-	-	-	-	-
L	130 ≤ P ≤ 560	PM	-	-	-	-	-	-	-	-	-	-	-
		NOx	-	-	-	-	-	-	-	-	-	0,4	-
M	75 ≤ P ≤ 130	PM	-	-	-	-	-	-	-	-	-	-	-
		NOx	-	-	-	-	-	-	-	-	-	-	0,4
N	56 ≤ P ≤ 75	PM	-	-	-	-	-	-	-	-	-	-	-
		NOx	-	-	-	-	-	-	-	-	-	-	0,4
P	37 ≤ P ≤ 56	PM	-	-	-	-	-	-	-	-	-	-	-
		NOx	-	-	-	-	-	-	-	-	-	-	-

(1) only for engines with net power > 56 kW

(2) only for engines with net power > 19 kW

(3) sum of hydro-carbons and oxides of nitrogen

where the baseline identifiers correspond to those in Regulation No.96 revision n.

**8.4 NO<sub>2</sub> emissions requirements for Type I and Type II RECs**

8.4.1 For a Type I REC, NO<sub>2</sub> emissions shall not be greater than the NO<sub>2</sub> baseline emissions, measured as defined in Annex IX.

8.4.2 For a Type II REC, NO<sub>2</sub> emissions shall not be more than [...] % greater than the baseline emissions, measured as defined in Annex XI.

**Comment [JM8]:** Tolerance needed?

**9. Family criteria for particulate reduction  
REC Application range**

The application range describes the range of engines or engine systems to which -which are covered by- the REC system-family may be applied. The applicant shall provide detailed information about the application range to the Type Approval Authority / Technical Service as specified in Annex I.

The application range is defined by the engine family to which the test engine as defined in [paragraph 12] belongs.

The application range may be extended to

- a) other engine families produced by the same engine manufacturer, and
- b) engine families of other engine manufacturers

if the applicant can demonstrate that the following criteria are the same as the test engine:

(i) individual cylinder displacement — The vehicle / engine application range may be defined from for particulate reduction REC of different sizes and/or volumes provided that the following compliance criteria are met.

(ii) —

(iii) — Where a particulate reduction REC of the same construction, but with different volumes etc., is specified as suitable for various engines of the same manufacturer and vehicle or machinery types of the same manufacturer, the engine family to be retrofitted shall not differ with respect to the features set out in No. 5.1, and shall be listed in the application range, in accordance to 6.

(iv) —

(v) — If the applicant can demonstrate show that other engine families / vehicles and machinery produced by that manufacturer, or other engine families and vehicle or machinery types of other manufacturers of the application range covered by the test engine are identical with respect to the application range family formation criteria of 5.1, the application range in accordance to 6 can be extended to these engine families.

(vi) —

(vii) 5.1 — Application range Family formation criteria for particulate reduction REC

(viii) —

(i) within  $[\pm 15 \text{ } [20]\%]$  of the individual cylinder displacement displacement of a single cylinder of the test engine

(ii) method of aspiration (turbocharged or normally-aspirated engine).

(iii) with or without EGR.

(iv) whether a constant speed or a variable speed engine.

(v) engine baseline emission stage.

**?Are additional requirements needed for NOx or combined systems?**

## 10. Modifications to engine baseline emissions

Any engine operation parameter specified by the original engine manufacturer, such as maximum allowable exhaust gas back pressure, [to be completed] shall not be affected by the REC.

In cases where additional measures with respect to emission-relevant components and / or system components, such as modifications to the exhaust gas recirculation (EGR) control, are necessary in order to ensure

proper functioning of the engine and exhaust after-treatment systems in conjunction with the REC, the applicant shall provide a detailed description of the design modification along with an explanation of how the modification will change the operation and performance of the emission control strategy. To support its claims, the applicant shall submit additional test data, engineering justification and analysis, or any other information deemed necessary by the Type Approval Authority or Technical Service to address the differences between the modified and original designs.

The emission control system of the original engine manufacturer shall not be modified, except for modifications allowed by written permission of the original engine manufacturer. Any modification upstream of the original de-NO<sub>x</sub> System is not allowed. Modifications downstream of the original de-NO<sub>x</sub> system are permissible if the above mentioned parameters defined by the original engine manufacturer are not affected.

The performance of any On-Board Diagnostics (OBD) system and NO<sub>x</sub> control system of the original engine system shall not be compromised by the REC.

**11. Specifications concerning the emissions of pollutants**

**Comment [JM9]:** Title: Specifications concerning Emissions measurement?

The gaseous and particulate components emitted by the engine or engine system in combination with the REC submitted for testing shall be measured by the methods described in the applicable annexes of Regulation 49 and Regulation 96.

If a heated chemi-luminescent detector (CLD) is used for the determination of NO<sub>2</sub> in accordance with [6], two parallel measuring chambers to determine NO<sub>2</sub> and NO simultaneously shall be used. The use of two individual CLDs which are operated in parallel is not permitted.

[Two CLDs in parallel are permitted providing that the converter efficiencies are shown to be within [3%] of each other]

**12. Durability requirements Requirements for retrofit emission control devices**

**Comment [LES10]:** Wording in accordance to Anlage XXVII deleted.

12.1. The applicant shall provide evidence of the proper performance of the tests described in paragraph numbers [6] and confirm that the REC system will comply with the applicable provisions during normal operation over a useful life of:

a) for category M<sub>2</sub> and M<sub>3</sub> and N vehicles, a mileage of [200 000] km or a service life of up to [6] years, whichever occurs first depending on which criterion is first reached;

[or]

b) ~~in for non road mobile machinery<sup>14</sup>-all other applications, having an installed net power higher than 18 kW, but not more than 560 kW Non road mobile machinery over [4.000] operating hours or a service life of up to [6] years, depending on which criterion is first reached, whichever occurs first.~~

12.2. The applicant shall conduct a 1,000 hour durability test on an engine and REC combination. This test shall be either a field test in a typical vehicle or machine application or a test [using an appropriate duty cycle] on an engine



test ~~cell~~<sup>bed</sup>. The engine for the durability run may be different from the test engine used for tests to establish the reduction level of the REC, but must be an engine within the declared application range of the particular REC.

12.3. The content of the test is as follows:

- 1,000 hour testing of the REC ~~system~~ with recording of all relevant operating data of the engine concerned including continuous second-by-second data logging of exhaust temperature before the ~~filter-REC~~ and pressure loss ~~of the filter over the REC~~, type and consumption of fuel and lubricating oil. In the case of a field test the REC ~~system~~ must be sealed by the Technical Service and the data-logging shall be carried out by the ~~filter REC~~ manufacturer or by the operator of the ~~vehicle or machine~~ in-on which the endurance test is performed.

- In the case of REC ~~systems~~ that operate with additives or make use of a reagent, ~~verification of the correct dosing rate shall additionally be performed~~ at the beginning of the field test, after 500 hours of operation and after 1,000 hours of operation. ~~Verification of the reliability of dosage by measuring the additive / reagent content in the tank, with measurements to be carried out with a full, a half-empty and an almost empty tank.~~

12.4. After completion of the durability run the ~~aged-REC~~ used to demonstrate durability shall be used for any further evaluation testing with the original test engine. ~~9.3~~ ~~If the durability test is performed in an engine test cell the REC manufacturer shall determine the test points where NO<sub>x</sub> and/or PM emissions will be measured during the applicable test cycles. The minimum number of test points shall be three, one at the beginning, one approximately in the middle and one at the end of the 1000 hour period. The test points at the beginning and the end of the test period shall be in the first 100 hours and the last 100 hours of the test period respectively.~~

~~9.4~~ ~~For each pollutant NO<sub>x</sub> and / or PM emissions tests at each test point during the 1000 hour period a "best fit" linear regression analysis shall be made on the basis of all test results in order to determine the final emission result.~~

### 13. Particulate reduction REC ~~system~~ family

13.1. The approval of a particulate reduction ~~system-REC~~ will continue to be valid for a nominally similar system in a different configuration or application provided that it does not deviate from the tested system with ~~with~~ respect to the following features:

- a) Type of retention and functioning of reduction material (for example, adhesive or mechanical fixing, metallic or ceramic material, barrier filtration or aerodynamic ~~separation~~<sup>separation</sup>);
- b) Design and characteristics of the filter [or other active] material (for example, whether it consists of sheets or plates, or is braided or wound, the cell, material, or non-woven density, the porosity and pore diameter of barrier filter media, the number of pockets, blades or balls in aerodynamic ~~separators~~<sup>separators</sup>, the surface roughness of critical components, and the diameters of wires, balls, or fibres);

**Comment [LES11]:** Content form SNR regarding the durability test

**Comment [LES12]:** These are in fact the family criteria, for that reason Anlage XXVII wording is deleted.

- c) Minimum total charge of catalytically active materials of the particulate reduction system including upstream catalysts (if fitted) (grams/m<sup>3</sup>);
- d) Maximum total charge of catalytically active materials of the particulate reduction system including upstream catalysts (if fitted) (grams/m<sup>3</sup>);
- e) The design characteristics of the canning or packaging (for example, the storage or retention of the carrier of the active elements);
- f) Active Volume, which must be within  $\pm 30\%$  of the volume of the tested device;
- g) Type of regeneration (whether periodic or continuous);
- h) Regeneration ~~strategy-principle~~ (for example, catalytic, thermal, or electrothermal) and regeneration ~~strategy or forced~~(for example ~~passive, active, forced-regeneration~~);
- i) Method and control strategy for introducing additives or reagents (if used);
- j) Type of additive or reagent (if used);
- k) Installation conditions (max. + 0.5 m introduction difference between the turbocharger outlet (turbine) and the inlet of the particulate reduction system);
- l) Type of any catalytically active material;
- m) With or without an upstream oxidation catalyst.
- 13.2. When testing the particulate reduction REC ~~in-on~~ the engine test ~~cell~~bed, the REC must be fitted so that there is a distance of at least 2 metres ~~to the REC inlet~~ from the outlet of the turbocharger (turbine) ~~or the outlet plane of the exhaust manifold where no turbocharger is fitted to the REC inlet~~. If the applicant can show that a distance shorter than the minimum distance specified here is used in all subsequent applications of the REC, the length of the pipe used in the test cell may be correspondingly reduced. Insulation or similar means of maintaining the exhaust temperature are permissible only if they are also used in the subsequent installation of the REC on the vehicle or machine.

## 14. Compliance criteria for NO<sub>x</sub> reduction REC system family

- 14.1. Families may be formed from NO<sub>x</sub> reduction REC of different sizes or volumes, or both, provided that the following compliance criteria are met:
- a) Where a NO<sub>x</sub> reduction REC of the same construction, but with different volumes, is specified as suitable for various engines and vehicle or machinery types, the family shall not differ with respect to the features set out in Section 11. of this Regulation;
- b) Where the application range for a NO<sub>x</sub> reduction REC family is aligned with an engine manufacturer's engine family covered by the respective test engine in accordance with Regulation No. 49 for vehicles of category M>3.5t and N<sub>2</sub>;
- c) If the applicant can show that other engine families produced by that manufacturer, or other engine families of other manufacturers of the

- application range covered by the test engine, are identical with respect to the family formation criteria, then the application area can be extended to these engine families.
- 14.2. The family formation criteria for the extension of the application range are:
- within  $\pm 15\%$  of the displacement of a single cylinder
  - the method of aspiration (turbocharged or normally-aspirated engine)
  - with or without EGR
  - whether a constant speed or a variable speed engine.
- 14.3. The approval of a NO<sub>x</sub> reduction system will continue to be valid for a nominally similar system (employing the same NO<sub>x</sub> reduction technology) in a different configuration or application provided that it does not deviate from the tested system with respect to the following features:
- 14.3.1. Consistent features applicable to all NO<sub>x</sub> reduction REC:
- Critical dimensions of the active elements of the device (such as the size of valves or ducts, or the volume of a catalytic element) must be the same as those on the tested device, or must not differ from those dimensions in the tested device by an amount greater than can be justified as insignificant by relevant tests or robust engineering analysis. The active volume, for instance, of a catalytic element must be within  $\pm 30\%$  of the active volume of the tested device;
  - Any temperature control method employed (for example, catalytic, thermal, or electrothermal heating);
  - Any control strategy employed, including features of the implementation of that strategy such as delay periods, dosing rates for reagents, the positioning and characteristics of sensors, and the time constants and flow characteristics associated with valves;
  - Where the tested device was tested in association with other pollution control devices, the same arrangement of devices retained for the device under consideration;
- 14.3.2. Consistent features applicable to NO<sub>x</sub> reduction REC employing Selective Catalytic Reduction:
- The catalyst substrate material, the mechanical design of the substrate (whether, for instance, it is monolithic, built up from sheets or plates, woven, or is produced by packing loose components into a container) and the shape, cross-sectional area, and density of the exhaust gas channels formed in it;
  - The nature of the catalyst employed and the ratio of its active surface area to the nominal exposed surface area of the substrate being within 0.03 of that featured in the device tested;
  - The presence of a loading density for the catalytic material (in terms of mass per unit of surface area exposed to the exhaust gas flow) no lower than that featured in the unit tested, and a consistency of loading (in terms of the ratio of the highest to the lowest local loading density in the device) no greater than that featured in the unit tested;
  - The method of attaching the catalyst to the substrate, including the characteristics of any fastening or adhesive;
  - The nature of the reagent;

**Comment [S13]:** This requirement is driven by the suggestion that loading density is not a good enough parameter on its own. If someone were to use plates or wires, for instance, their surface finish might be relevant.

**Comment [S14]:** Are these performance-critical features, and, if so, can they be measured by a method which is not prohibitively expensive, or would we have to rely upon a description of the loading process and the opinion of a technical expert as to whether similarity is likely to have been achieved?

f) The introduction conditions for the reagent (which must be introduced at a point providing the same distribution and condition at the point where it is required). This condition will not be considered to have been met if the introduction point is further than a maximum of 0.5 metres from its position relative to the inlet of the catalyst container in the tested device).

**Comment [S15]:** Is this a reasonable figure for this case?

14.4. Further use of the existing oxidation catalyser(s):

When testing the NO<sub>x</sub> reduction REC in an engine test cell, the REC must be fitted so that there is a distance of at least 2 metres from the outlet of the turbocharger (turbine) [or the exit flange of the exhaust manifold in the case of an engine not fitted with a turbocharger] to the REC inlet. If the applicant can show that a distance shorter than the minimum distance specified here is [will be?] used in all subsequent applications of the REC, the length of the pipe used in the test cell may be correspondingly reduced. Insulation or similar means of maintaining the exhaust temperature are permissible only if they are [will also be?] also used in the subsequent installation of the REC on the vehicle or machine.

**15. Compliance criteria for a NO<sub>x</sub> and PM reduction REC family**

15.1. The approval of a NO<sub>x</sub> and PM reduction system will continue to be valid for a nominally similar system in a different configuration or application provided that it does not deviate from the tested system with respect to the following features:

- a) The NO<sub>x</sub> reduction elements of the REC are in conformance with the requirements of Section 11 of this Regulation;
- b) The PM reduction elements of the REC are in conformance with the requirements of Section 10 of this Regulation;
- c) The physical relationship between the NO<sub>x</sub> and PM reduction elements of the device are the same as the relationship between these elements in the tested device.

12. Active devices

**Comment [LES16]:** Deleted. 1. Never applied in Anlage XXVII, 2. Creates possible loophole.

12.1 If a particulate reduction REC is presented for approval that is associated with a device or devices (such as a by-pass valve) which would have the effect of altering the reduction level of the REC under certain circumstances in such a way that the REC no longer met the limits set out in paragraph [ ] for which the applicant wishes the REC to be approved, then the applicant shall demonstrate

- a) the conditions under which such devices are activated/deactivated;
- b) that the devices are used only for the protection of the particulate reduction REC or the engine, or for the regeneration of the particulate reduction REC, and are not permanently activated;
- c) that after an activation the device is deactivated not later than after two test cycles specified for the REC in accordance with paragraph number [ ], and that after deactivation the original condition and reduction level is restored [within four minutes]. Operation of the device in accordance with this condition must be demonstrated in an endurance run that includes at least 5 activation and deactivation cycles.
- e) that the specified endurance criteria are complied with [for both the device and the REC] and
- f) that the driver or operator is informed of the activation of such a device.
- g) that the average reduction level of the REC during an endurance run that includes at least 5 activation and deactivation cycles meets the limits for which the applicant wishes the REC to be approved.

## 16. Fuel

- 16.1. The testing of the REC shall be conducted with commercially available fuel representative of that generally used for the type of vehicle or machine to which the REC will be fitted.
- 16.2. The REC manufacturer may, as an alternative to using market fuel, apply to the Approval Authority for permission to perform the tests on the REC using a reference fuel. The reference fuel to be used in this case will be the fuel specified in either Regulation No. 49 or Regulation No. 96 for testing of engines for type-approval to the standard indicated in paragraph 4 that the vehicle or machine is intended to achieve after the REC under test has been fitted.
- 16.3. The specific fuel consumption of the engine during the applicable test cycle shall be not more than [4% for PM REC, ?% for NOx REC?] greater in the retrofitted condition than the mean specific consumption in the non-retrofitted condition.

The measurements for determining the fuel consumption may be carried out in parallel with the measurements carried out in accordance with paragraph number [---] for continuously regenerating systems or carried out in accordance with paragraph number [---] for periodically regenerating systems. [If the fuel consumption measurements (for technical or other reasons) are not carried out in parallel with the measurements to establish the reduction level of the REC, then they must be carried out using an identical procedure to that specified for those measurements.]

## 17. Choice of the test engines and REC combination

~~The engine chosen for testing should~~The test engines shall originate from an engine family ~~of engines~~ corresponding to the subsequent application range of the REC. The emissions performance of the ~~chosen~~ test engine shall be ~~within~~meet the limits ~~set for type approval to~~ for the applicable baseline emission ~~limit stage~~.

The test engine [and REC combination] for the selected application range area shall meet the following criteria:

- a) the engine shall have a nominal power output between 100% and [60%] of the maximum power of the parent engine in the particular family when assessed in accordance with the procedures of in Regulation ~~No. 49 and / or Regulation 96~~;
- b) the ~~engine and~~ REC system shall have the highest space velocity within the smallest used filter volume ( $V_{FI}$ ) that corresponds to the subsequent application range for of the selected test engine the REC system;
- c) the REC system shall have the minimum total charge of catalytically active materials specified by the manufacturer.

~~In all cases, the applicable test cycles [from Regulation No. number 49 or Regulation number No.96] shall are to be used for the exhaust gas verification measurements. [The emissions of the relevant pollutants are to be measured during at least every fifth test cycle during the measurements for verification of the regeneration characteristic.]~~

**Comment [S17]:** Test cycle paragraph from here to the beginning of Section 18, , and wording modified .

For REC intended to be used on engines type-approved in accordance with Regulation No.96, testing on one test engine for each power category for which the REC is intended to be used is mandatory.

The selected test engine must comply in both series production condition and in retrofitted condition with all of the pollutant emissions limits associated with the stage or standard to which it was originally type-approved. Any modification made to the test engine for the purposes of the REC approval tests must be a modification that will be made to all engines with which the REC is subsequently used. Where vehicles or machines are fitted with on-board diagnostic systems those systems shall not be affected limited with respect to their monitoring function after the retrofit system has been installed. The characteristics of the electronic engine control unit (as regards, for example, injection timing, air-mass flow metering, or exhaust emissions reduction strategies) shall not be altered by the retrofitting. Any modification of the test engine that changes the original emission behaviour (e.g. alternation of the injection timing) is not permitted.

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## 18. Test Cycles

18.1

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18.2. Tests of Type I and Type II (particulate reduction) REC

18.2.1. In cases where the approval of the engine with which the REC is to be used is an on road approval (performed in accordance with Regulation No.49) the test cycle to be used for approval of the REC must

18.2. Where the engine is being used in an on road application but does not have an approval issued in accordance with the requirements of Regulation No.49, the test cycle to be used for must meet one of the following requirements:

a) It is the test cycle associated with the emissions stage in Regulation No.49 for which approval of the REC is being sought, or with a later emissions stage;

b) It is the WHSC or the WHDC;

18.2. For the purposes of establishing the emissions of NO<sub>2</sub> during tests of a Type I or Type II REC, the specific test cycle defined in paragraph [15.8] of this Regulation shall be used.

18.3. Tests of Type III (NO<sub>x</sub> reduction) REC 18.4. Tests of Type IV (PM and NO<sub>x</sub> reduction) REC

18.4.1. Tests of Type IV REC must be undertaken using test cycle that meet all of the requirements of paragraph 18.1, paragraph 18.2, and paragraph 18.3, above.

**Comment [JM18]:** Test Cycles (section 18 in previous draft) moved to Annexes.

~~REC testing is conducted for the purpose of this Regulation in order to show the capability of the REC to reduce the PM or PN and/or the NOx emissions from a vehicle or machine from one emission stage or standard [as defined in Regulation No 49 or Regulation No 96] to the subsequent emission stage [or to an emissions stage or standard subsequent to that one].~~

**Comment [LES19]:** Not needed.

## 18. Operating behaviour

No impairment of the operating behaviour of the vehicle or machine, and no additional safety hazards associated with the vehicle or machine shall arise as a result of the installation of the particulate reduction system.

Consider machinery directive

## 19. Noise

The applicant shall prove that the retrofitting of a particulate reduction system will not lead to deterioration in the noise. Noise measurement may be omitted in the case of particulate reduction systems fitted in addition to the [original equipment manufacturer's] standard production silencer system. **If testing is done, it must comply with applicable international standards.**

**Comment [JM20]:** Title: Use of Additives or Reagents?

## 20. Use of additives

In the case of a particulate reduction REC which makes use of a consumable additive or reagent, testing of the non-regulated emissions in accordance with [Annex ] becomes necessary.

See SNR provisions in Annex III/ [max. allowable values to be defined].

## 21. Installation of a REC

21.1. Retrofitting with a REC must be performed in accordance with the installation instructions provided by the REC manufacturer. Any additional instructions (provided, for instance, by the vehicle or machine manufacturer) must also be taken into consideration. The user or operator of the vehicle or machine that has been retrofitted is responsible for proper installation.

21.2. ~~Maintenance to be introduced => CARR~~  
~~Installation requirements to be introduced => CARR~~

The REC manufacturer must provide proper installation guidelines. The vehicle or machine to be retrofitted must be in a [properly maintained and] serviceable condition. Defects that could prevent achievement of the emission reduction level for which the REC is approved, or could adversely affect its endurance are to be rectified as necessary before the retrofitting.

21.3. ~~The REC manufacturer shall supply, with each REC delivered, written instructions that shall state that the proper installation and maintenance of the REC is essential to its correct functioning.~~

- 21.4. The instructions must indicate requirements for the proper maintenance of the REC, including, where relevant, the use of consumable reagents. They must indicate any requirements or limitations on the use of the vehicle or machine that are necessary in order to ensure correct functioning of the REC.
- 21.5. The instructions shall be written in clear and non-technical language, and be suitable for passing to the owner or operator of the vehicle or machine to which the REC will be fitted. The instructions shall be in the language of the country in which the REC is sold or in which the REC is expected to be used.
- 21.6. Where the REC uses consumable reagents, the instructions shall specify whether those reagents need to be refilled by the vehicle or machine operator between normal maintenance intervals, and shall indicate a likely rate of reagent consumption.
- 21.7. The instructions shall state that, where the fitting of the REC is a condition for operation of the vehicle or machine in a particular country or area, or where fitting of the REC entitles the vehicle or machine owner to incentives or privileges, the failure to maintain the REC in proper working order (including the failure to ensure a proper supply of any reagent), may be a criminal offence or constitute a breach of contract.

## 22. Conformity of production

The conformity of production procedures shall comply with those set out in the Agreement, appendix 2 (E/ECE/324 - E/ECE/TRANS/505/Rev.2).

## 23. Modification and extension of approval of a REC

- 23.1. Every modification of the REC system shall be notified to the authority which granted the retrofit system type approval. The authority may then either:
- 23.1.1. Consider that the modifications made are unlikely to have an appreciably adverse effect and that in any case the retrofit system still complies with the requirements, or
- 23.1.2. Require a further test report from the technical service responsible for conducting the tests.
- 23.2. In both cases described in paragraphs 11.1.1. and 11.1.2. above, the authority shall be presented in the updated installation manual.
- 23.3. Confirmation or refusal of approval, specifying the alteration, shall be communicated by the procedure specified in paragraph 5.3. above to the Parties to the 1958 Agreement applying this Regulation.
- 23.4. The competent authority issuing the extension of approval shall assign a series number for such an extension and inform thereof the other Parties to the 1958 Agreement applying to this Regulation by means of a communication form conforming to the model in annexes ... to this Regulation.

**Comment [JM21]:** (based on R.115 –to be discussed)

## 24. Penalties for non-conformity of production

- 24.1. The approval granted in respect of a type of REC system pursuant to this

**Comment [JM22]:** (based on R.115 –to be discussed)



Regulation may be withdrawn if the requirements laid down in [paragraph 23 & 24?] above are not complied with.

24.2. If a Party to the Agreement applying this Regulation withdraws an approval it has previously granted, it shall forthwith so notify the other Contracting Parties applying this Regulation, by means of a communication form conforming to the models in [annexes ...] to this Regulation.

**Comment [S23]:** Should this be "definitively"?

**Comment [JM24]:** (based on R.115 –to be discussed)

**25. Production definitely discontinued**

If the holder of the approval completely ceases to manufacture a type of retrofit system approved in accordance with this Regulation, he shall so inform the authority which granted the approval. Upon receiving the relevant communication, that authority shall inform thereof the other Parties to the 1958 Agreement applying this Regulation by means of a communication form conforming to the model in annexes ... to this Regulation.

**26. Names / ~~and~~ and addresses of technical services responsible for conducting approval tests and of Administrative departments**

**Comment [JM25]:** (based on R.115 –to be discussed)

The Parties to the Agreement applying this Regulation shall communicate to the United Nations Secretariat the names and addresses of the technical services responsible for conducting approval tests and of the administrative departments which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval, issued in other countries, are to be sent.

## Annex 1.

### Information document

#### INFORMATION DOCUMENT NO..... RELATING TO THE TYPEAPPROVAL OF RETROFIT EMISSION CONTROL DEVICES (REC) FOR HEAVY DUTY VEHICLES, AGRICULTURAL TRACTORS AND NON-ROAD MOBILE MACHINERY (NRMM) EQUIPPED WITH COMPRESSION IGNITION ENGINES

Any drawings must be supplied in appropriate scale and sufficient detail on size A4 or on a folder of A4 format. Photographs, if any, must show sufficient detail.

If the system, components or separate technical units have electronic controls, information concerning their performance must be supplied.

#### 1. GENERAL

1.1. Make (trade name of manufacturer):

1.2. Type:

1.5. Name and address of manufacturer:

1.7. In the case of components and separate technical units, location and method of affixing of the ECE approval mark:

1.8. Address(es) of assembly plant(s):

#### 2. DESCRIPTION OF THE DEVICE

2.1. Make and type of the REC:

2.2. Drawings of the REC, identifying in particular all the characteristics referred to in items 2.3. to 2.3.2. of this appendix:

2.3. Description of the vehicle type or types for which the REC is intended:

2.3.1. Number(s) and/or symbol(s) characterising the engine and vehicle type(s):

2.3.2. Is the REC intended to be compatible with OBD requirements: Yes / No (Strike out what does not apply):

2.4. Description and drawings showing the position of the REC relative to the engine exhaust manifold(s):

**Comment [JM26]:** The standard UN format appears to be to have the Information document as Annex 1, Communication document as Annex 2 and markings examples as Annex 3. The other Annexes previously proposed therefore start at Annex 4.

**Comment [JM27]:** (to be discussed). Content below is based on reg.103.

**Annex 2.**

**Communication**

**Comment [JM28]:** (to be discussed). Content below is based on Reg.103.

(maximum format: A4 (210 x 297 mm))

issued by:                      Name of administration  
 .....  
 .....  
 .....



concerning: 2<sup>2</sup>                      APPROVAL GRANTED  
                     APPROVAL EXTENDED  
                     APPROVAL REFUSED  
                     APPROVAL WITHDRAWN  
                     PRODUCTION DEFINITELY DISCONTINUED

of a Retrofit Emission Control Device (REC) pursuant to Regulation No. [nnn]

Approval No. ....                      Extension No. ....

**Reason for extension:**

1.                      Applicant's name and address;
2.                      Manufacturer's name and address;
3.                      Manufacturer's trade name or mark;
4.                      Type and Commercial designation of the replacement catalytic converter;
5.                      Means of identification of type, if marked:
  - 5.1.                      Location of that marking;
6.                      Vehicles type(s) for which the device type qualifies as an REC;
7.                      Type(s) of vehicle(s) on which the REC has been tested:
  - 7.1                      Has the REC demonstrated compatibility with OBD requirements: Yes / No <sup>2</sup>
8.                      Location and method of affixing of the approval mark;
9.                      Submitted for approval on :
10.                      Technical Service responsible for approval tests:
  - 10.1.                      Date of test report;

<sup>1</sup>                      Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).  
<sup>2</sup>                      Strike out what does not apply.

10.2. Number of test report:

11. Approval granted / extended / refused / withdrawn <sup>2</sup>

12. Place:

13. Date:

14. Signature:

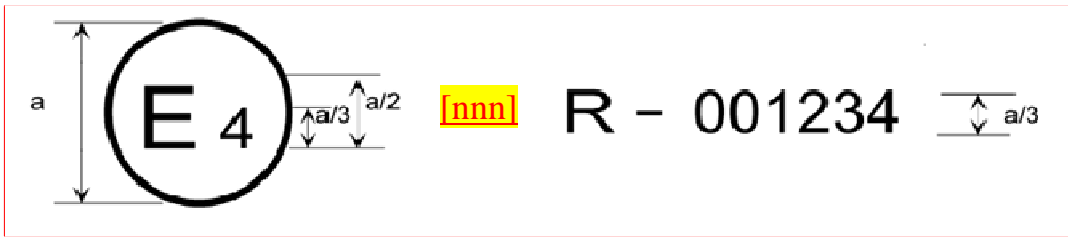
15. Annexed to this communication is a list of documents in the approval file deposited at the administrative services having delivered the approval and which can be obtained upon request

**Annex 3.**

**Arrangement of the REC type approval mark**

Model A

(See paragraph 5.4. of this Regulation)



a = 8 mm min

The above example approval mark affixed to a Retrofit Emission Control device (REC) shows that the type concerned has been approved in the Netherlands (E 4), pursuant to Regulation No. [nnn] under approval No. 001234. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. [nnn] in its original form.

**Comment [JM29]:** (to be discussed)  
Contents below is based on Reg.103.

**Comment [JM30]:** nnn = Regulation No., to be defined

**Annex 4****Application range**

<u>Number</u>	<u>Vehicle- Manufactu rer</u>	<u>Brand name</u>	<u>Model year from/to</u>	<u>Engine type</u>	<u>Capacity /cylinder (cm<sup>3</sup>)</u>	<u>Capacity V<sub>H</sub> (cm<sup>3</sup>)</u>	<u>engine net power kW with min<sup>-1</sup></u>	<u>Engine Baseline emissions</u>	<u>Silencer replaced</u>	<u>Technical Report Noise Emission</u>	<u>Type identification of the particulate reduction REC</u>	<u>Reduction Level and REC category</u>
<u>1</u>			<u>1996 - 2006</u>		<u>1994</u>	<u>12000</u>	<u>185 KW 220 KW 260 KW</u>	<u>Stage A</u>	<u>yes</u>			<u>1 / A</u>
<u>2</u>			<u>1996 - 2006</u>		<u>1994</u>	<u>12000</u>	<u>185 KW 220 KW 260 KW</u>	<u>Stage B</u>	<u>yes</u>			<u>2 / B</u>
<u>3</u>			<u>1996 - 2006</u>		<u>1994</u>	<u>1200</u>	<u>185 KW 220 KW 260 KW</u>	<u>Stage II</u>	<u>no</u>			<u>1 / B</u>

## Annex 5

### Requirements for Level 1 Particulate Reduction REC

1. Type I, Type II and Type IV REC approved to PM Reduction Level 1 shall provide a reduction efficiency for PM mass of at least 50% from the engine baseline emissions of the test engine as defined in paragraph [---] when measured using the test procedure(s) set out in Annex 9 and associated with the limit values to be achieved
2. Following installation of the REC, the test engine and/ REC combination shall meet the next higher PM emission stage with respect to the limits of Regulation No. 49 or~~and~~ No. 96, as appropriate, based on the engine baseline emissions, as measured using the test procedure(s) set out in Annex 9 and associated with the limit values to be achieved.
  - 2.1. For RECs intended for application to heavy-duty vehicles the PM emissions limits to be met are:
    - 2.1.1. For engines with baseline PM emissions corresponding to Row A of Tables 1 and 2 of Regulation No.49 Revision 5, 0.02 g/kWh on the ESC cycle and 0.03 g/kWh on the ETC cycle
    - 2.1.2. For engines with baseline PM emissions corresponding to Row B1 of Tables 1 and 2 of Regulation No.49 Revision 5, 0.02 g/kWh on the ESC ETC cycles.
  - 2.2. For RECs intended for application to non-road mobile machinery and tractors the PM emissions limits to be met are those shown in table 8.4 of this Regulation.
3. Following installation of the REC, the test engine and/ REC combination for NO<sub>x</sub> emissions measurement shall meet the requirements of paragraph 8.4 of this Regulation with respect to NO<sub>x</sub> emissions.

**Comment [S31]:** Should this be, for consistency, "on-road applications covered by Regulation No. 49"?

**Annex 6**

**Requirements for Level 2 Particulate reduction REC**

- 1. Type I, Type II and Type IV REC approved to PM Reduction Level 2 shall provide a reduction efficiency for PM mass of at least 90% from the engine baseline emissions of the test engine as defined in paragraph [---] when measured using the test procedure(s) set out in Annex 9 and associated with the limit values to be achieved
- 2. Following installation of the REC, the test engine and/ REC combination shall meet the next higher PM emission stage with respect to the limits of Regulation No. 49 or No. 96 as appropriate, based on the engine baseline emissions, as measured using the test procedure(s) set out in Annex 9 and associated with the limit values to be achieved.
  - 2.1. For RECs intended for application to heavy-duty vehicles the PM emissions limits to be met are:
    - 2.1.1. For engines with baseline PM emissions corresponding to Row A of Tables 1 and 2 of Regulation No.49 Revision 5, 0.02 g/kWh on the ESC cycle and 0.03 g/kWh on the ETC cycle
    - 2.1.2. For engines with baseline PM emissions corresponding to Row B1 of Tables 1 and 2 of Regulation No.49 Revision 5, 0.02 g/kWh on the ESC ETC cycles.
  - 2.2. For RECs intended for application to non-road mobile machinery and tractors the PM emissions limits to be met are those shown in table 8.4 of this Regulation
- 3. Following installation of the REC, the test engine and/ REC combination for NO<sub>2</sub> emissions measurement shall meet the requirements of paragraph 8.4 of this Regulation with respect to NO<sub>2</sub> emissions.

**Comment [S32]:** Should this read, "the next but one higher," or "the emissions stage above the next higher," or "the emissions stage that is two stages higher," in the case of Level 2 devices?



**Annex 7****Requirements for Level 1 NOx reduction REC**

1. Type III and Type IV REC approved to NOx Reduction Level 1 shall provide a reduction efficiency for ~~PM~~ mass of NO<sub>x</sub> of at least 50% from the engine baseline emissions of the test engine as defined in paragraph [---] when measured using the test procedure(s) set out in Annex 10 and associated with the limit values to be achieved. ~~achieved~~
2. Following installation of the REC, the test engine and/ REC combination shall meet the next higher NOx emission stage with respect to the limits of Regulation No. 49 ~~and~~ No. 96, as appropriate, based on the engine baseline emissions, as measured using the test procedure(s) set out in Annex 10 and associated with the limit values to be achieved.
  - 2.1. For RECs intended for application to heavy-duty vehicles the NOx emissions limits to be met are:
    - 2.1.1. For engines with baseline NOx emissions corresponding to Row A of Tables 1 and 2 of Regulation No.49 Revision 5, 3.5 g/kWh on the ESC and ETC cycle to achieve NOx emissions equivalent to Row B1 of Tables 1 and 2 of Regulation No.49 Revision 5.
    - 2.1.2. For engines with baseline NOx emissions corresponding to Row A of Tables 1 and 2 of Regulation No.49 Revision 5, 2.0 g/kWh on the ESC and ETC cycle to achieve NOx emissions equivalent to Row B2 of Tables 1 and 2 of Regulation No.49 Revision 5.
    - 2.1.3. For engines with baseline NOx emissions corresponding to Row B1 of Tables 1 and 2 of Regulation No.49 Revision 5, 2.0 g/kWh on the ESC ETC cycles to achieve NOx emissions equivalent to Row B2 of Tables 1 and 2 of Regulation No.49 Revision 5.
  - 2.2. For RECs intended for application to non-road mobile machinery and tractors the NOx emissions limits to be met are those shown in table 8.5 of this Regulation.

**Comment [JM33]:** For both Annexes VII and VIII wording is needed to cover Type IV systems meeting Row C (EEV) requirements .

## Annex 8

### Requirements for Level 2 NOx reduction REC

1. Type III and Type IV REC approved to NOx Reduction Level 2 shall provide a reduction efficiency for ~~PM~~ mass of NO<sub>x</sub> of at least 70% from the engine baseline emissions of the test engine as defined in paragraph 1.1.1 when measured using the test procedure(s) set out in Annex 10 and associated with the limit values to be achieved.
2. Following installation of the REC, the test engine and REC combination shall meet the next higher NOx emission stage with respect to the limits of Regulation No. 49 or No. 96 as appropriate, based on the engine baseline emissions, as measured using the test procedure(s) set out in Annex 10 and associated with the limit values to be achieved.
  - 2.1. For RECs intended for application to heavy-duty vehicles the NOx emissions limits to be met are:
    - 2.1.1. For baseline NOx emissions corresponding to Row A of Tables 1 and 2 of Regulation No.49 Revision 5, 3.5 g/kWh on the ESC and ETC cycle to achieve NOx emissions equivalent to Row B1 of Tables 1 and 2 of Regulation No.49 Revision 5.
    - 2.1.1. For baseline NOx emissions corresponding to Row A of Tables 1 and 2 of Regulation No.49 Revision 5, 2.0 g/kWh on the ESC and ETC cycle to achieve NOx emissions equivalent to Row B2 of Tables 1 and 2 of Regulation No.49 Revision 5.
    - 2.1.2. For baseline NOx emissions corresponding to Row B1 of Tables 1 and 2 of Regulation No.49 Revision 5, 2.0 g/kWh on the ESC ETC cycles to achieve NOx emissions equivalent to Row B2 of Tables 1 and 2 of Regulation No.49 Revision 5.
  - 2.2. For RECs intended for application to non-road mobile machinery and tractors the NOx emissions limits to be met are those shown in table 8.5 of this Regulation.

## Annex 9

**Test of a particulate reduction REC**

1. Testing of a particulate reduction REC is performed in a series of stages as follows:

- i) Establishment of the engine baseline emissions.
- ii) Determination of the reduction level.
- iii) Performance of an endurance run.
- iv) Determination of whether the REC regenerates periodically or continuously.
- v) Test of the regeneration characteristic (if appropriate).
- vi) Establishment of the regeneration adjustment factor (if appropriate).
- vii) Determination of the NO<sub>2</sub> emissions and of emissions of the other regulated pollutants.

In Annex 12 a flow chart outlines the test sequence for particulate reduction REC.

2. The engine baseline emissions are established by performance of an emissions test procedure on the engine system without the REC in accordance with the requirements of Regulation No.49 or Regulation No.96, as appropriate.

3. The reduction level is determined by performance of an emissions test procedure on the engine system in accordance with the requirements of Regulation No.49 or Regulation No.96, as appropriate, with the REC fitted in accordance with the requirements of this Regulation.

4. The endurance run shall be performed in accordance with the requirements of Section 12 of this Regulation.

5. The regeneration strategy and the regeneration characteristics are established by use of the following procedure. [The emissions of NO<sub>2</sub> and of the regulated pollutants are determined by measurements taken immediately after the tests to establish the regeneration characteristics.]

5.1. In order to assess the regeneration performance of a REC system at least 25 ETC or WHTC test cycles or 25 NRTC cycles, must be carried out. The test cycle used must be a cycle appropriate to the emissions stage or standard that the REC system is intended to permit the vehicle or machine to meet.

The gaseous emissions and the particulate mass, and the particulate number when appropriate, must be measured during at least each fifth test cycle. A separate test of the particulate reduction system is carried out for each family or application range defined in the type approval procedure for the engine with which the REC system is intended to be used. That is, one system test takes place for each application area.

In Annex 12 a flow chart outlines the test sequence for particulate reduction REC.

If the applicant can prove that a particulate reduction system that has been tested for vehicles of category M2 and N vehicles is designed for use in the same manner [and will work effectively] on C.I. engines for use in non-road

**Comment [JM34]:** Complete Annex to be further reviewed

**Comment [S35]:** Sequence ought to mirror that in the flowchart

**Comment [JM36]:** Is order correct? Should regen factor, for instance, be determined before reduction level? Is the reference in the flowchart supposed to be to the declared reduction level?

**Comment [S37]:** Is the reference in the flowchart supposed to be to the declared reduction level?

**Comment [JM38]:** Would the regeneration procedures (1 iv), v) and vi)) be best handled as an Appendix / Appendices to this Annex?

**Comment [LES39]:** 100 cycles deleted due to 1000hrs durability run.

**Comment [JM40]:** Is every 5<sup>th</sup> cycle enough? Couldn't a system regenerate and reload within that period?

mobile machinery, and the family of test engines used in accordance with the requirements of paragraph 5.1 is representative for such applications and meets the family criteria of paragraph 5.1, then the application range for which the system is approved may be extended to C.I. engines for use in non-road mobile machinery. Extending the range of a particulate reduction system that has been approved for use with C.I. engines in non-road mobile machinery to cover on-road applications in the way described in this paragraph is not permitted.

## 5.2.

A particulate reduction REC is considered to have been proved to have a continuously operating regeneration process if a suitable assessment variable can be regarded as constant over at least 25 applicable test cycles. The particulate emission and the exhaust gas backpressure are regarded as suitable assessment variables for this purpose. **[If an applicant wishes to use one or more different assessment variables, he must present a robust technical case to the approval authority in support of his request to do so.]**

The particulate emission and the exhaust gas backpressure are considered constant within the meaning of this regulation where there is a coefficient of variance of less than 15% over 25 test cycles. The exhaust gas backpressure is measured continuously for the purposes of this assessment and the particulate emissions are measured during at least every fifth test cycle.

The coefficient of variance (CoV) is calculated as follows.

$$\text{Variance} = \frac{\text{Standard deviation } X(n)}{\text{Average value } X(n)}$$

with:

$$\text{Standard deviation} = \sqrt{\frac{n \sum x^2 - (\sum x)^2}{n^2}}$$

and:

$$\text{Average value} = (x_1 + x_2 + \dots + x_n) / n$$

where:

n = number of measured values

x = respective single measured value

## 5.3.

If an REC manufacturer intends to apply for approval for an REC that can reduce emissions of **particulate mass one or more of the relevant pollutants** by two subsequent emission stages, then additional verification becomes necessary.

This additional verification required in this case is performed in accordance with the procedure set out in **paragraph number 13.2 and paragraph number 15.6.** on a test engine selected in accordance with the procedure set out in **paragraph 12** on the basis of the final emission level to be achieved by the retrofitted engine.

It will be considered sufficient to perform the additional testing on only one engine family member representative of the application range. For that reason it is permissible to transfer the emission category extension that has been gained by this additional testing to other engine families in the same application range.

The REC used in the additional verification procedure required in order to extend the approval to a further (subsequent) emission category must be from the application range of the basic REC for which the approval was issued. [It must not be a REC which has been approved by extension of the original approval.] If the REC is not from the application range of the basic REC for which the approval was issued and the system is not identical, then a full test for a new type in accordance with this regulation is necessary.

If the scope of application is widened, then the applicant must additionally certify in the letter of application for approval that the REC is also designed and suitable for higher raw emission burdens when used on lower emission level engines.

5.4. Test of the regeneration characteristic of a particulate reduction REC for Reduction level 1

Particulate systems achieving Reduction level 1 are subjected to further testing in order to verify their regeneration characteristic.

This further testing is carried out by loading the system [with particulate matter] until a constant exhaust gas backpressure is reached or over a time period of a maximum of 100 hours [if no constant value for the backpressure has been achieved before that time]. The exhaust gas backpressure is considered constant if, when measured after a period of at least 50 hours, the exhaust gas backpressure does not vary by more than plus or minus 4 mbar within a period of 30 min. The test points of the cycle used for loading the system are to be selected so that a maximum exhaust gas temperature of 180 C at the inlet of the particulate reduction system is not exceeded. The loading of the system with particulate matter is preferably carried out by running the test engine at a constant speed of between 50% and 75% of its rated speed.

After the REC has been loaded with particulate matter until the backpressure is constant, or after a maximum of 100 hours of running to load the system as defined above, regeneration is activated. This can, for example, be activated by running the engine at a higher load mode step so as to increase the exhaust temperature. After completion of the regeneration, exhaust gas measurements are to be taken during at least three appropriate test cycles (That is, three ESC cycles, ETC cycles, WHSC cycles, WHTC cycles, NRSC cycles, or NRTC cycles.) The measured exhaust gas pollutant values shall not deviate from the measured exhaust gas pollutant values before the REC loading procedure by more than 15% for the gaseous emissions or more than 20% for the particulate mass or particulate number emissions.

The manufacturer shall confirm in writing that the maximum temperatures occurring during the regeneration process will not damage or significantly shorten the effective life of the REC.

As an alternative to using the loading procedure described above, the manufacturer may provide a particulate reduction REC already loaded to the limit for the regeneration test.

5.5. Assessment criteria for continuously regenerating particulate reduction systems

The REC system test of the particulate reduction REC is considered satisfactory if the reduction level criteria defined in paragraph number 3 are met.

## 5.5.1. Regulated pollutants

The emissions of the regulated pollutants (CO, HC, PM and NO<sub>x</sub>) in the initial condition and in the retrofitted condition shall be within the limit values for the emissions stage or standard for which the engine was originally type-approved. The NO<sub>2</sub> to NO<sub>x</sub> ratio for the initial condition and the retrofitted condition is to be recorded and shown in the test report.

The determination of the NO<sub>2</sub> and NO<sub>x</sub> mass emissions is to be determined by simultaneous measurement in accordance with [section 1.7](#)

## 5.6. Assessment criteria for periodically regenerating particulate reduction systems

This provision only applies to REC which are regenerated on a periodic basis.

The emissions shall be measured during at least three appropriate hot-start test cycles (That is, three hot-start ESC cycles, ETC cycles, WHSC cycles, WHTC cycles, NRSC cycles, or NRTC cycles.) One of the cycles from which measurements are taken should include a regeneration event on a stabilized REC system. The other two cycles from which measurements are taken should be cycles in which regeneration does not occur. If regeneration takes longer than one test cycle, consecutive test cycles shall be run until regeneration is complete.

The REC manufacturer shall declare the conditions under which the regeneration process normally occurs (the particulate loading, temperature, exhaust back-pressure, or other relevant parameters.). The manufacturer shall also provide the frequency of the regeneration event in terms of the fraction of tests during which the regeneration occurs. The exact procedure used to determine this fraction shall be agreed [with the manufacturer] by the type approval authority on the basis of good engineering judgement. (This frequency fraction is the factor *F* in the procedure for calculation of [nominal] particulate emissions set out below.)

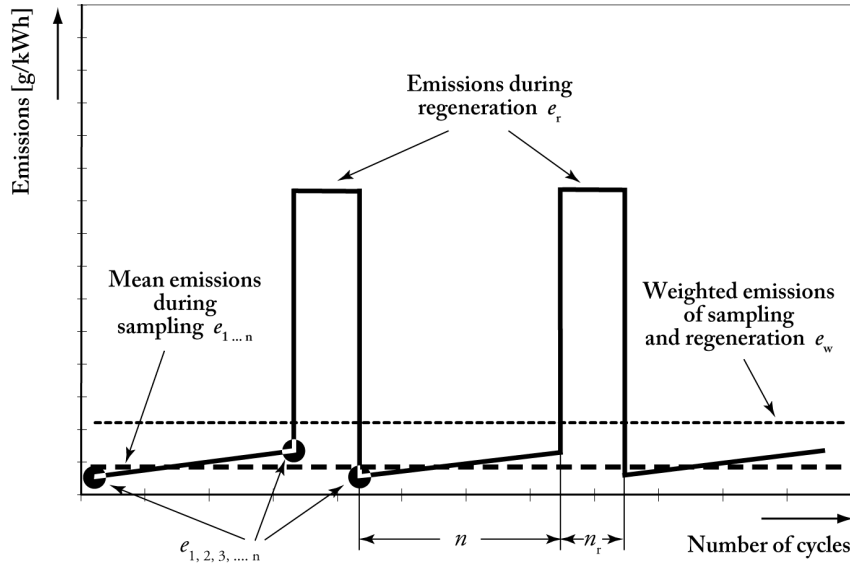
For a regeneration test, the manufacturer shall provide a particulate reduction REC system that has been loaded with particulate matter. As an option, the manufacturer may run consecutive test cycles [as set out in paragraph 10.4] until the particulate reduction REC is loaded. Emissions measurement is not required on cycles run for the purposes of loading the REC with particulate matter.

Average emissions between regeneration phases shall be determined from the arithmetic mean of several tests approximately equidistant in terms of the number of unmeasured test cycles between them. As a minimum, at least one test cycle as close as possible prior to a regeneration test and one test cycle immediately after a regeneration test shall be included in the calculation of the arithmetic mean.

During the regeneration test, all the data needed to detect regeneration shall be recorded (CO or NO<sub>x</sub> emissions, temperature before and after the REC, exhaust back pressure, and any other relevant parameters). It is permissible for the applicable emission limits to be exceeded during the regeneration process. The test procedure is shown schematically in [figure 1.1](#).

Figure 1.1:

**Scheme of periodic regeneration**



The system test of a periodically regenerating particulate reduction REC is considered passed if the [nominal] particulate emissions calculated using the procedure set out below are within the limit set for the reduction level for which the applicant wishes the REC to be approved.

The particulate emissions PM mass (g/kWh) for periodically regenerating systems are determined as follows.

$$PM\ mass = PM\ mass_r \times F + (1-F) \times PT_{wor}$$

Where:

$F =$  frequency of the regeneration event in terms of fraction of tests during which the regeneration occurs [-]

$PM\ mass_{wor} =$  average specific emission from a test in which the regeneration does not occur [g/kWh]

$PM\ mass_r =$  average specific emission from a test in which the regeneration occurs [g/kWh]

The manufacturer may choose, on the basis of good engineering analysis, to calculate either a multiplicative or an additive regeneration adjustment factor  $k_r$ , expressing the average emission rate, as follows:

$$k_r = PM\ mass / PM\ mass_{wor} \quad (\text{multiplicative adjustment factor})$$

or

$$k_{Ur} = PM\ mass - PM\ mass_{wor} \quad (\text{upward adjustment factor})$$

or

$$k_{Dr} = PM\ mass - PM\ mass_r \quad (\text{downward adjustment factor})$$

If more than two measurements between the regeneration phases are used to determine the emissions, these further measurements must be taken at equal intervals and an arithmetical average taken.

5.6.1. Regulated pollutants

The emissions of regulated pollutants (CO, HC, PM and NO<sub>x</sub>) shall be within the limit values for the standard to which the engine was originally type approved, both in the initial condition and in the retrofitted condition. The NO<sub>2</sub>/NO<sub>x</sub> ratio for both the initial condition and the retrofitted condition are to be recorded and shown in the test report.

The determination of the NO<sub>2</sub> - and NO<sub>x</sub>- mass emissions is to be determined by simultaneous measurement in accordance with section 13.7.

5.6.2. Weighted gaseous emissions

The emission of gaseous components M<sub>gas</sub> (g/kWh) for periodically regenerating systems is determined as follows.

$$M_{gas} = M_{gas_r} \times F + (1-F) \times M_{gas_{wor}}$$

where:

F = frequency of the regeneration event in terms of the fraction of tests during which the regeneration occurs [-]

M<sub>gas<sub>wor</sub></sub> = average specific emission from a test in which the regeneration does not occur [g/kWh]

M<sub>gas<sub>r</sub></sub> = average specific emission from a test in which the regeneration occurs [g/kWh]

The manufacturer may choose, on the basis of good engineering analysis, to calculate either a multiplicative or an additive the regeneration adjustment factor k<sub>r</sub>, expressing the average emission rate, as follows:

$$k_r = M_{gas} / M_{gas_{wor}} \quad (\text{multiplicative adjustment factor})$$

or

$$k_{Ur} = M_{gas} - M_{gas_{wor}} \quad (\text{upward adjustment factor})$$

or

$$k_{Dr} = M_{gas} - M_{gas_r} \quad (\text{downward adjustment factor})$$

5.7. Determination of NO<sub>2</sub> emissions

The testing shall be performed on the test engine selected by the criteria described in paragraph 10.

[The test engine shall, in addition to the requirements of paragraph 10, comply with the engine baseline emission ranges given in table 11.1 [to be adjusted for other engines than Euro III]]

Table 1.1

Engine baseline emissions for NO<sub>2</sub> determination

Euro stage		HC in g/kWh	NO <sub>2</sub> in g/kWh
EURO III (Cylinder capacity: up to 800 cm <sup>3</sup> )	ESC	0.20-0.40	0.40-0.50
	ETC	0.10-0.25	0.70-0.80
EURO III	ESC	0.05-0.20	0.15-0.20



(Cylinder capacity: over 800 cm <sup>3</sup> )	ETC	0.10-0.25	0.20-0.30
EURO III (Engines with EGR systems)	ESC		
	ETC		

#### 5.7.1. Selection of the particulate reduction REC for NO<sub>2</sub> determination

The system to be tested shall be

- the particulate reduction REC with the largest active volume and, if a diesel oxidation catalyst (DOC) is used upstream, the catalytic converter with the largest active surface area and

- the particulate reduction REC containing the maximum total charge of catalytically active materials and maximum platinum charge of the particulate reduction REC within the defined REC family.

The chosen particulate reduction REC shall be fitted in such a way that the shortest distance between the engine and the particulate reduction REC, as specified in the application range for the particulate reduction REC, is achieved,

The REC shall be unloaded and shall not have been run in for longer than 50 hours.

For particulate reduction REC with zone coatings following [additional] provisions must be considered:

[The properties of the coated zone of the particulate reduction REC which has the maximum loading of precious metals shall not deviate from those of the other particulate reduction REC within the REC family].

#### 15.8.2 Preparation for testing and NO<sub>2</sub> determination

In addition to the testing methods to be used in accordance with section [---] following provisions shall be considered:

~~The use of a gas dehydrator and the application of chemical desiccants to remove water from the sample prior to the measurement of NO<sub>2</sub> are not permitted.~~

~~If a CLD is used, a heated chemiluminescence detector with an NO<sub>2</sub>/NO converter shall be used. Two parallel measuring chambers to determine NO<sub>x</sub> and NO continuously at the same time are mandatory. The use of two individual CLD which are operated in parallel is not permitted.~~

#### 15.8.3 Conditioning of the test engine and the particulate reduction REC

~~The engine / engine system and particulate reduction REC combination is conditioned for at least 60 minutes at the maximum engine net power (P<sub>max</sub>). The maximum power (P<sub>max</sub>) is the maximum engine net power as declared by the manufacturer.~~

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~~Once the engine has been stabilised, the first test cycle must be started within 20 seconds after the completion of the preconditioning phase.~~

**Comment [LES41]:** This is already covered by the test procedures of R. 49 and R. 96.

#### 15.8.4 Test cycle

~~[A distinction is made between particulate reduction REC that are approved for vehicles according to Regulation 49 and particulate reduction REC that are intended for use in non-road mobile machinery according to Regulation 96. The test cycle for commercial vehicles is [the urban part of] the ETC cycle. The NRTC cycle is used to test systems intended for non-road mobile machinery. Where a REC is approved for use in both, non-road mobile machinery and commercial vehicles, both cycles must be performed and both results shall be reported].~~

#### 15.7.2. Determination of emissions

Three successive test cycles shall be conducted. The emissions shall be determined over all three cycles and averaged. The standard deviation shall not exceed 15%.

The calculation of the NO<sub>x</sub> and NO<sub>2</sub> emissions shall be determined for the urban part of the ETC for C.I. engines used in vehicles of category M<sup>2</sup> and N<sup>2</sup>.

For C.I. engines used in non-road mobile machinery 1/ having an installed net power higher than 18 kW, but not more than 560 kW ~~the calculation~~ the calculation of the NO<sub>x</sub> and NO<sub>2</sub> emissions shall be determined over the complete NRTC cycle.

#### 6. Test Cycles.

6.1. In cases where the approval of the engine with which the REC is to be used is an on-road approval (performed in accordance with Regulation No.49) the test cycle to be used for approval of the REC must be the test cycle associated with the emissions stage in Regulation No.49 for which approval of the REC is being sought.

6.2. Where the engine is being used in an on-road application and has an approval issued in accordance with the requirements of Regulation No.49, the test cycle to be used for the establishment of the base emissions of the engine must be the test cycle associated with the emissions stage in Regulation No.49 for which the engine has an approval.

6.3. Where the engine is being used in an on-road application but does not have an approval issued in accordance with the requirements of Regulation No.49, the test cycle to be used for the establishment of the base emissions of the engine must meet one of the following requirements:

a) It is the test cycle associated with the emissions stage in Regulation No.49 for which approval of the REC is being sought, or with a later emissions stage;

b) It is the WHSC or the WHDC.

6.4. Notwithstanding the requirements of paragraphs 18.2.1 to 18.2.3, above, where the REC is to be used in an on-road application, such as in a vehicle fitted with a series hybrid transmission, where the engine will be operated as a constant speed engine within the definition of such an engine set out in

UNECE Regulation No.96, the test cycle to be used for approval must meet one of the following requirements:

a) It is the test cycle associated with the emissions stage in Regulation No.49 for which approval is being sought;

b) It is the WHSC;

c) It is the WHDC;

d) It is the appropriate test cycle for a non-road constant-speed engine of the power category into which the base engine would fall under the terms of UNECE Regulation No.96.

6.5. In cases where the approval of the engine with which the REC is to be used is a non-road approval (performed in accordance with Regulation No.96) the test cycle to be used for approval of the REC must be the test cycle associated with the emissions stage in Regulation No.96 for which approval of the REC is being sought.

6.6. Where the engine is being used in a non-road application and has an approval issued in accordance with the requirements of Regulation No.96, the test cycle to be used for the establishment of the base emissions of the engine must be the test cycle associated with the emissions stage in Regulation No.96 for which the engine has an approval.

6.7. Where the engine is being used in a non-road application but does not have an approval issued in accordance with the requirements of Regulation No.96, the test cycle to be used for the establishment of the base emissions of the engine must be the test cycle associated with the emissions stage in Regulation No.96 for which approval of the REC is being sought, or with a later emissions stage.

6.8. For the purposes of establishing the emissions of NO<sub>2</sub> during tests of a Type I or Type II REC, the specific test cycle defined in paragraph 1.7.2 of this Annex shall be used.

**Comment [S42]:** we are probably moving towards permitting engines for series hybrid applications to be tested on a non-road cycle (but to the on-road emissions limits) on the grounds that this is a more realistic test of the way that they will actually be used. We have had one company approach us with an engine for an application like this which had a controller that did not permit it to be run on the standard heavy-duty test cycle.

**Annex 10****Test of a NO<sub>x</sub> reduction REC**

1. Testing of a particulate reduction REC is performed in a series of stages as follows:

- i) Establishment of the engine baseline emissions.
- ii) Determination of the reduction level.
- iii) Performance of an endurance run.
- iv) Determination of the NO<sub>2</sub> emissions and of emissions of the other regulated pollutants.

In Annex [TBA] a flow chart outlines the test sequence for NO<sub>x</sub> reduction REC.

2. The engine baseline emissions are established by performance of an emissions test procedure on the engine system without the REC in accordance with the requirements of Regulation No.49 or Regulation No.96, as appropriate.

3. An endurance run is performed in accordance with the requirements of Section 12 of this Regulation.

The gaseous emissions and the particulate mass, and the particle number count when appropriate, must be measured during at least each fifth test cycle during the endurance run.

4. The reduction level is determined by performance of an emissions test procedure on the engine system in accordance with the requirements of Annex 7 or Annex 8 of this Regulation, as appropriate.

1.1. In order to assess a NO<sub>x</sub> reduction system, an endurance run of at least [100] ETC or WHTC test cycles, or [50] NRTC cycles, must be carried out. [The test cycle used must be a cycle appropriate to the emissions stage or standard that the reduction system is intended to permit the vehicle or machine to meet.] The endurance run is used to verify the functional capability and stability of the system and also its reduction efficiency. The gaseous emissions and the particulate mass, and the particle number count when appropriate, must be measured during at least each fifth test cycle. 5. A separate test of the NO<sub>x</sub> reduction system is carried out for each family or application range defined in the type-approval procedure for the engine with which the REC is intended to be used. That is, one system test takes place for each application area.

6. If the applicant can prove that a NO<sub>x</sub> reduction system that has been tested for vehicles of Category M < 3.5 t or Category N, is designed for use in the same manner [and will work effectively] on C.I. engines for use in non-road mobile machinery, and the family of test engines used in accordance with the requirements of paragraph [5A] is representative for such applications and meets the compliance criteria of [paragraph 11], then the application range for which the system is approved may be extended to C.I. engines for use in non-road mobile machinery.

Extending the range of a NO<sub>x</sub> reduction system that has been approved for use with C.I. engines in non-road mobile machinery to cover on-road applications in the way described in this paragraph is not permitted.

**Comment [JM43]:** Complete Annex to be further reviewed

**Comment [S44]:** Does this need to be kept? Is it possible that a NO<sub>x</sub> control device could increase the emissions of PM?

**Comment [S45]:** This is potentially at odds with the requirement that separate tests for NO<sub>2</sub> must be done on on-road and non-road cycles in order to qualify a REC for use in both sectors.

## 7. Regulated pollutants

In the case of an engine type-approved in accordance with the requirements of Regulation No. 49 or Regulation No. 96, the emissions of each of the regulated pollutants (CO, HC, NO<sub>x</sub>, and PM) in the initial condition and in the retrofitted condition shall be within the limit values for the emissions stage or standard for which the engine was originally type-approved. The NO<sub>2</sub> to NO<sub>x</sub> ratio for the initial condition and the retrofitted condition is to be recorded and shown in the test report.

In the case of an engine not type-approved in accordance with the requirements of either Regulation No. 49 or Regulation No. 96, the emissions of each of the regulated pollutants (CO, HC, NO<sub>x</sub>, and PM) in the initial condition and in the retrofitted condition shall be either:

- a) within the limit values for the emissions stage or standard immediately below that for which certification of the REC is sought, or
- b) where certification of the REC is being sought for the lowest emissions stage or standard, within the limit values for that emissions stage or standard.

The determination of the NO<sub>2</sub> and NO<sub>x</sub> mass emissions is to be determined by simultaneous measurement in accordance with [5]. UBA NO<sub>2</sub> measurement procedure to be added. 8. Determination of emissions of the regulated pollutants and of NO<sub>2</sub>.

In order to determine the emissions of the regulated pollutants and NO<sub>2</sub>, three successive test cycles as defined in this paragraph shall be conducted. The emissions shall be determined over all three cycles and averaged. The standard deviation shall not exceed 15%.

In the case of a REC intended for an on-road application, calculation of the regulated pollutants and NO<sub>2</sub> emissions shall be determined for the urban part of the ETC or for one of the additional test cycles identified in paragraph 18.3 of this Regulation.

For C.I. engines used in non-road mobile machinery having an installed net power higher than 18 kW, but not more than 560 kW the calculation of the regulated pollutant and NO<sub>2</sub> emissions shall be determined over the complete NRTC cycle.

## 9. Test cycles.

9.1. In cases where the approval of the engine with which the REC is to be used is an on-road approval (performed in accordance with Regulation No.49) the test cycles to be used for approval of the REC must be the test cycle associated with the emissions stage in Regulation No.49 for which approval of the REC is being sought. The REC must, in addition, be shown to achieve the reduction level and the emission limit value associated with the emissions stage in Regulation No.49 for which approval of the REC is being sought when it is tested on either:

- a) the WHSC or
- b) the WHDC or
- c) a test cycle consisting of [5] urban elements of the ETC.

9.2. Where the engine is being used in an on-road application and has an approval issued in accordance with the requirements of Regulation No.49, the test cycle to be used for the establishment of the base emissions of the engine

**Comment [LES46]:** Covered by R. 49 and R.96

**Comment [S47]:** The test cycles used for the original type-approval has been deliberately excluded, here. It would seem odd to permit a NO<sub>2</sub> reduction REC, which might well be using SCR, to be tested on a cycle that we now know does not adequately test SCR devices in the urban areas where we care most about them working.

must be the test cycle associated with the emissions stage in Regulation No.49 for which the engine has an approval.

9.3. Where the engine is being used in an on-road application but does not have an approval issued in accordance with the requirements of Regulation No.49, the test cycle to be used for the establishment of the base emissions of the engine must meet one of the following requirements:

a) It is the test cycle associated with the emissions stage in Regulation No.49 for which approval of the REC is being sought, or with a later emissions stage;

b) It is the WHSC

c) It is the WHDC;

d) It is a test cycle consisting of [5] urban elements of the ETC;

Comment [S48]: Same as S47

9.4. Notwithstanding the requirements of paragraphs 18.3.1 to 18.3.3, above, where the REC is to be used in an on-road application, such as in a vehicle fitted with a series hybrid transmission, where the engine will be operated as a constant speed engine within the definition of such an engine set out in UNECE Regulation No.96, the test cycle to be used for approval must meet one of the following requirements:

a) It is the WHSC

b) It is the WHDC;

c) It is a test cycle consisting of [5] urban elements of the ETC ;

d) It is the appropriate test cycle for a non-road constant-speed engine of the power category into which the base engine would fall under the terms of UNECE Regulation No.96.

Comment [S49]: Same as S47

Comment [S50]: Same as S42

Comment [S51]: This is potentially controversial!

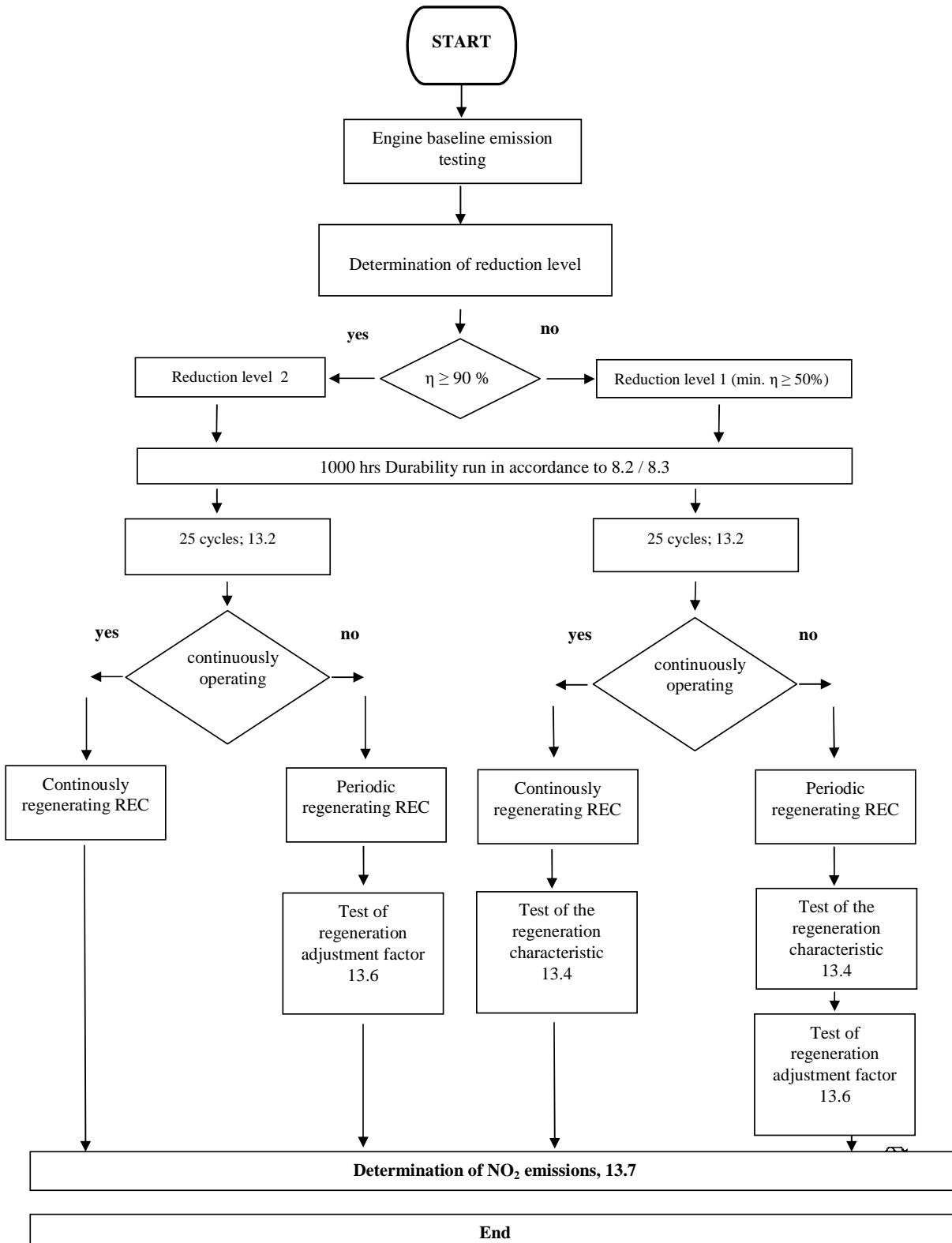
9.5. In cases where the approval of the engine with which the REC is to be used is a non-road approval (performed in accordance with Regulation No.96) the test cycle to be used for approval of the REC must be the test cycle associated with the emissions stage in Regulation No.96 for which approval of the REC is being sought.

9.6. Where the engine is being used in a non-road application and has an approval issued in accordance with the requirements of Regulation No.96, the test cycle to be used for the establishment of the base emissions of the engine must be the test cycle associated with the emissions stage in Regulation No.96 for which the engine has an approval.

9.7. Where the engine is being used in a non-road application but does not have an approval issued in accordance with the requirements of Regulation No.96, the test cycle to be used for the establishment of the base emissions of the engine must be the test cycle associated with the emissions stage in Regulation No.96 for which approval of the REC is being sought, or with a later emissions stage;

**Annex 11****Tests of a PM and NO<sub>x</sub> reduction REC**

1. Tests of a PM and NO<sub>x</sub> reduction REC shall meet the requirements for testing for each of the pollutants set out in section 4.5 and section 4.5A above.
2. Regulated pollutants
  - In the case of an engine type-approved in accordance with the requirements of Regulation No. 49 or Regulation No. 96, the emissions of each of the regulated pollutants (CO, HC, NO<sub>x</sub>, and PM) in the initial condition and in the retrofitted condition shall be within the limit values for the emissions stage or standard for which the engine was originally type-approved. The NO<sub>2</sub> to NO<sub>x</sub> ratio for the initial condition and the retrofitted condition is to be recorded and shown in the test report.
  - In the case of an engine not type-approved in accordance with the requirements of either Regulation No. 49 or Regulation No. 96, the emissions of each of the regulated pollutants (CO, HC, NO<sub>x</sub>, and PM) in the initial condition and in the retrofitted condition shall be either:
    - a) within the limit values for the emissions stage or standard immediately below that for which certification of the REC is sought, or
    - b) where certification of the REC is being sought for the lowest emissions stage or standard, within the limit values for that emissions stage or standard.
3. Test cycles.
  - 3.1. Tests of PM and NO<sub>x</sub> reduction REC must be undertaken using test cycles that meet all of the requirements of Annex 9 and Annex 10 of this Regulation.





## Annex 13

## Measurement of secondary emissions

Comment [JM53]: To be further reviewed

Text below is from SNR 277205 ~~new version available?~~ text needs to be adapted to this draft and it needs to make clear that secondary emission testing is not directly linked to each type approval measure. Standards recommended only [?]

## 1. Introduction

Depending on the method of exhaust gas treatment and the properties of the catalytically active substances, a variety of reaction products may be formed. The most important of these are toxic substances with carcinogenic, mutagenic, teratogenic or hormone-like effects. For example, it is known that platinum-based catalytic converters increase NO<sub>2</sub>-emissions, while those containing copper produce substantial amounts of polychlorinated dibenzodioxins and -furans (PCDD/F) if chlorine is present. On the other hand, particle filter systems often significantly reduce emissions of polycyclic aromatic hydrocarbons (PAH), including the carcinogenic ones. The data cited in section [5.5 of SNR 277205] and in this [Appendix] are binding for catalytic particle filter systems. Because it is not possible to list all potential secondary emissions, the catalogue of substances to be measured should be adjusted whenever reasons for a potential formation of further secondary pollutants exist.

## 2. Secondary emissions

2.1 Nitrogen dioxide (NO<sub>2</sub>)

~~Nitrogen dioxide (NO<sub>2</sub>), a toxic secondary pollutant formed in the presence of strongly oxidizing catalytic converters (e.g. platinum), has to be measured in addition to nitrogen monoxide (NO). Here the dry exhaust gas (permeation dryer) is analyzed with a chemiluminescence detector (CLD); deleted, see PNM REC annex see 1.5.3~~

## 2.2. Volatile organic compounds (VOC)

Benzene and 1,3-butadiene, both carcinogenic substances, have to be analyzed as toxicologically relevant leading compounds for more than 100 known gaseous hydrocarbons. A proportion of the exhaust is collected in gas-tight bags. The content of each hydrocarbon is determined with a gas chromatography system coupled with flame ionization detector (GC-FID).

## 2.3 Oxidized volatile organic compounds (VOCOX)

Formaldehyde and acetaldehyde, both highly reactive and carcinogenic gases, have to be measured as toxicologically relevant leading compounds in the class of partially oxidized volatile hydrocarbons. A proportion of the exhaust is fed through a dinitrophenylhydrazine solution during the sampling process (chemisorption). The reactive aldehydes are converted to the corresponding hydrazones and thus stabilised. The derivatives are separated by means of liquid chromatography and the contents are measured with a UV/VIS photometer (LC-UV/VIS).

## 2.4 Polycyclic aromatic hydrocarbons (PAH)

As leading compounds for the PAH class of substances, at least the following carcinogenic substances have to be analysed: chrysene, benz(a)anthracene,

benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene. In addition, the contents of pyrene and fluoranthene, which are precursor compounds for mutagenic nitro-PAH, also has to be measured. PAH can appear both in particulate and gaseous form. A proportion of the exhaust is filtered into a multi-stage glass apparatus (dioxin train), cooled below dew point and fed through an adsorption material. The integral sample, which includes PAH present in the gas-, liquid and solid-phase, is purified and fractionated by means of liquid chromatography. Separation is carried out with a gas chromatograph (GC), and quantification is achieved by means of high resolution mass spectrometry (GC-HRMS).

2.5 Nitrated polycyclic aromatic hydrocarbons (nitro-PAH)

There are numerous nitration products found in NO<sub>x</sub>-rich diesel exhaust. As leading compounds for the nitro-PAH class of compounds, at least the mutagenic substances 3-nitrofluoranthene and 1-nitropyrene have to be measured. In order to evaluate the nitration potential of the filter system, the following substances which are more common and thus more readily accessible for analysis are measured as representatives of other mutagenic and carcinogenic nitro-PAH: 1-nitronaphthalene, 2-nitronaphthalene, 3-nitrophenanthrene, 9-nitrophenanthrene, and 9-nitroanthracene. Other mutagenic and carcinogenic nitro- and di-nitro-PAH are also of interest, but their contents are generally lower. Nitro-PAH are also sampled in the glass apparatus described above. Separation of individual isomers and quantification are carried out by means of GC-HRMS.

2.6 Polychlorinated dibenzodioxins / furanes (PCDD/F)

As leading compounds for the 210 PCDD/Fs, at least the 17 toxic 2,3,7,8-chlorinated PCDD/Fs and the resulting overall toxicity (TEQ or toxicity equivalent) have to be determined. The overall toxicity is deduced from the concentrations of the 17 toxic isomers and their relative toxicity (toxicity equivalence factor). PCDD/Fs are also retained in the glass apparatus described above. The integral sample is purified by means of liquid chromatography. Separation and quantification of individual isomers is achieved with gas chromatography, combined with high-resolution mass spectrometry (GC-HRMS).

2.7 Catalytically active elements (coating metals and additives)

The catalytically active elements of fuel additives and filter coatings have to be measured in accordance with the manufacturer's specifications. The particles or particle-bound compounds are fractionated into 13 size classes from proportionally diluted exhaust using a 12-stage electric low-pressure impactor and a backup filter. The metal content of each size class is quantified using microwave digestion followed by inductively coupled plasma mass spectrometry (ICP-MS).

Component	Sampling	Analytical method	Standard / Reference
NO <sub>2</sub>	Heated sampling line and permeation dryer from undiluted exhaust gas	Chemiluminescence detector (CLD)	EN 14792 ISO 16000 DIN EN ISO 16017 [UBA Procedure]
VOC	From exhaust gas diluted to a constant volume flow (Constant Volume Sampling Tunnel, CVS tunnel) [Partial Flow]	Gas chromatography flame ionization detector (GC-FID)	ISO 16000 DIN EN ISO 16017
VOCOX	From exhaust diluted to a constant volume flow (CVS tunnel), chemisorptions in dinitrophenylhydrazine solution	Liquid chromatography ultraviolet detector (LCUV/ VIS)	ISO 16000 DIN EN ISO 16017
PAH	Flow proportional sampling from undiluted exhaust, multiple stage glass apparatus based on the filter/condenser method (UNE-EN 1948-1)	Gas chromatography high-resolution mass spectrometry (GCHRMS) or liquid chromatography ultraviolet/fluorescence detector (LCUV/ fluorescence)	VDI 3874
Nitro-PAH	Flow proportional sampling from undiluted exhaust, multiple level glass apparatus based on filter / condenser method (UNE-EN 1948-1)	Gas chromatography high-resolution mass spectrometry (GCHRMS)	VDI 3874
PCDD/F	Flow proportional sampling from undiluted exhaust gas, multiple stage glass apparatus based on filter/condenser method (UNE-EN 1948-1)	Gas chromatography high-resolution mass spectrometry (GCHRMS)	UNE-EN 1948
Catalytically active elements (metals)	Flow proportional sampling from undiluted exhaust, size-fractionated sampling with 12-stage electric low pressure impactor (ELPI) plus backup filter	Microwave digestion, inductively-coupled plasma mass spectrometry (ICP-MS)	DIN EN 13890 DIN 51002-1

NH<sub>3</sub> to be introduced.

CRITERIA to be introduced?