



Economic Commission for Europe

Inland Transport Committee

World Forum for Harmonization of Vehicle Regulations

Working Party on Pollution and Energy

[-----] session

Geneva, [Day / Month / Year]

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 and forestry tractors and non-road mobile machinery (NRMM) equipped with Compression Ignition engines.

Comment [DB1]: Check with text in R.E.3

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 2.1 dated 31.10.2011

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].

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I. Proposal

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

Comment [DB2]: See p.1

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1. Purpose

This regulation provides a harmonized method for the classification, evaluation and approval of retrofit emission control systems (REC) for oxides of nitrogen (NO_x), particulate matter (PM mass and PM number) or for both NO_x and PM, and for the determination of the levels of emissions from compression-ignition (C.I.) engines used in applications 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.

Comment [DB3]: Needed?

2. Scope

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

- 2.1 on category M₂, M₃ and N vehicles¹ and their C.I. engines,
- 2.2 on C.I. engines having a net power higher than 18 kW but not more than 560 kW installed used in non-road mobile machinery¹ ~~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 having a net power higher than 18 kW but not more than 560 kW installed used in non-road mobile machinery¹ ~~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 having a net power higher than 18 kW but not more than 560 kW installed used in category T-vehicles¹ ~~having an installed net power higher than 18 kW but not more than 560 kW~~;

Comment [DB4]: List in alphabetical order

3. Definitions

For the purpose of this Regulation:

- 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_x-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;

¹ 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).

- 3.4. “*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 as defined in this Regulation. The regeneration system and strategy are part of the particulate reduction REC;
- 3.5. “*NOx-reduction REC*” means a REC that has a NOx mass emission reduction efficiency which qualifies it to be certified as meeting one of the classification type as defined in this Regulation;
- 3.6. “*Type I* 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 NO₂ emissions;
- 3.7. “*Type II* 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 NO₂ emissions by more than the percentage specified in paragraph 3.7 based on the engine baseline emission NO₂ level;
- 3.8. “*Engine baseline emission*” means the 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 raw emissions. For engines with after-treatment the engine baseline emissions are equal to the tailpipe emissions downstream of the after-treatment system;
- 3.9. “*Type III* retrofit emission control device (REC)” means a retrofit emission control device which is intended to control NOx emissions only;
- 3.10. “*Type IV* retrofit emission control device (REC)” means a retrofit emission control device which is intended to control both particulate matter emissions and NOx emissions, and thus NO₂ 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;
- 3.12. “*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_x) (for example, passive and active lean NO_x catalysts, NO_x adsorbers, and selective catalytic reduction (SCR) systems);
- 3.14. “*Emission control monitoring system*” means the system that monitors the operation of the emission control measures implemented in the engine and/or REC system in accordance with the requirements of paragraph 3.14;
- 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 emissions and the emissions downstream of the REC system, both measured in accordance with the procedures defined in this Regulation;

Comment [JM5]: Correct referencing to be discussed with GRPE secretariat.

Comment [DB6]: Needs correcting

- 3.18. "*Gaseous pollutants*" means carbon monoxide, hydrocarbons (assuming a ratio of CH_{1.85} for diesel), oxides of nitrogen (NO_x expressed as NO₂ equivalent) ~~and including~~ nitrogen dioxide (NO₂);
- 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;
- 3.20. "*NRSC cycle*" means a test cycle consisting of steady state modes which is defined in the relevant series of amendments to Regulation No.96;
- 3.21. "*NRTC cycle*" means a test cycle consisting of 1173 second-by-second transient modes defined in the relevant series of amendments to Regulation No.96;
- 3.22. "*Particulate matter (PM)*" 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;
- 3.23. "*PM number*" means the number of particles which is defined in the relevant series of amendments to Regulation No.49;
- 3.24. "*Particulate reduction REC family*" means a family of particulate reduction systems that are technically identical with respect to their functioning in accordance with paragraph number [---];
- 3.25. "NO_x reduction REC family" means a family of NO_x reduction systems that are technically identical with respect to their functioning in accordance with 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;
- 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;
- 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 [JM7]: (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.

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 approval².
- 5.4.2. The number of this Regulation, followed by the letter "R", a dash and the

Comment [JM8]: (based on R.115 and 582/2011/EU)

^{2/}

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 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.

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.

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.

Comment [JM9]: (based on R.115)

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. [Specific durability requirements are in paragraph 12.]
- 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 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.

Comment [DB10]: Check wording.

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 [LES11]: Aligned with wording of other ECE Regs.

8. 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

Comment [DB12]: Swap the order: LVs with tables 8.3 first and then reduction efficiencies per technology family

Table 8.1:

Reduction levels

	Reduction efficiency (%)	
	NO _x	PM mass
Reduction Level 1	[50] – [as specified in Annex 7 IV]	50 – [as specified in Annex 5 I]
Reduction Level 2	[70] – [as specified in Annex 8 IV]	90 – [as specified in Annex 6 II]

Comment [JM13]: Reduction levels to be specified in the Annexes

8.2. Reduction levels

8.2.1. The reduction 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 1-5 to IV-8 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 1-1.

8.2.2. For the purpose of this regulation the reduction efficiency for NO_x shall be applicable to systems which are intended to reduce NO_x, and the PM reduction level to systems intended to reduce PM. For Type IV REC any combination of the reduction levels for these two pollutants shown in Annexes 5I to 8IV of this Regulation is permitted.

8.2.3. A Type I, Type II, Type III or Type IV REC may be approved to any reduction level as indicated in Table 8.2.

Table 8.2:

REC Types and Reduction levels

	Reduction level	
	NO _x	PM mass
Type I	-	1 or 2
Type II	-	1 or 2
Type III	1 or 2	-
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 requirements for each type 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 ¹⁾ / 0,03 ²⁾ g/kWh	-		0,02 ¹⁾ / 0,03 ²⁾ 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 [JM14]: Baseline A, Type IV: EEV (Row C)_ requirement for PM is 0.02g/kWh on both cycles.

¹⁾ for the ESC cycle

²⁾ for the ETC cycle

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

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Table 8.4:
REC Matrix for Regulation No. 96 / REC 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 ⁽¹⁾	-	-	0,025 ⁽¹⁾
D	$18 \leq P \leq 37$	PM	-	-	-	0,6 ⁽²⁾	-	-	-	-	-	-
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 ⁽¹⁾	-	-	0,025 ⁽¹⁾
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 n.

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Table 8.5:

REC Matrix for Regulation No. 96 / REC 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 _x	4,0 ⁽³⁾	-	-	-	-	2,0	-	-	-	0,4	-
F	$75 \leq P \leq 130$	NO _x	-	4,0 ⁽³⁾	-	-	-	-	3,3	-	-	-	0,4 ⁽¹⁾
G	$37 \leq P \leq 75$	NO _x	-	-	4,7 ⁽³⁾	-	-	-	-	3,3 ⁽¹⁾	-	-	-
D	$18 \leq P \leq 37$	NO _x	-	-	-	7,5 ⁽²⁾	-	-	-	-	-	-	-
H	$130 \leq P \leq 560$	NO _x ⁽³⁾	-	-	-	-	-	2,0	-	-	-	0,4	-
I	$75 \leq P \leq 130$	NO _x ⁽³⁾	-	-	-	-	-	-	3,3	-	-	-	0,4 ⁽¹⁾
J	$37 \leq P \leq 75$	NO _x ⁽³⁾	-	-	-	-	-	-	-	3,3 ⁽¹⁾	-	-	0,4 ⁽¹⁾
K	$19 \leq P \leq 37$	NO _x ⁽³⁾	-	-	-	-	-	-	-	-	-	-	-
L	$130 \leq P \leq 560$	NO _x	-	-	-	-	-	-	-	-	-	0,4	-
M	$75 \leq P \leq 130$	NO _x	-	-	-	-	-	-	-	-	-	-	0,4
N	$56 \leq P \leq 75$	NO _x	-	-	-	-	-	-	-	-	-	-	0,4
P	$37 \leq P \leq 56$	NO _x	-	-	-	-	-	-	-	-	-	-	-

(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 4.

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Table 8.6:
REC Matrix for Regulation No. 96 / REC 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 ⁽³⁾	-	-	-	2,0	-	-	-	-	0,4	-
F	75 ≤ P ≤ 130	PM	-	-	-	-	-	0,025	-	-	-	-	0,025
		NOx	-	4,0 ⁽³⁾	-	-	-	3,3	-	-	-	-	0,4 ⁽¹⁾
G	37 ≤ P ≤ 75	PM	-	-	-	-	-	-	0,025 ⁽¹⁾	-	-	-	0,025 ⁽¹⁾
		NOx	-	-	4,7 ⁽³⁾	-	-	-	3,3 ⁽¹⁾	-	-	-	-
D	18 ≤ P ≤ 37	PM	-	-	-	0,6 ⁽²⁾	-	-	-	-	-	-	-
		NOx	-	-	-	7,5 ⁽²⁾	-	-	-	-	-	-	-
H	130 ≤ P ≤ 560	PM	-	-	-	-	0,025	-	-	-	-	0,025	-
		NOx ⁽³⁾	-	-	-	-	2,0	-	-	-	-	0,4	-
I	75 ≤ P ≤ 130	PM	-	-	-	-	-	0,025	-	-	-	-	0,025
		NOx ⁽³⁾	-	-	-	-	-	3,3	-	-	-	-	0,4 ⁽¹⁾
J	37 ≤ P ≤ 75	PM	-	-	-	-	-	-	0,025 ⁽¹⁾	-	-	-	0,025 ⁽¹⁾
		NOx ⁽³⁾	-	-	-	-	-	-	3,3 ⁽¹⁾	-	-	-	0,4 ⁽¹⁾
K	19 ≤ P ≤ 37	PM	-	-	-	-	-	-	-	-	-	-	-
		NOx ⁽³⁾	-	-	-	-	-	-	-	-	-	-	-
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 NO₂ emissions requirements for Type I and Type II RECs.
 - 8.4.1 For a Type I REC, NO₂ emissions shall not be greater than the NO₂ baseline emissions, measured as defined in Annex IX.13.
 - 8.4.2 For a Type II REC, NO₂ emissions shall not be more than [...]30% greater than the baseline emissions, measured as defined in Annex X.13.
- 8.5 PM Number emissions requirements...
- 8.6 Other secondary emissions requirements...

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Comment [JM15]: Measurement tolerance of e.g. 2%?

Comment [DB16]: Wording needs to be improved.

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Comment [DB17]: To be developed further by CH and DE

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9. Application range

The application range describes the range of engines or engine systems to which the REC 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 engines 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 within [± 15 -20%] 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]

Comment [DB18]: Needs to be investigated if additional information on 'engine family' is needed.

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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. Back-pressure modifications can be allowed by written permission of the original engine manufacturer.

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_x system is not allowed. Modifications downstream of the original de-NO_x 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 NOx control system of the original engine system shall not be compromised by the REC.

Comment [DB19]: Check wording.

11. 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 NO₂ in accordance with [] , two parallel measuring chambers to determine NO_x 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

12.1. The applicant shall confirm that the REC system will comply with the applicable provisions during normal operation over a useful life of:

a) for category M₂ and M₃ and N vehicles, a mileage of [200 000] km or a service life of [6] years, whichever occurs first

b) for all other applications, [4 000] operating hours or a service life of [6] years, 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 agreed between the TAA and the applicant or a test [using an appropriate duty cycle] on an engine test bed. 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 with recording of all relevant operating data of the engine concerned including continuous second-by-second data logging of exhaust temperature before the REC and pressure loss over the REC, type and consumption of fuel and lubricating oil. In the case of a field test the REC must be sealed by the Technical Service and the data-logging shall be carried out by the REC manufacturer or by the operator of the vehicle or machine on which the endurance test is performed.

- In the case of REC that operate with additives or makes 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.

12.4. After completion of the durability run the REC used to demonstrate durability shall be used for any further evaluation testing with the original test engine.

13. Particulate reduction REC family

13.1. The approval of a particulate reduction REC will continue to be valid for a nominally similar system in a different configuration or application provided

Comment [DB20]: maintenance provisions during durability run to be specified?

that it does not deviate from the tested system 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);
- 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, the surface roughness of critical components, and the diameters of wires, balls, or fibres);
- c) Minimum total charge of catalytically active materials of the particulate reduction system including upstream catalysts (if fitted) (grams/m³);
- d) Maximum total charge of catalytically active materials of the particulate reduction system including upstream catalysts (if fitted) (grams/m³);
- 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 of each active component (e.g. DOC, filter substrate,...); which must be within $\pm 30\%$ of the volume of the tested device;
- g) Type of regeneration (whether periodic or continuous);
- h) Regeneration principle (for example, catalytic, thermal, or electrothermal) and regeneration strategy (for example passive, active, forced);
- 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 REC);
- l) Type of any catalytically active material;
- m) With or without an upstream oxidation catalyst.

Comment [DB21]: Check wording

Comment [DB22]: Boundaries of the volume to be checked (+ & -)

Comment [DB23]: Better wording to be found for active systems

- 13.2. When testing the particulate reduction REC on the engine test 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. 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.

Comment [DB24]: This is for passive systems; definition on passive regeneration is needed.

14. NO_x reduction REC family

- 14.1. Families may be formed from NO_x reduction REC of different sizes or volumes, or both, provided that the following compliance criteria are met:

a) Where a NO_x 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 4.4.2 of this Regulation;

b) Where the application range for a NO_x 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 N1;

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.

Comment [DB25]: Refer to the new definitions from R.E.3

~~4.4.2. The family formation criteria for the extension of the application range are:~~

Comment [DB26]: Already covered in para.9

~~a) within [± 15%] of the displacement of a single cylinder~~

~~a) the method of aspiration (turbocharged or normally aspirated engine)~~

~~b) with or without EGR.~~

~~e) whether a constant speed or a variable speed engine.~~

14.32. The approval of a NO_x reduction system will continue to be valid for a nominally similar system (employing the same NO_x reduction technology) in a different configuration or application provided that it does not deviate from the tested system with respect to the following features:

14.32.1. Consistent features applicable to all NO_x reduction REC:

a) 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 ± 30% of the active volume of the tested device;

b) Any temperature control method employed (for example, catalytic, thermal, or electrothermal heating);

c) 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;

d) Where the tested device was tested in association with other pollution control devices, the same arrangement of devices retained for the device under consideration;

14.32.2. Consistent features applicable to NO_x reduction REC employing Selective Catalytic Reduction:

a) 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;

b) 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;

Comment [DB27]: Need to find improved wording from (supplier-OEM)

c) 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;

d) The method of attaching the catalyst to the substrate, including the characteristics of any fastening or adhesive;

e) The nature of the reagent;

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 [S28]: Is this a reasonable figure for this case?

14.43. Further use of the existing oxidation catalyser(s);

Comment [DB29]: Heading seems strange; shape and length of the mixing tube needs to be considered.

When testing the NO_x 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. NO_x and PM reduction REC family

15.1. The approval of a NO_x 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_x 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_x and PM reduction elements of the device are the same as the relationship between these elements in the tested device.

Comment [LES30]: Deleted. 1. Never applied in Anlage XXVII, 2. Creates possible loophole.

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 and [2] % for NO_x REC? greater in the retrofitted condition than the mean specific consumption in the non-retrofitted condition.

Comment [DB31]: 4% is in Anlage XXVII

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 test engines shall originate from an engine family corresponding to the subsequent application range of the REC. The emissions performance of the test engine shall meet the limits for the applicable baseline emission stage.

The test engine [and REC combination] for the selected application range 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 Regulation 49 and / or Regulation 96;
- b) the REC ~~system~~ shall have the highest space velocity within the application range of the REC ~~system~~ combined with the selected test engine;
- c) the REC ~~system~~ shall have the minimum total charge of catalytically active materials specified by the manufacturer.

Comment [DB32]: Check wording

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 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. Where vehicles or machines are fitted with on-board diagnostic systems those systems shall not be affected 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.

Comment [JM33]: Test Cycles (section 18 in previous draft) moved to Annexes.

18. Operating behaviour and safety hazard

No impairment of the operating behaviour of the vehicle or machine, and no additional safety ~~hazards~~ ~~hazard~~ (increased surface temperature etc.) associated with the vehicle or machine shall arise as a result of the installation of the ~~particulate reduction system~~ REC.

Comment [DB34]: Consider additional generic wording

~~Consider machinery directive~~

Comment [DB35]: Ask Mr Billi if ok.

~~The operator is responsible for the operation of the vehicle or machine equipped with the REC.~~

Comment [DB36]: Consider additional wording.

19. Environmental nNoise

The applicant shall prove that the retrofitting of a ~~particulate reduction system~~ REC will not lead to deterioration in the ~~environmental~~ noise. Noise measurement may be omitted in the case of ~~particulate reduction systems~~ REC fitted in addition to the [original equipment manufacturer's] standard production silencer system.

[If testing is done, it must comply with applicable international standards.]

20. Use of additives or reagents

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 13] becomes necessary.

See SNR provisions in Annex 13/ [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, authorities and other parties) 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. ~~The vehicle or machine to be retrofitted must be in a properly maintained 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. 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 must provide installation guidelines. 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. 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 or additives. 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 or additives, 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. The instructions shall specify the type and quality of the consumable reagents or additives used.
- 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 or additive), 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).

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Comment [DB37]: Is this sufficient?

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

- 23.1. Every modification [relevant in the context of this Regulation] of the REC system shall be notified to the authority, which granted the retrofit system REC 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 REC 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 [DB38]: Add clarification about relevant modifications related to the test report or information document?

24. **Penalties for non-conformity of production**

- 24.1. The approval granted in respect of a type of REC system pursuant to this 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 [DB39]: Text to be checked; copy from Reg.115

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.

Comment [S40]: Should this be "definitively"?

26. **Names and addresses of technical services conducting approval tests and of Administrative departments**

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 [JM41]: 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.

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Comment [DB42]: Leif-Erik Schulte will provide information document similar to the one from Anlage XXVII

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Annex 2. Communication

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

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



concerning: 2²

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 ²
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:

¹ Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).

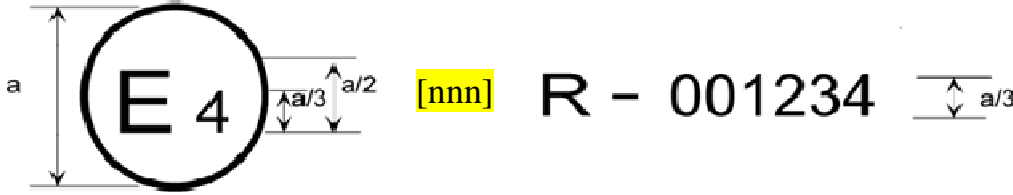
² Strike out what does not apply.

-
- 10.2. Number of test report:
 11. Approval granted / extended / refused / withdrawn ²
 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)



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.

There should be some indication to the Type of the REC (Type. I, II, III or IV) - look for other examples.

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a = 8 mm min

Comment [DB43]: Min measure big enough?

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Comment [DB44]: Check in working group

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Annex 4

Application range (example)

Comment [DB45]: To be considered in working group

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Comment [DB46]: NRMM and NOx REC to be considered

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

Comment [DB47]: Noise is covered in other part of this Reg.

Comment [DB48]: Needed?
As both HDV and NRMM

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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 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 and 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 shall meet the requirements of paragraph 8.4 of this Regulation with respect to NO₂ emissions.

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Comment [DB49]: Triplicate tests

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Comment [S50]: Should this be, for consistency, "on-road applications covered by Regulation No. 49"?

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Comment [DB51]: Tables could be transferd to the annexes.

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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 and 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 shall meet the requirements of paragraph 8.4 of this Regulation with respect to NO₂ emissions.

Comment [DB52]: For Euro VI retrofit, there will be a separate annex incl. WHTC etc.

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Comment [S53]: 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?

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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 mass of NO_x 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 Annex10 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 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 and 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.

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Comment [JM54]: For both Annexes VII and VIII wording is needed to cover Type IV systems meeting Row C (EEV) requirements .

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Annex 8**Requirements for Level 2 NO_x reduction REC**

1. Type III and Type IV REC approved to NO_x Reduction Level 2 shall provide a reduction efficiency for mass of NO_x of at least [70]% 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.
2. Following installation of the REC, the test engine and REC combination shall meet the next higher NO_x 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 NO_x emissions limits to be met are:
 - 2.1.1. For baseline NO_x 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 NO_x emissions equivalent to Row B1 of Tables 1 and 2 of Regulation No.49 Revision 5.
 - 2.1.1. For baseline NO_x 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 NO_x emissions equivalent to Row B2 of Tables 1 and 2 of Regulation No.49 Revision 5.
 - 2.1.2. For baseline NO_x emissions corresponding to Row B1 of Tables 1 and 2 of Regulation No.49 Revision 5, 2.0 g/kWh on the ESC and ETC cycles to achieve NO_x 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 NO_x emissions limits to be met are those shown in table 8.5 of this Regulation.

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[Annex for Euro VI retrofit](#)

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 NO₂ 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 particulate 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 NO₂ 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.

If the applicant can prove that a particulate reduction system that has been tested for vehicles of category M2 and N vehicles^{1/} 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 [] is representative for such applications and meets the family criteria of paragraph [], then the application range for which the system is approved may be extended to C.I. engines for use in non-

Comment [JM55]: 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 [DB56]: Clarify test cycles

Comment [JM57]: Would the regeneration procedures (1 iv), v) and vi)) be best handled as an Appendix / Appendices to this Annex?

Comment [LES58]: 100 cycles deleted due to 1000hrs durability run.

Comment [JM59]: Is every 5th cycle enough? Couldn't a system regenerate and reload within that period?

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:

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

Comment [DB60]: Check if $n \cdot (n-1)$ should be in denominator rather than 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 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 [REC 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_x) 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

Comment [DB61]: Nr needed?

type-approved. The NO₂ to NO_x ratio for the initial condition and the retrofitted condition is to be recorded and shown in the test report.

The determination of the NO₂ and NO_x 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 [REC](#)

This provision only applies to [RECs](#) 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.)

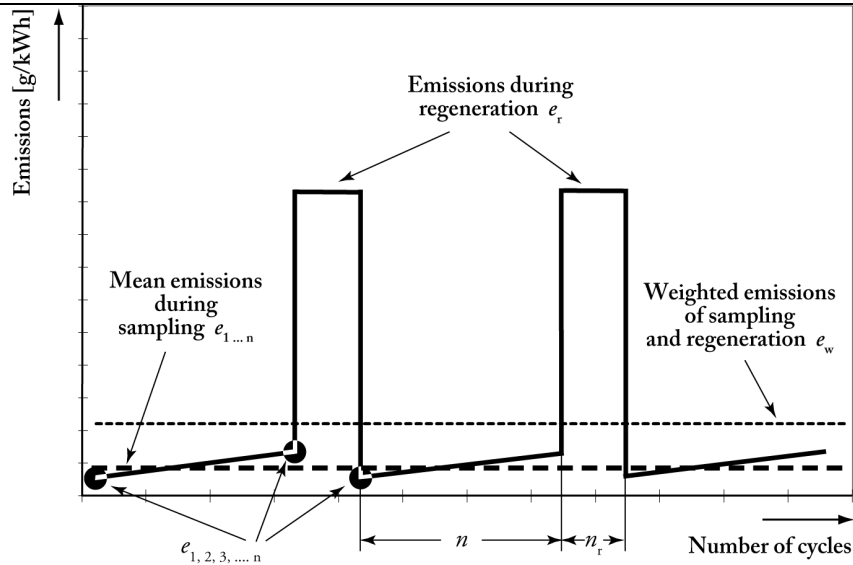
For a regeneration test, the manufacturer shall provide a particulate reduction REC system that has been loaded with particulate matter. As an option, the manufacturer may run consecutive test cycles [as set out in paragraph 10.4] until the particulate reduction REC is loaded. Emissions measurement is 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_x 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.

$$\text{PM mass} = \text{PM mass}_r \times F + (1-F) \times \text{PM mass}_{\text{wor}}$$

Where:

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

$\text{PM mass}_{\text{wor}}$ = 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:

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

or

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

or

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

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_x) 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 NO₂/NO_x ratio for both the initial condition and the retrofitted condition are to be recorded and shown in the test report.

The determination of the NO₂ - and NO_x- 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_{gas} (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_{gas_{wor}} = average specific emission from a test in which the regeneration does not occur [g/kWh]

M_{gas_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 the regeneration adjustment factor k_r, 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 NO₂ 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 NO₂ determination

Euro stage		HC in g/kWh	NO ₂ in g/kWh
EURO III (Cylinder capacity: up to 800 cm ³)	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 ³)	ETC	0.10-0.25	0.20-0.30
EURO III	ESC		
(Engines with EGR systems)	ETC		

5.7.1. -Selection of the particulate reduction REC for NO₂ determination

The particulate reduction REC system to be tested shall be

- the a 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 particulate reduction 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].

5.7.2. Determination of NO₂ 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_x and NO₂ emissions shall be determined for the urban part of the [ETC/ WHTC] for C.I. engines used in vehicles of category M² and N².

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 of the NO_x and NO₂ 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,

Comment [DB62]: Not the largest volume... - check if wording can be improved

Comment [DB63]: Does urban part of... needs to be defined?

Comment [DB64]: Further consideration of only urban part of ETC cycle? What about urban part of Euro VI cycle?

Comment [DB65]: Text needs to be carefully reviewed and to be revised by the working group

Comment [DB66]: To be reviewed by working group.

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 NO₂ 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 [DB67]: ... needs new wording

Comment [DB68]: Deleted - relates to the Annex on Euro VI.

Comment [DB69]: To be revised - there are no specific requirements for hybrid powertrains in current legislation for HDVs

Comment [DB70]: Improve wording

Comment [DB71]: Clear distinction has to be made between the 1st suitability test and the real baseline test

Annex 10**Test of a NO_x reduction REC**

1. Testing of a ~~NO_x 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 NO₂ emissions and of emissions of the other regulated pollutants.

In Annex [TBA] a flow chart outlines the test sequence for NO_x 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 ~~be~~ 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.
5. A separate test of the NO_x 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_x 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 [SA] 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_x 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. .

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_x, 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

Comment [S72]: This is potentially at odds with the requirement that separate tests for NO₂ must be done on on-road and non-road cycles in order to qualify a REC for use in both sectors.

NO₂ to NO_x 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_x, 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.

8. Determination of emissions of the regulated pollutants and of NO₂.

In order to determine the emissions of the regulated pollutants and NO₂, 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 NO₂ 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 NO₂ 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 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;

Comment [LES73]: Covered by R. 49 and R.96

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Comment [S74]: The test cycles used for the original type-approval has been deliberately excluded, here. It would seem odd to permit a NO₂ 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.

- 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 [S75]: 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.~~
- 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_x reduction REC

1. Tests of a PM and NO_x reduction REC shall meet the requirements for testing for each of the pollutants set out in ~~section 45~~ and ~~section 45A~~ 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_x, 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 NO₂ to NO_x ratio for the initial condition and the retrofitted condition is to be recorded and shown in the test report.

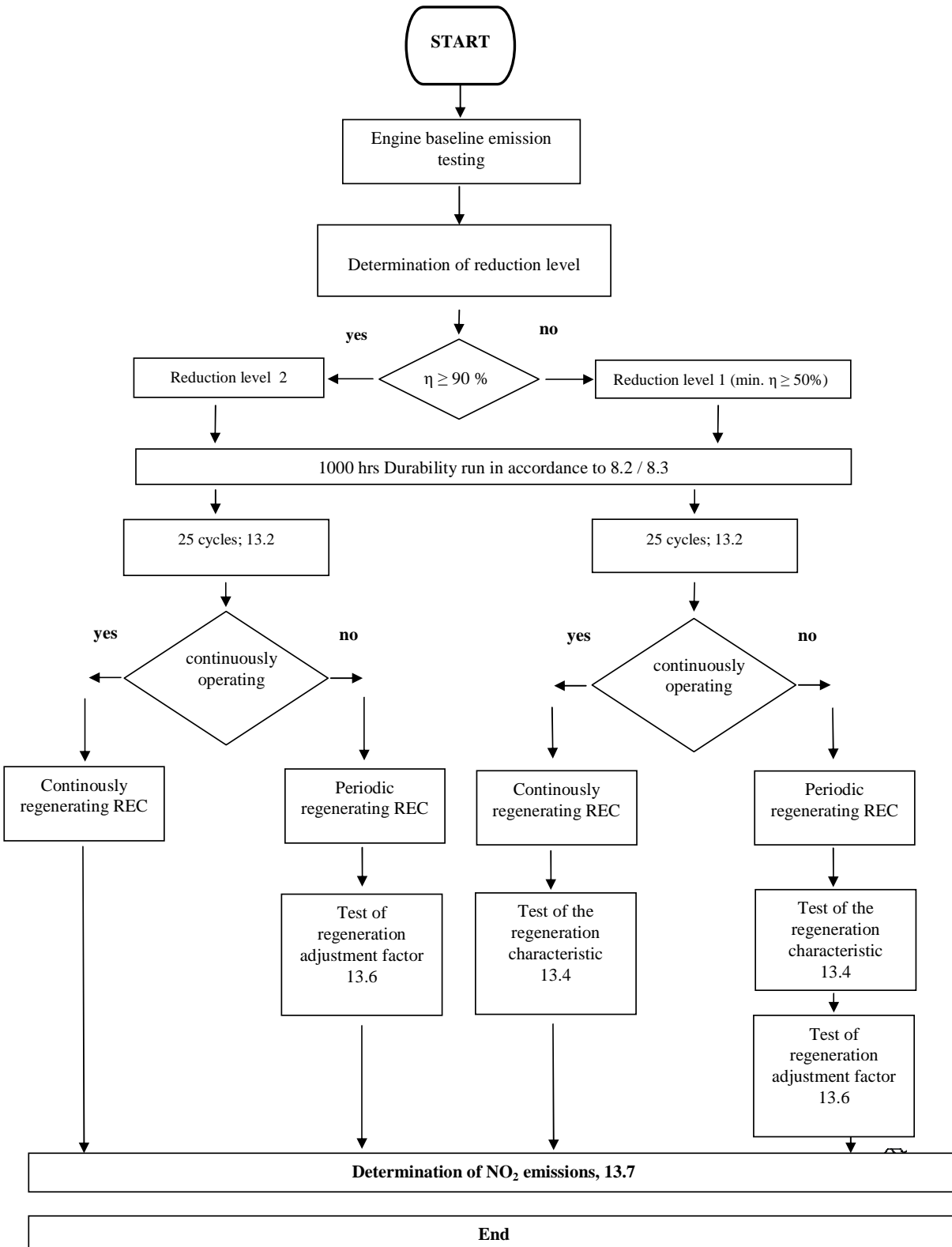
In the case of an engine not type-approved in accordance with the requirements of either Regulation No. 49 or Regulation No. 96, the emissions of each of the regulated pollutants (CO, HC, NO_x, and PM) in the initial condition and in the retrofitted condition shall be either,

 - 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_x reduction REC must be undertaken using test cycles that meet all of the requirements of Annex 9 and Annex 10 of this Regulation.

Test sequence for particulate reduction REC

Comment [JM76]: To be reviewed

Comment [DB77]: Cycles; 25 cycles for regen. etc TBD



Annex 13

Measurement of secondary emissions

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. Standard 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 NO₂ emissions, while those containing copper produce substantial amounts of polychlorinated dibenzodioxins and furanes (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

Deleted, see PNM REC annex

2.1. 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

Comment [DB78]: 1st discussion on 21/9/11

Comment [DB79]: EMA Europe: not related to Type Approval measurements; studies on harmfulness?; costly! There are no limits in CH – mainly for research

Comment [DB80]: EIC: has any REC ever failed the VERT secondary emissions requirements?

Comment [DB81]: Hungary: should be no limits but no increase

Comment [DB82]: Chair: NM Number in separate chapter shortlist of WLTP/DTP/AP could be a starting point (NO₂, N₂O, NH₃, EtOH, aldehydes) Limits and/ or evaluation ate to be discussed with DTP/AP chair. See what EC plans to do following the outcome of WLTP **for the time being the REC Informal Group will abstain of having an Annex on Secondary Emissions**

Comment [DB83]: SN 277206 is newest standard

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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 Nitroated polycyclic aromatic hydrocarbons (nitro-PAH)

There are numerous nitration products found in NO_x-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).

Comment [DB84]: Hungary: this should not be considered

Component	Sampling	Analytical method	Formatted: Indent: Left: 2 cm, Hanging: 2 cm, Right: 2 cm, Space After: 6 pt, Tabs: 1.69 cm, Left + 1.9 cm, Left
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)	Formatted: Indent: Left: 2 cm, Hanging: 2 cm, Right: 2 cm, Space After: 6 pt, Tabs: 1.69 cm, Left + 1.9 cm, Left
VOCOX	From exhaust diluted to a constant volume flow (CVS tunnel), chemisorptions in dinitrophenylhydrazine solution	Liquid chromatography ultraviolet detector (LCUV/VIS)	Formatted: Indent: Left: 2 cm, Hanging: 2 cm, Right: 2 cm, Space After: 6 pt, Tabs: 1.69 cm, Left + 1.9 cm, Left
PAH	Flow proportional sampling from undiluted	Gas chromatography high-resolution mass spectrometry (GCHR)	Formatted: Indent: Left: 2 cm, Hanging: 2 cm, Right: 2 cm, Space After: 6 pt, Tabs: 1.69 cm, Left + 1.9 cm, Left

	<p>exhaust, multiple stage glass apparatus based on the filter/co ndenser method (UNE-EN 1948-1)</p>	<p>MS) or liquid chromat ography ultraviolet/fluorescence detector (LCUV/ fluoresce nce)</p>	
<p>Nitro-PAH</p>	<p>Flow proportional sampling from undilute d exhaust, multiple level glass apparatus based on filter/ condens er method (UNE- EN 1948-1)</p>	<p>Gas chromatography high resolution mass spectrometry (GCHR MS)</p>	<p>Formatted: Indent: Left: 2 cm, Hanging: 2 cm, Right: 2 cm, Space After: 6 pt, Tabs: 1.69 cm, Left + 1.9 cm, Left</p>
<p>PCDD/F</p>	<p>Flow proportional sampling from undilute d exhaust gas, multiple stage glass apparatu s-based on filter/co ndenser method (UNE- EN 1948- 1)</p>	<p>Gas chromatography high resolution mass spectrometry (GCHR MS)</p>	<p>Formatted: Indent: Left: 2 cm, Hanging: 2 cm, Right: 2 cm, Space After: 6 pt, Tabs: 1.69 cm, Left + 1.9 cm, Left</p>
<p>Catalytically active e t</p>	<p>Flow proportional sampling from undilute d</p>	<p>Microwave digestion inductively-coupled plasma mass</p>	<p>Formatted: Indent: Left: 2 cm, Hanging: 2 cm, Right: 2 cm, Space After: 6 pt, Tabs: 1.69 cm, Left + 1.9 cm, Left</p>

<p>e m e n t s (metals)</p>	<p>exhaust, size- fractiona ted samplin g—with 12-stage electric low pressure impactor (ELPI) plus backup filter</p>	<p>spectrometry (ICP- MS)</p>
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NH3 to be introduced

CRITERIA to be introduced

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