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Retrofit Emission Control Devices (REC)

Draft new Regulation on uniform provisions concerning the approval of Retrofit Emission Control Devices (REC) for heavy duty vehicles, agricultural and forestry tractors and non-road mobile machinery equipped with Compression Ignition engines.

Submitted by the chairman of the informal working group on REC The text reproduced below was prepared by the chairman of the informal working group on REC 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 rev.00 Version GRPE 65 [Values], [dates], [provisions] and [parameter] not fixed yet are indicated in [square brackets], and [highlighted in yellow].

Regulation No. xx

Draft new Regulation on uniform provisions concerning the approval of Retrofit Emission Control Devices (REC) for heavy duty vehicles, agricultural and forestry tractors and non-road mobile machinery equipped with Compression Ignition engines.

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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 particulate matter (PM), for oxides of nitrogen (NO_x), or for both PM and NO_x, 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.

The regulation provides a framework for approval of RECs for different applications with corresponding environmental performance levels.

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, excluding those vehicles approved according to Regulation No. 83,
- 2.2. on C.I. engines having a net power higher than 18 kW but not more than 560 kW installed in non-road mobile machinery¹, 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 in non-road mobile machinery¹, 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 in category T vehicles¹.

3. Definitions

For the purposes of this Regulation,

- 3.1. “*Active regeneration*” means any additional measure to initiate regeneration either on a periodic or continuously regenerating REC.
- 3.2. “*Adjustment factors*” means additive upward adjustment factor and downward adjustment factor or multiplicative factors to be considered during periodic regeneration;
- 3.3. “*Application range*” means the range of engines to which a retrofit emission control device (REC) approved in accordance with regulation can be applied;
- 3.4. “*Class 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;
- 3.5. “*Class II retrofit emission control device (REC)*” means a retrofit emission control device which is intended to control particulate matter emissions only,

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).

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- and which does not increase the direct tailpipe NO₂ emissions by more than the percentage specified in paragraph 8.4.2 based on the engine baseline emission NO₂ level;
- 3.6. “*Class III retrofit emission control device (REC)*” means a retrofit emission control device which is intended to control NO_x emissions only;
- 3.7. “*Class IV retrofit emission control device (REC)*” means a retrofit emission control device which is intended to control both particulate matter emissions and NO_x emissions;
- 3.8. “*Continuous regeneration*” means the regeneration process of an exhaust after-treatment system that occurs either permanently or at least once per applicable test cycle;
- 3.9. “*deNO_x 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);
- 3.10. “*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 18;
- 3.11. “*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;
- 3.12. “*Engine family*” means an engine manufacturer's grouping of engine systems which, through their design as defined in Paragraph 7 of Regulation 49 or Paragraph 7 of Regulation 96 as appropriate, have similar exhaust emission characteristics; all members of the family shall comply with the applicable emission limit values;
- 3.13. “*Engine system*” means the engine, the emission control system and the communication interface (hardware and messages) between the engine system electronic control unit(s) (ECU) and any other powertrain or vehicle control unit;
- 3.14. “*ESC*” 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;
- 3.15. “*ETC*” 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;
- 3.16. “*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;
- 3.17. “*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 nitrogen dioxide (NO₂);
- 3.18. “*Manufacturer*” means the person or body who is responsible to the approval authority for all aspects of the type-approval and for ensuring conformity of

production. It is not essential that the person or body be directly involved in all stages of the construction of the vehicle, system, component or separate technical unit which is the subject of the approval process;

- 3.19. "*NO_x Control Diagnostic system (NCD)*" means a system of the REC which has the capability of
- (a) detecting a NO_x Control Malfunction;
 - (b) identifying the likely NO_x control malfunctions by means of information stored in computer memory and/or communicating that information off-board.
- 3.20. "*NO_x-reduction REC*" means a REC that has a NO_x mass emission reduction efficiency which qualifies it to be certified as meeting the classification class as defined in this Regulation;
- 3.21. "*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 15;
- 3.22. "*NRSC*" means a test cycle consisting of steady state modes defined in, and to be applied in accordance with, the relevant series of amendments to Regulation No. 96;
- 3.23. "*NRTC*" means a test cycle consisting of 1173 second-by-second transient modes defined in, and to be applied in accordance with, the relevant series of amendments to Regulation No. 96;
- 3.24. "*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 No. 96;
- 3.25. "*Particulate reduction REC*" means a REC that has a particulate mass or particle number emission reduction efficiency which qualifies it to be certified as meeting the classification class as defined in this Regulation. The regeneration system and strategy are part of the particulate reduction REC;
- 3.26. "*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 14;
- 3.27. "*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;
- 3.28. "*particle number*" means the number of particles which is defined in the relevant series of amendments to Regulation No. 49;
- 3.29. "*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;
- 3.30. "*Reduction efficiency*" means the ratio between the emissions downstream of the REC system (E_{REC}) and the engine baseline emissions (E_{Base}) and both measured in accordance with the procedures defined in this Regulation and calculated as defined in paragraph 8.3.4;

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- 3.31. “*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 the reduction level specified in paragraph 8.3;
- 3.32. “*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;
- 3.33. “*Scan-tool*” means an external test equipment used for off-board communication with the NCD system.
- 3.33.1. “*Generic scan-tool*” means a scan-tool, which is publicly available, and which shall be capable to read failure messages.
- 3.33.2. “*Proprietary scan-tool*” means a scan-tool, which is used only by the REC manufacturer and its authorized dealership, and which shall be capable to read failure messages and to enable an engine start after activation of the operator inducement system.
- 3.34. “*WHSC*” 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;
- 3.35. “*WHTC*” 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;

4. Application for approval

- 4.1. The application for [type] approval of a 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 1;
 - (c) the Application Range (as defined in paragraph 10) 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;
 - (d) the instruction manual for the retrofit installation;
 - (e) the end-user service manual including maintenance instructions.
- 4.3. The applicant shall provide the Information Document in accordance with Annex 1. The applicant shall also provide sample(s) of the REC to be tested and to be retained by the Technical Service for at least 5 years after the date of type approval.

5. Markings and labels

- 5.1. All REC shall be marked with the trade name or mark of the retrofit manufacturer that is indicated in Annex 1, and the identifying part number as recorded in the information document issued in accordance with the model set out in Annex 1.
- 5.2. All REC shall be identified by a label, in which the approval mark including the class, as set out in Annex 3 shall be placed. This label has to be permanently fixed to the REC, and shall be clearly readable after installation of the REC.
- 5.2.1 To ensure visibility of such a label in an installed system, the manufacturer may provide a duplicate label for fitment by the REC installer. Such label must clearly include the word 'duplicate'.
- 5.2.2 Labels shall be durable for the useful life of the device. Labels shall be clearly legible and their letters and figures shall be indelible. Additionally, labels shall be attached in such a manner that their fixing is durable for the useful life of the device, and the labels cannot be removed without destroying or defacing them.
- 5.3. The approval mark shall consist of:
- a) A circle surrounding the letter "E" followed by the distinguishing number of the country which has granted the approval².
 - b) The number of this Regulation, followed by the letter "R", a dash and the approval number to the right of the circle as defined Annex 3. The approval number appears in the communication form for this type (see paragraph 6.2. and annex 2) preceded by two figures indicating the latest series of amendments to this Regulation.
 - c) The Class of the REC.
- 5.4. REC samples for approval testing shall be clearly identified with at least the applicant's name and the reference of the application.

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.

² The distinguishing numbers of the Contracting Parties to the 1958 Agreement are reproduced in Annex 3 to the Consolidated Resolution on the Construction of Vehicles (R.E.3), document ECE/TRANS/WP.29/78/Rev.2/Amend.1 - www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29resolutions.html.

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- 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 Communication conforming to the model in Annex 2 to this Regulation.

7. General requirements

- 7.1. A REC approved in accordance with this Regulation 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. A REC approved in accordance with this Regulation shall be fitted with an on-board operator warning system that signals to the driver the presence of a failure affecting the efficiency of the REC.
- 7.2.1 A particulate reduction REC shall be equipped with a monitoring device that detects incorrect operation or removal of the device and that triggers an audible and/or visual alarm to the operator and interrupts the input of any reagent or additive. The warning system can be based for example on the continuous measurement of the engine exhaust back-pressure
- 7.2.2. Specific requirements applicable to NO_x reduction RECs are provided in paragraph 7.4. to 7.6. and Annex 10.
- 7.2.3. Combined PM and NO_x reduction RECs (Class IV RECs) have to meet the provisions of paragraphs 7.2.1. and 7.2.2.
- 7.3 A REC approved in accordance with this Regulation 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 9.
- 7.4. Devices that by-pass or reduce the efficiency of the REC are not permitted.
- 7.5. Specific requirements for REC requiring a reagent or additive.
- 7.5.1. Each separate storage 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.
- 7.5.2. The driver or machine operator shall be informed of the level of reagent or additive in the storage tank on the vehicle or machine through a specific mechanical or electronic indication in accordance with Annex 10. The reagent level indicator and the warning indicator shall both be placed in close proximity to the fuel level indicator.
- 7.5.3. The characteristics of the reagent, including the type of reagent, information on concentration when the reagent is in solution, operational temperature conditions and reference to international standards for composition and quality must be specified by the REC manufacturer in Annex I.
- 7.5.4. Detailed written information fully describing the functional operation characteristics of the operator warning system in paragraph 4 and of the operator inducement system in paragraph 5 shall be provided to the approval authority at the time of type-approval.

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- 7.5.5. The REC manufacturer shall provide installation documents that will ensure that the REC, when installed in the vehicle or machine, will operate, in conjunction with the necessary machinery parts, in a manner that will comply with the requirements of paragraph 7. This documentation shall include the detailed technical requirements and the provisions of the REC (software, hardware, and communication) needed for the correct installation of the REC in the machine.
- 7.6. The approval shall be conditional upon the following:
- 7.6.1. the manufacturer providing written maintenance instructions to be given by the installer to the driver or operator.
- 7.6.2. the manufacturer providing installation documents for the REC.
- 7.6.3. the manufacturer providing instructions for an operator warning system, an inducement system and reagent freeze protection (where applicable) to be given by the installer to the workshop or the driver or the operator, as appropriate.
- 7.6.4. the manufacturer providing a written statement to the installer, to be provided to the driver or operator, on the normal operating conditions (temperature range, environmental conditions,...) within which the REC will operate correctly.
- 7.7. Maintenance requirements
- 7.7.1. The REC manufacturer shall furnish written instructions about the REC system and its correct operation to be provided to all drivers or operators of vehicles or machines.
- These instructions shall state that if the REC system is not functioning correctly, the driver or operator will be informed of a problem by the operator warning system and that activation of the operator inducement system as a consequence of ignoring this warning will result in the vehicle or machine being unable to re-start.
- 7.7.2. The instructions shall indicate requirements for the proper use and maintenance of the REC in order to maintain its emissions performance, including the proper use of consumable reagents.
- 7.7.3. The instructions shall be written in a clear and non-technical manner using the same language as is used in the operator's manual on the vehicle or machine.
- 7.7.4. The instructions shall specify if consumable reagents have to be refilled by the driver or operator between normal maintenance intervals. The instructions shall also specify the required reagent quality. They shall indicate how the driver or operator should refill the reagent tank. The information shall also indicate a likely rate of reagent consumption and how often it should be replenished.
- 7.7.5. The instructions shall specify that use of, and refilling of, a required reagent of the correct specifications is essential in order for the vehicle or machine to comply with the requirements for the issuing of the approval of the REC for that vehicle or machine.
- 7.7.6. The instructions shall state that it may be a criminal offence to use a vehicle or machine that does not consume any reagent if the reagent is required for the reduction of emissions.

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- 7.7.7. The instructions shall explain how the operator warning and inducement systems work. In addition, the consequences, in terms of performance and fault logging, of ignoring the warning system and not replenishing the reagent or rectifying the problem shall be explained.
- 7.8. The NO_x control strategy of the REC shall be operational under all environmental conditions regularly pertaining in the territory of the Contracting Parties, especially at low ambient temperatures.
- 7.9. Reagent freeze protection
- 7.9.1. It is permitted to use a heated or a non-heated reagent tank and dosing system. A heated system shall meet the requirements of paragraph 7.9.2. A non-heated system shall meet the requirements of Annex 9, paragraph 6. The use of a non-heated reagent tank and dosing system shall be indicated in the written instructions to the driver or operator of the vehicle or machine.
- 7.9.2. Reagent tank and dosing system
- 7.9.2.1. If the reagent has frozen, the reagent shall be available for use within a maximum of 70 minutes after the start of the vehicle or machine at 266 K (- 7 °C) ambient temperature.
- 7.9.2.2. Design criteria for a heated system
- 7.9.2.2.1. The reagent tank and dosing system shall be soaked at 255 K (- 18°C) for 72 hours or until the reagent becomes solid, whichever occurs first.
- 7.9.2.2.2. After the soak period in paragraph 7.9.2.2.1., the vehicle/machine/engine shall be started and operated at 266 K (- 7 °C) ambient temperature or lower as follows:
- 10 to 20 minutes idling, followed by
 - up to 50 minutes at no more than 40 per cent of rated load.
- 7.9.2.2.3. At the conclusion of the test procedure in paragraph 7.9.2.2.2., the reagent dosing system shall be fully functional.
- 7.9.2.3. Evaluation of the design criteria may be performed in a cold chamber test cell using an entire vehicle or machine or parts representative of those to be installed on a vehicle or machine or based on field tests.
- 7.10. Requirements on NO_x control measures for REC requiring a reagent
- 7.10.1. The REC manufacturer shall provide information that fully describes the functional operational characteristics of the NO_x control measures using the documents set out in Annex I.
- 7.10.2. The REC shall be equipped with a NO_x Control Diagnostic system (NCD) able to identify the NO_x control malfunctions. The NCD shall be designed, constructed and installed so as to be capable of meeting the requirements of paragraph 7 during the normal life of the REC under normal conditions of use.
- 7.10.2.1. The NCD system shall be operational at
- ambient temperatures between 266 K and 308 K (-7°C and 35°C);
 - all altitudes below 1600 m;
 - engine coolant temperatures above 343 K (70°C).

This paragraph (7.10.2.1.) does not apply in the case of monitoring for reagent level in the storage tank where monitoring shall be conducted under all conditions where measurement is technically feasible (for instance, under all conditions when a liquid reagent is not frozen).

7.10.3. The NCD system shall meet the requirements in Annex 10.

8. Performance requirements

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

- the emission limit values as specified in paragraph 8.2.
- the reduction levels as specified in paragraph 8.3.
- the NO₂ emission requirements specified in paragraph 8.4.
- the secondary emissions requirements specified in paragraph 8.6.

8.2. Limit values

The retrofitted engine system shall meet at least the limits of the next more stringent emission stage for the relevant pollutants (NO_x or PM₁₀ or both as appropriate for the REC Class) 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. The retrofitted engine system shall meet at least the limits for the stage to which the base engine was approved for each of the other controlled pollutants relevant to that stage.

8.2.1. The requirements for each class of REC in terms of meeting the limits of the next more stringent emission stage are illustrated in the tables in Annex 9.

8.3. Reduction levels and reduction efficiency

8.3.1 The reduction level of a REC system is characterised by means of its reduction efficiency as specified in Table 8.3:

Table 8.3:

Reduction levels

	<i>Minimum reduction efficiency (%)</i>	
	<i>PM mass</i>	<i>NO_x</i>
Reduction level 00	50	[40]

8.3.2. The reduction efficiency shall be determined by comparison of the emissions measured over the weighted WHTC for RECs to be applied to heavy-duty engines or over the weighted NRTC for RECs to be applied to non-road mobile machinery or Tractor engines. The reduction efficiency shall be calculated as defined in 8.3.4.

8.3.3. 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 Class IV REC the reduction levels for both NO_x and PM shown in Table 8.3 of this Regulation must be met.

8.3.4. The reduction efficiency shall be calculated from the measured emissions of the relevant pollutant downstream of the REC system (E_{REC}) and the engine system emissions measured before fitment of the REC (E_{Base}) for that pollutant, both measured in accordance with the procedures defined in this Regulation:

$$\text{reduction efficiency (percent)} = (1 - (E_{REC} \div E_{Base})) \times 100.$$

8.4. NO₂ emissions requirements

8.4.1. For a Class I REC, there shall be no incremental increase in NO₂ emissions above the NO₂ baseline emissions, measured as defined in Annex 5.

8.4.2. For a Class II REC, the NO₂ incremental increase shall not be more than [30] percentage points greater than the level recorded when no REC is fitted (baseline). As an example, if baseline NO₂ is 10 percent of NO_X, the maximum permitted NO₂ emission with the REC is [40] percent of NO_X measured as defined in Annex 5.

8.4.3. For Class III RECs, there should be no increase of NO₂ emissions measured in g/kWh and as defined in Annex 6.

8.4.4. For Class IV RECs, there should be no increase of NO₂ emissions measured in g/kWh and as defined in Annex 7.

8.5 [This paragraph is reserved for future use.]

8.6 Secondary emissions requirements

8.6.1 The manufacturer of the REC system shall provide documentary evidence to show that materials and processes used in the REC do not present any additional hazard to health and the environment.

8.6.2 For Class III and Class IV RECs, emissions of ammonia shall not exceed a mean value of 25 ppm when measured using the procedures defined in Appendix 7 to Annex 4 of the 06 series of amendments to Regulation 49.

8.6.3. The REC shall not increase secondary emissions to concentrations known to be hazardous to health.

8.6.4. The applicant for approval shall provide an assessment of the performance of the REC with respect to secondary emissions. The assessment shall address all likely secondary emissions from the REC having regard to its working principle, its design, its method of construction, and the materials employed.

8.6.4.1. The assessment shall, in particular,

- a) in cases where the REC contains copper or copper compounds, address the possible formation of dioxins.
- b) in cases where the REC makes use of a fuel-borne catalyst, consider the impact upon the production of secondary emissions of
 - i) the absence of that catalyst and
 - ii) its presence at up to twice the recommended or intended concentration.

8.6.4.2 The assessment shall name each of the species of secondary emissions considered.

8.6.4.3 The assessment may be based upon sound engineering analysis and judgement, upon the results of tests or simulations, upon the results of

analysis or tests of similar systems or technologies, or upon any combination of these elements.

- 8.6.4.4 For the purposes of this Regulation secondary emissions produced at concentrations not significantly higher than the concentrations produced by original equipment engine systems shall be considered not to be hazardous to health.
- 8.6.5. The applicant may be required to perform tests for secondary emissions as a prerequisite for approval in cases where the assessment of the performance of the REC with respect to secondary emissions produces a reasonable expectation that the requirements of paragraph 8.6.3 will not be met, but not otherwise.

9. Durability requirements

- 9.1. The applicant shall declare that the REC system when used and maintained according to the manufacturer's instructions 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.
- 9.2. The applicant shall conduct a 1 000 hours 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 Type Approval Authority and the applicant or a test on an engine test bed. In the case of testing on an engine test bed, the aging cycle, load and speed shall include conditions that approximate to 10% idle, 10% transient operation, 75% high speed-high load operation, and 5% low speed-medium load operation.
- 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 shall be an engine within the declared application range of the particular REC.
- 9.3. The content of the test is as follows:
- 1 000 hours service accumulation of the REC with recording of all relevant operating data of the engine concerned including type and consumption of fuel and lubricating oil and continuous second-by-second data logging of exhaust temperature before the REC and pressure loss over the REC. 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.
- 9.4. After completion of the durability run the REC system used to demonstrate durability shall be used for any further evaluation testing with the original test engine.

In the event that the original test engine is no longer functional, an engine of the same type may be used with the prior agreement of the approval authority.

- 9.5. The REC system must meet the requirements of paragraph 8 when tested in accordance with paragraph 9.4 after completion of the service accumulation.

10. Application range

- 10.1 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 as specified in Annex 4.

- 10.2 The application range is limited to the engine family to which the test engine as defined in paragraph 12 belongs.

- 10.3 The application range may be extended to

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

if the applicant can demonstrate that the following criteria features of the engines concerned are the same as those in the test engine:

- i) individual cylinder displacement within [\pm 20 percent] 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 engine³
- v) engine baseline emission stage and
- vi) with or without an aftertreatment system.

- 10.4 If the applicant can prove that a REC tested for vehicles of Category M2, M3 and N and their C.I. engines, is designed for use in the same structural manner on C.I. engines for use in non-road mobile machinery or Category T vehicles and the test engine according to paragraph 12 is representative for such applications and also meets the family criteria of paragraphs 14, 15 or 16 as appropriate, the application range can be extended to C.I. engines for use in non-road mobile machinery and Category T vehicles.

Extending the range of a particulate reduction system that has been approved for use with C.I. engines in non-road mobile machinery or category T vehicles to cover on-road applications in the way described in this paragraph is not permitted.

³ An engine approved to Regulation 49 will be considered a variable speed engine for this purpose.

11. Modifications to engine baseline emissions

- 11.1. Any engine operation parameter specified by the original engine manufacturer, such as maximum allowable exhaust gas back pressure or limits set for impact of external devices upon the electrical or data handling systems, shall not be affected by the REC. Modifications are not allowed without the written permission of the original engine manufacturer
- 11.2. In cases where additional measures with respect to emission-relevant components 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.
- 11.3. The emission control system of the original engine manufacturer shall not be modified, except for:
- a) modifications allowed by written permission of the original engine manufacturer or
 - b) in the case of a Class I or Class II REC, replacement of an existing diesel oxidation catalyst providing that
 - i) the requirements of paragraph 8.4 are met and that
 - ii) the retrofitted engine system meets at least the limits for the stage to which the base engine was approved for each of the other controlled pollutants relevant to that stage.
- 11.4. Modifications upstream of an original deNO_x system are not allowed without the written permission of the original engine manufacturer.
- 11.5. Subject to the requirements of paragraph 11.1. being met, modifications downstream of an original aftertreatment system are allowed.
- 11.6. The performance of any On-Board Diagnostics (OBD) system and NO_x control system of the original engine system shall not be compromised by the REC.

12. Choice of the test engines and REC combination

- 12.1. 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 be measured and shall meet the limits for the applicable baseline emission stage.
- 12.2. 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 percent and 60 percent of the maximum power of the parent engine in the

particular family when assessed in accordance with the procedures of Regulation No. 49 or Regulation No. 96 as appropriate;

- b) when combined with the selected test engine the REC shall have the highest space velocity within the application range of the REC family;
- c) the REC shall have the minimum volumetric concentration of catalytically active materials specified by the manufacturer for the REC family.

When the requirements of sub-paragraph b) and sub-paragraph c), above, are mutually incompatible, the requirements of sub-paragraph b) shall take priority.

12.3. 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.

12.4. 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.

13. Specifications concerning emissions measurement

13.1. 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.

13.2. If a heated chemiluminescent detector (CLD) is used for the determination of NO₂ in accordance with paragraph 8.4, two parallel measuring chambers to determine NO_x and NO simultaneously shall be used. Two CLDs in parallel are permitted providing that they both comply with the requirements of Regulation 49 or Regulation 96 as appropriate, and the absolute converter efficiencies are shown to be within 3 percent of each other.

14. Particulate reduction REC family

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

- a) Type of retention of the active element (for example, adhesive or mechanical fixing), and functioning;
- b) Working principle of the active element (for example, metallic or ceramic material, barrier filtration or aerodynamic separation);

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- c) 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);
 - d) Minimum volumetric concentration of catalytically active materials of the particulate reduction system including upstream catalysts (if fitted) (grams/m³);
 - e) Maximum volumetric concentration of catalytically active materials of the particulate reduction system including upstream catalysts (if fitted) (grams/m³);
 - f) The design characteristics of the canning or packaging (for example, the storage or retention of the carrier of the active elements);
 - g) Volume of each active component (e.g. DOC, filter substrate) which must be within ± 40 percent of the volume of the tested device;
 - h) Type of regeneration (whether periodic or continuous);
 - i) Regeneration principle (for example, catalytic, thermal, or electrothermal) and regeneration strategy (for example passive, active, forced);
 - j) Method and control strategy for introducing additives or reagents (if used);
 - k) Type of additive or reagent (if used);
 - l) Installation conditions (max. + 0.5 m introduction difference between the turbocharger outlet (turbine) and the inlet of the particulate reduction REC);
 - m) Type of any catalytically active material;
 - n) With or without an upstream oxidation catalyst.
 - o) Where the tested device was tested in association with other pollution control devices:
 - i) the retention of the same arrangement of devices for the REC under consideration and
 - ii) the other pollution control devices being similar in design and principle of operation to those used during testing;

14.2. 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 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 will also be used in the subsequent installation of the REC on the vehicle or machine.

15. NO_x reduction REC family

15.1. The approval of a NO_x reduction REC 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:

- 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, and including any reagent mixing device) 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 ± 40 percent of the active volume of the tested device;
- b) Any temperature control method employed (for example, catalytic, thermal, or electrothermal heating);
- c) Where the tested device was tested in association with other pollution control devices:
 - i) the retention of the same arrangement of devices for the REC under consideration and
 - ii) the other pollution control devices being similar in design and principle of operation to those used during testing];
- d) The catalyst substrate material and the mechanical design of the substrate (for example a coated monolith or an extruded monolith, sheets or plates) and the shape, cross-sectional area, and density of the exhaust gas channels formed in it;
- e) The same catalytically active material, washcoat, loading and catalyst distribution over the substrate as the Type Approved system, within reasonable production tolerances;
- f) Type of reagent or additive (if used);
- g) 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. If different reagents and/or strategies are used for different climatic conditions the strategy with the lowest total dosing during the test shall be tested;
- h) The reagent introduction location and conditions. This condition will be considered to have been met if the introduction point is at least the same distance from inlet of the catalyst as the tested device and the means of reagent introduction (for example, air assisted or not) and any mixing device are also the same.

15.2. 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 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 will also be used in the subsequent installation of the REC on the vehicle or machine.

16. NO_x and PM reduction REC family

The approval of a NO_x and PM REC 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 PM reduction elements of the REC are in conformance with the requirements of paragraph 14 of this Regulation.
- b) The NO_x reduction elements of the REC are in conformance with the requirements of paragraph 15 of this Regulation.
- c) The location of the PM and NO_x reduction elements of the REC relative to each other is the same as the relationship between these elements in the tested device (for example the PM REC upstream of the NO_x REC).

Devices where PM and NO_x reduction are performed on the same substrate may not be considered to be in the same family as devices where the two activities are performed on separate substrates.

17. Fuel and fuel consumption

- 17.1. 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.
- 17.2. 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 appropriate fuel specified in either Regulation No. 49 or Regulation No. 96.
- 17.3. The specific fuel consumption of the engine fitted with the REC during the applicable test cycles (annex 5, paragraphs 4.5., 4.6. and 4.7.; annex 6, paragraphs and annex 7, paragraphs) shall be not more than 4 percent greater in the retrofitted condition than the mean specific consumption in the non-retrofitted condition.

18. Operating behaviour and safety hazard

- 18.1 The REC shall be so designed that it can be used in its intended applications, when fitted in accordance with the supplied instructions, without exposing operators or bystanders to any safety hazard either directly or as result of modifications to the vehicle or machine or its operating characteristics.
- 18.2 The REC shall be so designed that it can be used in its intended applications, when fitted in accordance with the supplied instructions, without impairment of the operating behaviour of the vehicle or machine unless

-
- a) the impairment does not cause a safety hazard.
 - b) the impairment does not increase the fuel consumption beyond the level set in paragraph 17.
 - c) the nature and extent of the impairment is clearly stated in the instructions and information that will be passed to the retrofitter and to the operator and owner.

18.3 In order to ensure that the requirements of paragraph 20 and Annex 11 with respect to installation and the provision of information are properly complied with, the REC manufacturer shall make an assessment of the safety hazards that might arise from installation of the REC on the vehicle or machine. In performing this assessment he shall take as the baseline the level of safety provided by the vehicle or machine when it was first placed on the market.

19. Noise Emissions

The applicant shall provide evidence that the retrofitting of a REC in accordance with the supplied fitting instructions will not lead to an increase of the vehicle's noise emissions. Evidence that the REC is intended only to be fitted in addition to the original equipment manufacturer's standard production silencer system on a road vehicle⁴ will be considered to fulfil this requirement.

20. Installation of a REC

20.1. The REC manufacturer must provide written installation guidelines and operation and maintenance instructions in accordance with the requirements of Annex 11.

20.2. The attention of the REC manufacturer is drawn, in particular, to the requirement in Annex 11 for the guidelines and instructions,

- a) to be written in the language of the country in which the REC is sold or in which the REC is expected to be used, and to be in clear language appropriate to the intended readership.
- b) to remind the installer of his or her potential legal responsibilities.
- c) to indicate to the end user any requirements for the proper maintenance of the REC, including, where relevant, the use of consumable reagents or additives.
- d) to indicate any requirements or limitations on the use of the vehicle or machine that are necessary in order to ensure safety and correct functioning of the REC.

⁴ Road vehicles, for this purpose, are category M₂, M₃ and N vehicles 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), excluding those vehicles approved according to Regulation No. 83.

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- e) to specify whether any reagents need to be refilled by the vehicle or machine operator between normal maintenance intervals, and to indicate a likely rate of reagent consumption.
 - f) to specify the type and quality of any consumable reagents or additives used.
 - g) to remind the owner and operator of the vehicle or machine that, where the fitting of the REC is a condition for its operation 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 breach of contract or constitute a criminal offence.

21. Conformity of production

The conformity of production procedures shall comply with those set out in the 1958 Agreement, appendix 2 (E/ECE/324 - E/ECE/TRANS/505/Rev.2).

In addition the following specific requirements shall apply: (to be completed)

22. Modification and extension of approval of a REC

22.1. Every modification relevant in the context of this Regulation of the REC shall be notified to the authority, which granted the REC type approval. The authority will then assess whether or not the REC still complies with the requirements for inclusion in the appropriate REC family.

The authority may require a further test report from the technical service responsible for conducting the tests in order to assist in its assessment.

22.2. Where the type-approval authority approves the modification, a reference to the formal notification of that approval shall be included in the installation manual for the REC.

22.3. Confirmation or refusal of approval, specifying the alteration, shall be communicated by the procedure specified in paragraph 6 above to the Parties to the 1958 Agreement applying this Regulation.

22.4. 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 of that number by means of the Communication specified in Annex 2 to this Regulation.

23. Penalties for non-conformity of production

23.1. The approval granted in respect of a type of REC pursuant to this Regulation may be withdrawn if the requirements laid down in paragraph 21 and 22 above are not complied with.

23.2. 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 the Communication specified in Annex 2 to this Regulation.

24. 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 the Communication specified in Annex 2 to this Regulation.

25. 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 TYPE APPROVAL OF RETROFIT EMISSION CONTROL DEVICES (REC) FOR HEAVY DUTY VEHICLES, AGRICULTURAL TRACTORS AND NON-ROAD MOBILE MACHINERY EQUIPPED WITH COMPRESSION IGNITION ENGINES.

A list of the main components has to be attached to describe the range of validity of the type-approval. Any drawings and part lists 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.

[Upon request of the Type-Approval Authority, further information may be needed for REC family members to demonstrate compliance with paragraphs 14, 15 or 16 of this Regulation, as appropriate.]

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. Name and address of manufacturer:.....
.....
 - 1.3. Type of REC
 - 1.4. Location and method of affixing of the ECE approval mark:
.....
 - 1.5. Address(es) of assembly plant(s):.....
.....

2. DESCRIPTION OF THE DEVICE
 - 2.1. Class of REC
 - 2.2. Make(s) (Commercial name), and manufacturer's type identification of the REC:.....
.....
 - 2.2.1. Identifying part number(s) of the REC:.....
.....
 - 2.3. Engine type or types for which the REC is intended (application range):.....
(see Annex of (date)).....

-
- 2.4. Number(s) and/or character(s) characterising the engine baseline emission(s) performance¹:.....
 - 2.5. Number(s) and/or character(s) characterising the achieved engine emission(s) performance¹:
.....
 - 2.6. Reduction level of the REC as defined in 8.3:.....
 - 2.7. Is the REC intended to be compatible with OBD requirements: Yes / No².
 - 2.8. Description and drawings showing the position of the REC device relative to the engine exhaust manifold(s):.....
.....
 - 2.9. Maximum allowable exhaust back pressure of the REC:.....kPa

3. CHARACTERISTICS OF THE PARTICULATE REDUCTION REC

- 3.1. Dimensions, shape and active volume of the particulate matter reduction system:
- 3.2. Maximum distance to the REC inlet from the outlet of the turbocharger (turbine) or the outlet plane of the exhaust manifold where no turbocharger is fitted.):
.....
- 3.3. Description with drawings and part lists of the Particulate Matter (PM) reduction REC

The description shall include a list of the main components (stating the part numbers) that are assembled to a REC for each application. Furthermore the description shall provide all information necessary to permit decisions relating to the REC family to be made in accordance with paragraph 14 of this Regulation.
- 3.3.1. Type of retention of the active element (for example, adhesive or mechanical fixing)
- 3.3.2. Working principle of the PM reduction active element (for example metallic or ceramic material, barrier filtration or aerodynamic separation)
.....
.....
- 3.3.3. Design and characteristics of the filter or other active material as defined in paragraph 14.1 c) of this Regulation
- 3.3.3.1. Type(s) of catalytically active material(s) (if any).....
- 3.3.4. Location (upstream/downstream), function and working principle (e.g. oxidation) of any supplementary catalyst(s).....
- 3.3.4.1. Type(s) of catalytically active material(s):.....

¹ As defined in Paragraph 8.2 of this Regulation.

² (Strike out what does not apply)

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- 3.3.5. Minimum volumetric concentration of catalytically active materials of each element of the particulate reduction system including supplementary catalysts (if fitted) (grams/m³):.....
 - 3.3.6. Maximum volumetric concentration of catalytically active materials of each element of the particulate reduction system including supplementary catalysts (if fitted) (grams/m³):.....
 - 3.3.7. The design characteristics of the canning or packaging:.....
 - 3.3.8. Volume of each active component:.....
 - 3.4. Method or system of regeneration (comprehensive description and/or drawing).....
 - 3.4.1. Type of regeneration (for example periodic or continuous).....
 - 3.4.2. Regeneration principle, frequency and strategy:.....
 - 3.4.3. Method and control strategy for introducing additives or reagents (if used);
.....
 - 3.4.4. Type and concentration of reagent or additive
 - 3.4.5. Frequency of reagent or additive refill.....
 - 3.5. Description of PM reduction system monitoring (in accordance with paragraph 7 of this Regulation)
 - 3.6. Description of any modifications to the original engine or emissions control system as defined in Section 11 of this Regulation.....
 - 3.7. Normal operating temperature: (K) and pressure range (KPa)
 - 3.8. Use of insulation (yes/no)
 - 3.8.1. Design and characteristics of the insulation.

4. CHARACTERISTICS OF THE NO_x REDUCTION REC

- 4.1. Dimensions, shape and active volume of the NO_x reduction system:
.....
- 4.2. Maximum distance to the REC inlet from the outlet of the turbocharger (turbine) or the outlet plane of the exhaust manifold where no turbocharger is fitted.):
.....
- 4.3. Description and drawings of the NO_x reduction REC
The description shall include a list of the main components (stating the part numbers) that are assembled to a REC for each application. Furthermore the description shall provide all information necessary to permit decisions

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- relating to the REC family to be made in accordance with paragraph 15 of this Regulation
- 4.3.1. Type of retention of the active element (for example, adhesive or mechanical fixing).....
 - 4.3.2. Working principle of the NO_x reduction active element (for example Selective Catalytic Reduction, NO_x Storage and Reduction etc.);.....
 - 4.3.3. Design and characteristics of the substrate and active material as defined in paragraph 15.1 d) and e) of this Regulation ;
 - 4.3.3.1. Type(s) of catalytically active material(s):.....
 - 4.3.4. Location (upstream/downstream), function and working principle (e.g. oxidation) of any supplementary catalyst(s).....
 - 4.3.4.1. Type(s) of catalytically active material(s):.....
 - 4.3.5. Minimum volumetric concentration of catalytically active materials of each element of the NO_x reduction system including supplementary catalysts (if fitted) (grams/m³):.....
 - 4.3.6. Maximum volumetric concentration of catalytically active materials of each element of the NO_x reduction system including supplementary catalysts (if fitted) (grams/m³):.....
 - 4.3.7. The design characteristics of the canning or packaging:.....
 - 4.3.9. Volume of each active component:.....
 - 4.4. Method or system of regeneration (if applicable) (description and/or drawing).....
 - 4.5. Method and control strategy for introducing additive(s) or reagent(s) (if used);.....
 - 4.5.1. Type and concentration of additive(s) or reagent(s).....
 - 4.5.2. Normal operational temperature range of reagent (K)
 - 4.5.3. Frequency of reagent or additive refill.....
 - 4.6. Description of NO_x reduction system monitoring (in accordance with Annex 10).....
 - 4.7. Systems to ensure the correct operation of NO_x control measures (in accordance with Annex 10)
 - 4.8. Description of any modifications to the original engine or emissions control system as defined in Section 11 of this Regulation.....
 - 4.9. Normal operating temperature: (K) and pressure range (KPa)
 - 4.10. Use of insulation (yes/no)

4.10.1. Design and characteristics of the insulation.

5. CHARACTERISTICS OF THE NO_x AND PM REDUCTION REC

5.1. Dimensions, shape(s) and active volume of the NO_x and PM reduction system:

5.2. Maximum distance to the REC inlet from the outlet of the turbocharger (turbine) or the outlet plane of the exhaust manifold where no turbocharger is fitted.):

5.3. Description and drawings of the NO_x and Particulate Matter (PM) reduction REC

The description shall include a list of the main components (stating the part numbers) that are assembled to a REC for each application. Furthermore the description shall provide all information necessary to permit decisions relating to the REC family to be made in accordance with paragraph 16 of this Regulation.

5.4. Design of the NO_x and PM reduction system

5.3.1. Type of retention of the active element(s) (for example, adhesive or mechanical fixing),.....

5.3.2. Working principles of the NO_x reduction active element (for example Selective Catalytic Reduction, NO_x Storage and Reduction etc.) and of the PM reduction active element (for example metallic or ceramic material, barrier filtration or aerodynamic separation);.....

5.3.3. Design and characteristics of the substrate(s) and active material(s) as defined in paragraph 14.1 c) and 15.1 d) and e) of this Regulation.....

5.3.3.1. Type(s) of catalytically active material(s):.....

5.3.4. Location (upstream/downstream), function and working principle (e.g. oxidation) of any supplementary catalyst(s).....

5.3.4.1. Type(s) of catalytically active material(s):.....

5.3.5. Minimum volumetric concentration of catalytically active materials of each element of the NO_x and PM reduction system including supplementary catalysts (if fitted) (grams/m³)

5.3.6. Maximum volumetric concentration of catalytically active materials of each element of the NO_x and PM reduction system including supplementary catalysts (if fitted) (grams/m³)

5.3.7. The design characteristics of the canning or packaging:.....

5.3.9. Volume of each active component:.....

5.4. Method(s) or system(s) of regeneration (if applicable) (description and/or drawing).....

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- 5.4.1. Type of PM reduction system regeneration (for example periodic or continuous).....
 - 5.4.2. PM reduction system regeneration principle and regeneration strategy
 - 5.4.3. Method and control strategy for introducing additives or reagents (if used)
 - 5.4.4. Type and concentration of reagent(s) or additive(s) (if used):.....
 - 5.4.5. Frequency of reagent(s) or additive(s) refill.....
 - 5.5. Normal operational temperature range of NO_x reduction reagent(s)(K)
 - 5.6. Description of PM reduction system monitoring (in accordance with paragraph 7.1).....
 - 5.7. Description of NO_x reduction system monitoring (in accordance with Annex 10).....
 - 5.8. Systems to ensure the correct operation of NO_x control measures (in accordance with Annex 10)
 - 5.9. Description of any modifications to the original engine or emissions control system as defined in Section 11 of this Regulation.....
.....
 - 5.10. Normal operating temperature: (K) and pressure range (KPa)
 - 5.11. Use of insulation (yes/no)
 - 5.11.1. Design and characteristics of the insulation

Annex 2.

Communication

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

¹



issued by:

Name of administration

.....
.....
.....

concerning²: / Approval granted
Approval extended
Approval refused
Approval withdrawn
Production definitely discontinued

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

Approval No.

Extension No.

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 REC device:
.....
5. Means of identification of type,
- 5.1. Location of that marking:.....
6. Engine type(s) for which the device type qualifies as a REC:.....
.....
7. Type(s) of engine on which the REC has been tested:.....
.....
- 7.1 Has the REC demonstrated compatibility with OBD requirements: Yes / No²
8. Location and method of affixing of the approval mark:.....
9. Submitted for approval on:.....

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. Technical Service responsible for approval tests:.....
 - 10.1. Date of test report:.....
 - 10.2. Number of test report:.....
 11. Approval granted / extended / refused / withdrawn ²
 12. Reason(s) of extension (if applicable):.....
 13. Engine type or types for which the REC is intended (application range) based on test results:.....
 14. REC Class I / II / III / IV ² and reduction efficiency:.....
 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
 16. The following documents, bearing the approval number shown above, are annexed to this communication:.....
 - 16.1. Verification of the engine baseline emissions.....
 - 16.2. Determination of emissions with the REC fitted.....
 - 16.3. Results of the reduction efficiency.....
 - 16.4. Performance of an endurance run.....
 - 16.5. Determination of the NO₂ emissions and of emissions of the other regulated pollutants.....
 - 16.6. Declaration on noise emissions
 17. Place:.....
 18. Date:.....
 19. Signature:.....

Annex 2A

Addendum to the communication concerning a type of retrofit emission control device (REC) pursuant to Regulation no. 000

(Approval No. Extension No.)

1. Engines on which the retrofit emission control device has been tested:

<u>Engine No.</u>	<u>1</u>	<u>2</u>	<u>n</u>
<u>Make:</u>			
<u>Type:</u>			
<u>Engine:</u>			
<u>Power:</u>			
<u>Category:</u>			

2. Test results:

3. Engine type(s) for which the REC device is qualified (application range):
shall completed later (see current Annex 4)

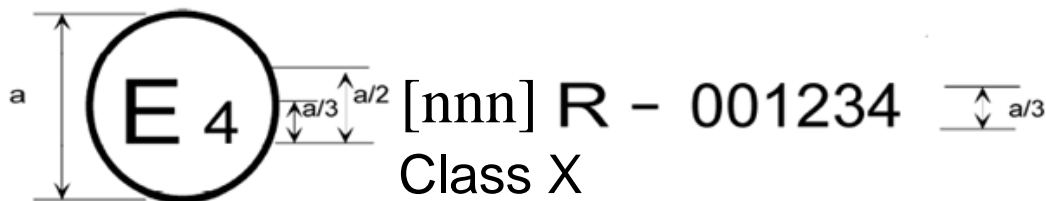
<u>Engine No.</u>	<u>1</u>	<u>2</u>	<u>n</u>
<u>Make:</u>			
<u>Type:</u>			
<u>Model year from/to:</u>			
<u>Capacity / cylinder:</u>			

Annex 3.

Arrangement of the REC System type approval mark

Model A

(See paragraph 5.4. of this Regulation)



a = 8 mm min

The above example approval mark affixed to a 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. The approval mark shall also show the Class of REC (I, II, III or IV).

Annex 4

Application range

<i>Number</i>	<i>Model year from/to</i>	<i>Engine type</i>	<i>Capacity / cylinder (cm³)</i>	<i>Capacity VH (cm³)</i>	<i>engine net power kW with min-1</i>	<i>Engine Baseline emissions</i>	<i>Silencer replaced</i>	<i>Type identification of the REC</i>	<i>REC Type and Reduction Level</i>

Annex 5

Test of a particulate reduction REC (Class I or II REC)

Testing of a particulate reduction REC is performed in the following series of stages, including an assessment of the emissions of secondary pollutants and determination of the NO₂ emissions (note that this may require a separate REC – see paragraph 6.7.1 of this Annex):

=> renumbering of Annex 5 is necessary incl. references within regulation, not done till now!

1. Performance of a service accumulation run.
The service accumulation run shall be performed in accordance with the requirements of paragraph 9 of this Regulation.
2. Establishment of engine baseline emissions without REC fitted
 - 2.1. The engine baseline emissions are established by performance of an emissions test on the engine system without the REC in accordance with the requirements of Regulation No.49 or Regulation No.96, as appropriate to the application and Type Approval level of the base engine.
 - 2.2. To enable the determination of reduction efficiency the emissions are additionally established by performance of an emissions test in accordance with the requirements of paragraph 8.3 of this regulation.
3. Determination of emissions and reduction efficiency with the REC fitted after service accumulation run.
 - 3.1. The emissions are determined by performance of an emissions test in accordance with the requirements of Regulation No.49 or Regulation No.96, as appropriate to the intended application and intended emission level of the candidate REC with the REC fitted in accordance with the requirements of this Regulation.
 - 3.2. For determination of reduction efficiency the emissions are additionally established by performance of an emissions test with the REC fitted in accordance with the requirements of Section 8.3 of this regulation.
4. Determination of particulate reduction REC regeneration strategy and regeneration characteristics
 - 4.1. The particulate reduction REC regeneration strategy (periodically or continuously) and the regeneration characteristics are established by use of the following procedure.
 - 4.2. In order to assess the regeneration performance of a particulate reduction REC at least 25 test 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 particle 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.

- 4.3. 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 average particulate emission and the average 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.

Where a continuously regenerating system as defined above also contains provision for active regeneration, then the assessment criteria defined in paragraph 4.7 shall be applied.

The PM mass 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 percent 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.

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

with:

$$\text{Standard deviation} = \sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}}$$

and:

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

where:

n = number of measured values

x = respective single measured value

- 4.4. If an REC manufacturer intends to apply for approval for a 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 4.3 and paragraph number 4.6 of this Annex 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.

4.5. Test of the regeneration characteristic of a particulate reduction REC

This 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 percent and 75 percent 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 percent for the gaseous emissions or more than 20 percent for the particulate mass or particulate number.

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.

4.6. Assessment criteria for continuously regenerating particulate reduction REC

The REC system test of the particulate reduction REC is considered satisfactory if the particulate emissions measured as defined in **paragraph 8** of the Regulation are met.

4.6.1. Regulated pollutants

The emissions of the regulated pollutants are determined by measurements taken immediately after the tests to establish the regeneration characteristics.

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 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 [paragraph 13.2](#)

4.7. Assessment criteria for periodically regenerating particulate reduction REC

This provision only applies to RECs which utilise active regeneration.

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.)

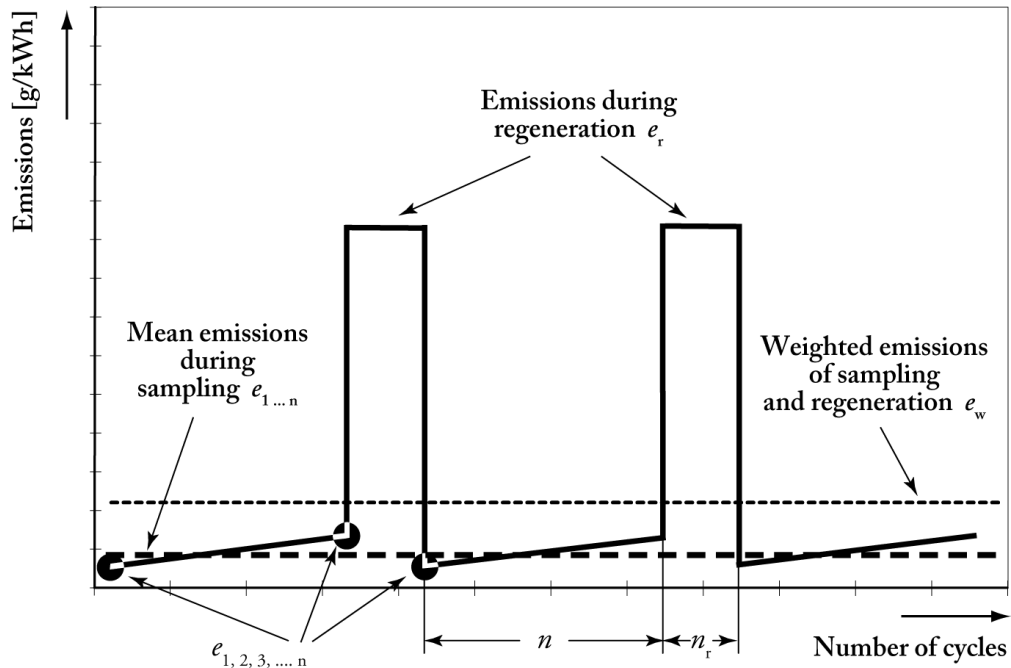
For a regeneration test, the manufacturer shall provide a particulate reduction REC system that has been loaded with particulate matter. As an option, the manufacturer may run consecutive test cycles as set out in [paragraph 4.5](#) until the particulate reduction REC is loaded. Emissions measurement 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

$k_{Dr} = \text{PM mass} - \text{PM mass}_r$ (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.

4.7.1. 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 4.8.2 of this annex and paragraph 13.

4.7.2. Weighted gaseous emissions

The emission of gaseous components M_{gas} (g/kWh) for periodically regenerating systems is determined as follows.

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

where:

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

$M_{\text{gas}_{\text{wor}}}$ = 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:

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

or

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

or

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

4.7.3. A similar procedure shall be applied for fuel consumption.

4.8. Determination of NO₂ emissions

The testing shall be performed on the test engine selected by the criteria described in paragraph 12.

4.8.1. Selection of the particulate reduction REC for NO₂ determination.

The particulate reduction REC to be tested shall be

- 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 and palladium 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.

4.8.2. Determination of NO₂ emissions

Three successive WHTC or NRTC test cycles, as appropriate to the application, shall be conducted. The emissions shall be determined over all three cycles and averaged. If the range of these results is greater than ± 15 percent of the mean, then an additional test cycle should be run.

The calculation of the NO_x and NO₂ emissions shall be determined for C.I. engines used in vehicles of category M and N over the complete WHTC cycle.

For C.I. engines used in non-road mobile machinery ¹ or Category T vehicles 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.

5. Test Cycles.

5.1. 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.

5.2. 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.

5.3. 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 be the test cycle associated with the emissions stage in Regulation No.49 for which approval of the REC is being sought.

5.4. 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.

-
- 5.5. 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.
- 5.6. 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
- 5.7 For the purposes of establishing the REC efficiency the appropriate test cycle is that defined in paragraph 8.3.
- 5.8. For the purposes of establishing the emissions of NO₂ during tests of a Class I or Class II REC, the specific test cycle defined in paragraph 4.8.2. of this Annex shall be used.

Annex 6

Test of a NO_x reduction REC (Class III REC)

Testing of a NO_x reduction REC is performed in the following series of stages, including an assessment of the emissions of secondary pollutants and determination of the NO₂ emissions (note that this may require a separate REC – see paragraph 3.5.1 of this Annex):

1. Performance of a service accumulation run.
The service accumulation run shall be performed in accordance with the requirements of Section 9 of this Regulation.
2. Establishment of engine baseline emissions without REC fitted
 - 2.1. The engine baseline emissions are established by performance of an emissions test on the engine system without the REC in accordance with the requirements of Regulation No.49 or Regulation No.96, as appropriate to the application and Type Approval level of the base engine.
 - 2.2. To enable the determination of reduction efficiency the emissions are additionally established by performance of an emissions test in accordance with the requirements of Section 8.3 of this regulation.
3. Determination of emissions and reduction efficiency with the REC fitted after service accumulation run.
 - 3.1. The emissions are determined by performance of an emissions test in accordance with the requirements of Regulation No.49 or Regulation No.96, as appropriate to the intended application and intended emission level of the candidate REC with the REC fitted in accordance with the requirements of this Regulation.
 - 3.2. For determination of reduction efficiency the emissions are additionally established by performance of an emissions test with the REC fitted in accordance with the requirements of Section 8.3 of this regulation.
 - 3.3. If an REC manufacturer intends to apply for approval for a REC that can reduce emissions of NO_x 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 3.4. of this Annex 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.

3.4. Assessment criteria for NO_x reduction REC

The REC system test of the NO_x reduction REC is considered satisfactory if the gaseous and particulate emissions measured as defined in paragraph 8 are met.

3.4.1. Regulated pollutants

The emissions of the regulated pollutants (CO, HC, PM and NO_x) in the initial condition shall be within the limit values for the emissions stage or standard for which the engine was originally type-approved.

The emissions of the regulated pollutants (CO, HC, PM and NO_x) in the retrofitted condition shall be within the limit values for at least the next higher emissions stage or standard than that for which the engine was originally type-approved.

3.4.2. A similar procedure shall be applied for fuel consumption.

3.4.3. 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 paragraph 13.2 of this Regulation.

3.5. Determination of NO₂ emissions

The testing shall be performed on the test engine selected by the criteria described in paragraph 12.

3.5.1. Selection of the NO_x reduction REC for NO₂ determination.

The NO_x reduction REC to be tested shall be

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

- the NO_x reduction REC containing the maximum [minimum] total charge of catalytically active materials and maximum platinum and palladium charge of the REC within the defined REC family.

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

The NO_x reduction REC shall not have been run in for longer than 50 hours.

3.5.2. Determination of NO₂ emissions

Three successive WHTC or NRTC test cycles, as appropriate to the application, shall be conducted. The emissions shall be determined over all three cycles and averaged. If the range of these results is greater than ± 15 percent of the mean, then an additional test cycle should be run.

The calculation of the NO_x and NO₂ emissions shall be determined for C.I. engines used in vehicles of category M and N over the complete WHTC cycle.

For C.I. engines used in non-road mobile machinery or Category T vehicles 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.

4. Test Cycles.
 - 4.1. 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.
 - 4.2. 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.
 - 4.3. 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 be the test cycle associated with the emissions stage in Regulation No.49 for which approval of the REC is being sought.
 - 4.4. 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.
 - 4.5. 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.
 - 4.6. 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
 - 4.7. For the purposes of establishing the REC efficiency the appropriate test cycle is that defined in paragraph 8.3.
 - 4.8. For the purposes of establishing the emissions of NO₂, the specific test cycle defined in paragraph 4.8.2. of this Annex shall be used.

Annex 7

Tests of a PM and NO_x reduction REC (Class IV REC)

1. Tests of a PM and NO_xNO_x reduction REC shall meet the requirements for testing for each of the pollutants set out in Annexes 5 and 6 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_xNO_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_xNO_x ratio for the initial condition and the retrofitted condition is to be recorded and shown in the test report.

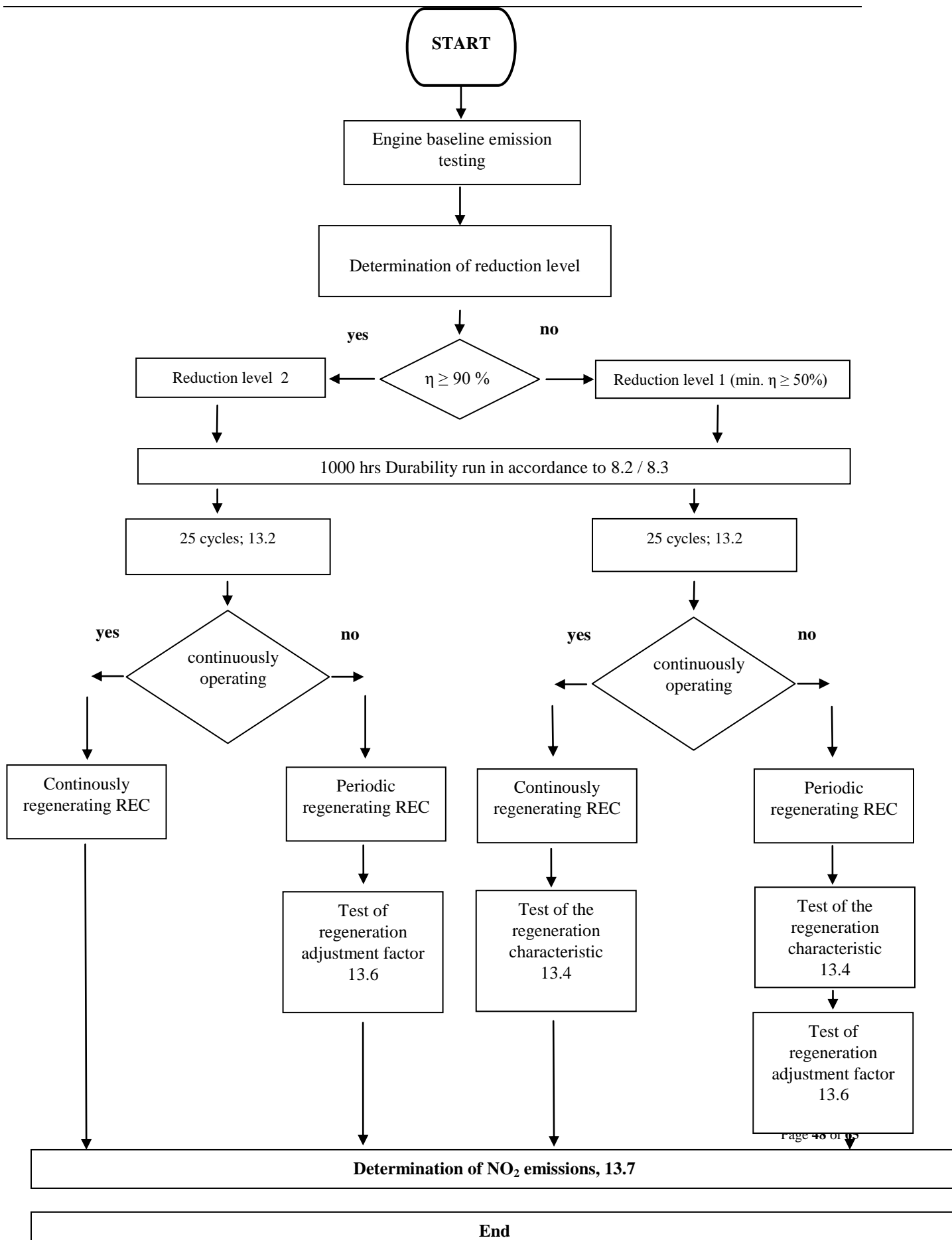
In the case of an engine not type-approved in accordance with the requirements of either Regulation No. 49 or Regulation No. 96, the emissions of each of the regulated pollutants (CO, HC, NO_xNO_x, and PM) in the initial condition and in the retrofitted condition shall be either,

 - 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_xNO_x reduction REC must be undertaken using test cycles that meet all of the requirements of Annex 5 and Annex 6 of this Regulation.

Annex 8

Test sequence for particulate reduction REC

[Diagram on next page to be reviewed on completion of Annexes 5-7]



Annex 9

Limit value equivalence tables

The requirements for each type of REC in terms of meeting the limits of the next more stringent emission stage, as required by paragraph 8.2 of this Regulation, are illustrated in the tables below.

The tables below show emission limits in g/kWh that would have to be met in order to achieve equivalence to the standard shown from each baseline. The efficiency requirements detailed in paragraph 8.3 may require that the measured emissions are lower than these limit values.

Table 1:

Equivalence matrix for Regulation No.49 Standard series

Emission limits in g/kWh.

Baseline*	Component		Class I/II To the standard of				Class III To the standard of			Class IV To the standard of			
			A	B1	B2	C	A	B1	B2	A	B1	B2	C
Before A	NO _x	(ESC)	-	-	-	-	5,0	3,5	2,0	5,0	3,5	2,0	2,0
		(ETC)	-	-	-	-	5,0	3,5	2,0	5,0	3,5	2,0	2,0
	PM	(ESC)	0,10 ⁽¹⁾	0,02	0,02	0,02	-	-	-	0,10 ⁽¹⁾	0,02	0,02	0,02
		(ETC)	0,16 ⁽²⁾	0,03	0,03	0,02	-	-	-	0,16 ⁽²⁾	0,03	0,03	0,02

⁽¹⁾ 0,13 g /kWh for engines having a swept volume of less than 0,75 dm³ per cylinder and a rated power speed of more than 3000 min⁻¹

⁽²⁾ 0,21 g /kWh for engines having a swept volume of less than 0,75 dm³ per cylinder and a rated power speed of more than 3000 min⁻¹

Baseline*	Component		Class I/II To the standard of			Class III To the standard of			Class IV To the standard of		
			B1	B2	C	B1	B2	C	B1	B2	C
A	NO _x	(ESC)	-	-	-	3,5	2,0	2,0	3,5	2,0	2,0
		(ETC)	-	-	-	3,5	2,0	2,0	3,5	2,0	2,0
	PM	(ESC)	0,02	0,02	0,02	-	-	-	0,02	0,02	0,02
		(ETC)	0,03	0,03	0,02	-	-	-	0,03	0,03	0,02

Baseline*	Component		Class I/II To the standard of			Class III To the standard of			Class IV To the standard of		
			B2	C	D	B2	C	D	B2	C	D
B1	NO _x	(ESC)	-	-	-	2,0	2,0	-	2,0	2,0	-
		(ETC)	-	-	-	2,0	2,0	-	2,0	2,0	-
		(WHSC)	-	-	-	-	-	0,4	-	-	0,4
		(WHTC)	-	-	-	-	-	0,46	-	-	0,46
	PM	(ESC)	0,02	0,02	-	-	-	-	0,02	0,02	-
		(ETC)	0,03	0,02	-	-	-	-	0,03	0,02	-
		(WHSC)	-	-	0,01	-	-	-	-	-	0,01
		(WHTC)	-	-	0,01	-	-	-	-	-	0,01

Baseline*	Component		Class I/II To the standard of		Class III To the standard of		Class IV To the standard of	
			C	D	C	D	C	D
B2	NO _x	(ESC)	-	-	2,0	-	2,0	-
		(ETC)	-	-	2,0	-	2,0	-
		(WHSC)	-	-	-	0,4	-	0,4
		(WHTC)	-	-	-	0,46	-	0,46

	PM	(ESC)	0,02	-			-	-		0,02	-		
		(ETC)	0,02	-			-	-		0,02	-		
		(WHSC)	-	0,01			-	-		-	0,01		
		(WHTC)	-	0,01			-	-		-	0,01		

* where A, B1, B2 and C correspond to the limit values in Tables 1 and 2 of the 05 series of amendments to Regulation No. 49 and D corresponds to the limit values in the 06 series of amendments to Regulation No. 49.

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Table 2:

Equivalence Matrix for Regulation No. 96 / REC Class I / II

Baseline*	Net Power	Component g/kWh	Class 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 corresponds to that in Regulation No.96 revision n.

Table 3:

Equivalence Matrix for Regulation No. 96 / REC Class III

Baseline*	Net Power	Component g/kWh	Class 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 corresponds to that in Regulation No.96 revision n.

Table 4:
Equivalence Matrix for Regulation No. 96 / REC Class IV

Baseline*	Net Power	Component g/kWh	Class IV									
			H	I	J	K	L	M	N	P	Q	R
E	130 ≤ P ≤ 560	PM	-	-	-	-	0,025	-	-	-	0,025	-
		NO _x	4,0 ⁽³⁾	-	-	-	2,0	-	-	-	0,4	-
F	75 ≤ P ≤ 130	PM	-	-	-	-	-	0,025	-	-	-	0,025
		NO _x	-	4,0 ⁽³⁾	-	-	-	3,3	-	-	-	0,4 ⁽¹⁾
G	37 ≤ P ≤ 75	PM	-	-	-	-	-	-	0,025 ⁽¹⁾	-	-	0,025 ⁽¹⁾
		NO _x	-	-	4,7 ⁽³⁾	-	-	-	3,3 ⁽¹⁾	-	-	-
D	18 ≤ P ≤ 37	PM	-	-	-	0,6 ⁽²⁾	-	-	-	-	-	-
		NO _x	-	-	-	7,5 ⁽²⁾	-	-	-	-	-	-
H	130 ≤ P ≤ 560	PM	-	-	-	-	0,025	-	-	-	0,025	-
		NO _x ⁽³⁾	-	-	-	-	2,0	-	-	-	0,4	-
I	75 ≤ P ≤ 130	PM	-	-	-	-	-	0,025	-	-	-	0,025
		NO _x ⁽³⁾	-	-	-	-	-	3,3	-	-	-	0,4 ⁽¹⁾
J	37 ≤ P ≤ 75	PM	-	-	-	-	-	-	0,025 ⁽¹⁾	-	-	0,025 ⁽¹⁾
		NO _x ⁽³⁾	-	-	-	-	-	-	3,3 ⁽¹⁾	-	-	0,4 ⁽¹⁾
K	19 ≤ P ≤ 37	PM	-	-	-	-	-	-	-	-	-	-
		NO _x ⁽³⁾	-	-	-	-	-	-	-	-	-	-
L	130 ≤ P ≤ 560	PM	-	-	-	-	-	-	-	-	-	-
		NO _x	-	-	-	-	-	-	-	-	0,4	-
M	75 ≤ P ≤ 130	PM	-	-	-	-	-	-	-	-	-	-
		NO _x	-	-	-	-	-	-	-	-	-	0,4
N	56 ≤ P ≤ 75	PM	-	-	-	-	-	-	-	-	-	-
		NO _x	-	-	-	-	-	-	-	-	-	0,4
P	37 ≤ P ≤ 56	PM	-	-	-	-	-	-	-	-	-	-
		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 corresponds to that in Regulation No.96 revision n.

Annex 10

Requirements of the NO_x control diagnostic system of REC requiring a reagent

1. Introduction

This Annex sets out the requirements of the NO_x control diagnostic (NCD) system for RECs that rely on the use of a reagent in order to reduce emissions.
2. Diagnostic requirements
 - 2.1. The NCD system shall be able to identify REC related malfunctions considered by this Annex by means of failure messages stored in the REC computer memory and to communicate that information off-board upon request.
 - 2.2. The NCD system shall record a failure message for each distinct malfunction.
 - 2.3. The NCD system shall conclude whether a malfunction is present.
 - 2.3.1. The malfunction shall be detected within 60 minutes of operation, except for the cases laid down in paragraphs 2.3.1.1. and 2.3.2 of this Annex.
 - 2.3.1.1. In cases where more than 60 minutes running time is required for the monitors to accurately detect and confirm a malfunction, the Approval Authority may permit a longer period for monitoring provided the REC manufacturer justifies the need for the longer period (for example by technical rationale, experimental results, in house experience, etc.).
 - 2.3.2. The malfunction shall be detected within 10 minutes of operation for monitoring the reagent level and the dosing detection for a non-heated REC system.
 - 2.4. Failure messages shall not be erased by the NCD system itself from the REC computer memory until the failure related to that message has been remedied, except for the case laid down in paragraph 6.1.4. of this Annex.
 - 2.5. Any reprogrammable computer codes or operating parameters of the NCD system shall be resistant to tampering and afford a level of protection at least as good as the provisions in ISO 15031-7 (SAE J 2186) or SAE J1939-73
3. NCD family
 - 3.1. The REC manufacturer is responsible for determining the composition of an NCD family. Grouping engines within an NCD family shall be based on good engineering judgement and be subject to approval by the Approval Authority.

Engines that do not belong to the same engine family incl. engines from different engine manufacturers may still belong to the same NCD family.
 - 3.2. Parameters defining an NCD family
 - 3.2.1. An NCD family is characterised by basic design parameters that shall be common to NCD systems within the family.

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- 3.2.2. In order that NCD systems are considered to belong to the same NCD family, the following list of basic parameters shall be similar:
- (a) NO_x emission control systems
 - (b) methods of NCD monitoring
 - (c) criteria for NCD monitoring
 - (d) monitoring parameters (e.g. frequency)
- 3.2.3. These similarities shall be demonstrated by the REC manufacturer by means of relevant engineering demonstration or other appropriate procedures and subject to the approval of the Approval Authority.
- The manufacturer may request approval by the Approval Authority of minor differences in the methods of monitoring/diagnosing the NCD system due to engine configuration variation.
4. Operator warning system
- 4.1. The REC shall include an operator warning system using visual and audible alarms that informs the driver or operator when a low reagent level, incorrect reagent quality, interruption of dosing or a malfunction according to paragraph 10 of this Annex have been detected in accordance with paragraph 2.3 of this Annex and that will lead to activation of the operator inducement system described in paragraph 5 of this Annex, if not rectified in a timely manner.
- 4.1.1. The operator warning system shall not be easily disabled or ignored.
- 4.2. The operator warning system may consist of one or more lamps, or display short messages, including messages indicating clearly:
- the remaining time before activation of the inducement,
 - the amount of inducement, for example the amount of time for restart,
 - the conditions under which vehicle or machine disablement can be cleared.
- 4.3. Upon detection of the malfunction in accordance with paragraph 2.3. of this Annex, a visual warning in accordance with paragraph 4.2. of this Annex shall be activated.
- 4.4. 10 hours after detection of the malfunction, an audible warning shall be activated in addition to the visual warning.
- 4.5. Between 10 hours and 19 hours after detection of the malfunction, the visual and audible warnings shall escalate in intensity.
- 4.6. 19 hours after detection of the malfunction, the driver or operator shall be informed that after an additional hour of operation without having remedied the malfunction, the engine will not start after engine shut off.
- 4.6.1. This warning shall be clearly displayed by
- activating a second lamp, whose meaning is described in the REC manual, or
 - display a message, e.g. "engine will not start after shut-off"

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- 4.7. The operator warning system shall be deactivated when the conditions for its activation have ceased to exist. The operator warning system shall not be automatically deactivated without the reason for its activation having been remedied.
- 4.8. As part of the application for type-approval, the REC manufacturer shall demonstrate the operation of the operator warning system, as specified in paragraph 11 of this Annex.
5. Operator inducement system
- 5.1. The REC shall incorporate an operator inducement system that shall be activated, if failures of the REC system have not been rectified in a timely manner.
- 5.2. The operator inducement system shall be activated 20 hours after detection of the malfunction, unless otherwise noted in paragraphs 6.2 and 7.3. of this Annex.
- 5.3. The direct current to the engine starter (terminal 30 in accordance with DIN 72552) shall be interrupted, as follows:
- 5.3.1. An interruptor switch shall be installed between battery and engine starter, whose operation shall be controlled by the NCD system.
- 5.3.2. The connectors of the interruptor switch shall be made of breakaway safety devices, such as shear bolt, breakaway valve or similar.
- 5.4. After engine shut-off, an engine re-start shall not be possible for **[5]** hours.
- 5.5. As part of the application for type-approval, the REC manufacturer shall demonstrate the operation of the operator inducement system, as specified in paragraph 11 of this Annex.
- 5.6. Upon prior approval of the type approval authority, the REC may be fitted with a means to disable the operator inducement system during an emergency declared by a national or regional government, their emergency services or their armed services.
6. Specific requirements of the operator warning and inducement system
- 6.1. If a malfunction has not been remedied after engine re-start in accordance with paragraph 5.4. of this Annex, the following provisions apply:
- 6.1.1. The operator warning system shall be activated in accordance with paragraph 4.3. of this Annex.
- 6.1.2. The operator inducement system shall be activated in accordance with paragraph 5.3. of this Annex 2 hours after detection of the malfunction in paragraph 6.1.1. of this Annex.
- 6.1.3. After engine shut-off, an engine re-start shall not be possible for 48 hours.
- 6.1.4. Non-erasable failure messages identifying the reason of failures of the REC system shall be stored by the NCD system for at least 400 days.
- 6.1.4.1. The failures messages shall be accessible via a generic scan-tool, as defined in paragraph 0.3.

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- 6.1.5. If the failure has been remedied after the engine shut-off, the NCD system may enable an engine re-start prior to the 48 hours period upon request of a proprietary scan-tool, as defined in paragraph 0.4., using a pass code provided by the REC manufacturer or an authorized dealer upon request,
- 6.1.5.1. The REC manufacturer shall ensure that adequate tools are available on market for service or dealers.
- 6.1.5.2. The provision in paragraph 6.1.5. of this Annex shall not be used more than one time.
- 6.1.5.3. The provisions of paragraph 6.1.4. of this Annex apply.
- 6.2. Non-heated REC system
- 6.2.1. The operator warning system described in paragraph 4.3. of this Annex shall be activated if no reagent dosing occurs at an ambient temperature ≤ 266 K (-7°C) in accordance with paragraph 2.3.2.
- 6.2.2. The operator inducement system described in paragraphs 5.3. to 5.7. of this Annex shall be activated if no reagent dosing occurs within a maximum of 70 minutes after engine start at an ambient temperature ≤ 266 K (-7°C).
7. Reagent availability
- 7.1. Reagent level indicator
- The minimum acceptable performance level for the reagent indicator is that it shall continuously indicate the reagent level whilst the operator warning system referred to in paragraph 4 of this Annex is activated. The reagent indicator may be in the form of an analogue or digital display, and may show the level as a proportion of the full tank capacity, the amount of remaining reagent, or the estimated operating hours remaining.
- 7.2. Activation of the operator warning system
- 7.2.1. The operator warning system shall be activated in accordance with paragraph 4.3. of this Annex when the level of reagent goes below
- (a) 10 percent of the capacity of the reagent tank or a higher percentage at the choice of the REC manufacturer or
- (b) a level corresponding to 12 hours of usage of the vehicle or machine under average conditions of operation.
- 7.2.2. The warning provided shall be sufficiently clear, in conjunction with the reagent indicator, for the driver or operator to understand that the reagent level is low. When the warning system includes a message display system, the visual warning shall display a message indicating a low level of reagent. (for example “urea level low”, “AdBlue level low”, or “reagent low”).
- 7.2.3. Paragraphs 4.4. to 4.6. of this Annex do not apply.
- 7.2.4. The operator warning system shall escalate in intensity when the level of reagent goes below
- (a) 2.5 percent of the capacity of the reagent tank or a higher percentage at the choice of the REC manufacturer or

(b) a level corresponding to 3 hours of usage of the vehicle or machine under average conditions of operation.

This warning shall be clearly displayed by

- activating a second lamp, whose meaning is described in the REC manual, or
- display a message, for example “fill up urea”, “fill up AdBlue”, or “fill up reagent”.

7.2.5. It shall not be possible to turn off the operator warning system until the reagent has been replenished to a level not requiring its activation.

7.3. Activation of the operator inducement system

7.3.1. The operator inducement system described in paragraphs 5.3. to 5.7. of this Annex shall be activated if the reagent tank is empty, or at any level below 2.5 percent of its nominally full capacity at the discretion of the REC manufacturer.

7.3.2. It shall not be possible to turn off the operator inducement system until the reagent has been replenished to a level not requiring their respective activation.

8. Reagent quality monitoring

8.1. The REC shall include a means of determining the presence of an incorrect reagent in the tank, for example NO_x sensor, reagent quality sensor, or equivalent.

8.2. The manufacturer shall specify a minimum acceptable reagent concentration CD_{min}, which results in tailpipe NO_x emissions not exceeding a threshold of [twice the applicable REC type approval NO_x limit] or [an increase of not more than 1] g/kWh above the applicable REC type approval NO_x limit, whichever is the lower.

8.2.1. The correct value of CD_{min} shall be demonstrated during type approval as follows and recorded in the documentation package as specified in Annex 1.

8.2.1.1. The test shall be conducted by performing the hot part of the WHTC or NRTC cycle, whichever applies, using a reagent with the concentration CD_{min}.

8.2.1.2. A WHTC or NRTC preconditioning cycle or REC manufacturer defined preconditioning cycle may be conducted, permitting a closed loop NO_x control system to perform adaptation to the quality of the reagent with the concentration CD_{min}.

8.2.1.3. The NO_x emission resulting from this test shall be lower than the NO_x threshold specified in paragraph 8.2. of this Annex.

8.2.2. Any reagent concentration lower than CD_{min} shall be detected and be regarded, for the purpose of paragraph 8.1. of this Annex, as being incorrect reagent.

8.3. A specific counter ("the reagent quality counter") shall be attributed to the reagent quality. The reagent quality counter shall count the number of operating hours with an incorrect reagent.

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- 8.3.1. Optionally, the manufacturer may group the reagent quality failure together with the failures listed in paragraphs 9 and 10 of this Annex into a single counter.
- 8.4. Activation of the operator warning system
- 8.4.1. The operator warning system shall be activated in accordance with paragraph 4 of this Annex.
- 8.4.2. When the operator warning system includes a message display system, it shall display a message indicating the reason of the warning if technically feasible (for example “incorrect urea detected”, “incorrect AdBlue detected”, or “incorrect reagent detected”).
- 8.5. Activation of the operator inducement system
- 8.5.1. The operator inducement system shall be activated in accordance with paragraph 5 of this Annex.
9. Reagent dosing activity
- 9.1. The engine shall include a means of determining interruption of dosing.
- 9.2. A specific counter shall be attributed to the dosing activity (the "dosing activity counter"). The counter shall count the number of operating hours which occur with an interruption of the reagent dosing activity. This is not required where such interruption is demanded because vehicle or machine operating conditions are such that their emission performance does not require reagent dosing.
- 9.2.1. Optionally, the REC manufacturer may group the reagent dosing failure together with the failures listed in paragraphs 8 and 10 of this Annex into a single counter.
- 9.3. Activation of the operator warning system
- 9.3.1. The operator warning system shall be activated in accordance with paragraph 4 of this Annex.
- 9.3.2. When the warning system includes a message display system, it shall display a message indicating the reason of the warning (e.g. “urea dosing malfunction”, “AdBlue dosing malfunction”, or “reagent dosing malfunction”).
- 9.4. Activation of the operator inducement system
- 9.4.1. The operator inducement system shall be activated in accordance with paragraph 5 of this Annex.
10. Monitoring failures that may be attributed to tampering
- 10.1. In addition to the level of reagent in the reagent tank, the reagent quality, and the interruption of dosing, the following failures shall be monitored because they may be attributed to tampering:
- (i) disconnect reagent dosing valve;
 - (ii) disconnect reagent pump;
 - (iii) failures or disconnect of the NCD system, as described in paragraph 10.1.1. of this Annex.

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- 10.1.1. The NCD system shall be monitored for electrical failures and for removal or deactivation of any sensor that prevents it from diagnosing any other failures mentioned in paragraphs 7 to 9 of this Annex..
- A non-exhaustive list of sensors that affect the diagnostic capability are those directly measuring NO_x concentration, urea quality sensors, ambient sensors and sensors used for monitoring reagent dosing activity, reagent level, or reagent consumption.
- 10.2. A specific counter shall be attributed to each of the monitoring failures considered in paragraph 10.1. of this Annex. The NCD system counters shall count the number of operating hours when the diagnostic capability of the NCD system is not available. Grouping of several faults into a single counter is permitted.
- 10.2.1. Optionally, the manufacturer may group the NCD system failure together with the failures listed in paragraphs 8 and 9 of this Annex into a single counter.
- 10.3. As an alternative to the requirements in paragraph 10.1. of this Annex, the manufacturer may use a NO_x sensor located in the exhaust gas. In this case,
- the NO_x value shall not exceed a threshold of [twice the applicable REC type approval NO_x limit] or [an increase of not more than 1] g/kWh above the applicable REC type approval NO_x limit, whichever is the lower.
 - use of a single failure "high NO_x - root cause unknown" may be used,
- 10.4. Activation of the operator warning system
- 10.4.1. The operator warning system shall be activated in accordance with paragraph 4 of this Annex.
- 10.4.2. When the warning system includes a message display system, it shall display a message indicating either the reason of the warning (for example "reagent dosing valve disconnected", or "critical emission failure").
- 10.5. Activation of the operator inducement system
- 10.5.1. The operator inducement system shall be activated in accordance with paragraph 5 of this Annex.
11. Demonstration requirements
- 11.1. The compliance to the requirements of this Annex shall be demonstrated during type-approval by performing:
- (a) a demonstration of the operator warning system activation;
 - (b) a demonstration of the operator inducement system activation.
- 11.2. Demonstration of the operator warning system activation.
- 11.2.1. The compliance of the warning system activation shall be demonstrated by performing two tests: lack of reagent, and one failure category considered in paragraphs 8 to 10 of this Annex.
- 11.2.2. For the purpose of demonstrating the activation of the warning system in case of a wrong reagent quality, a reagent shall be selected with a dilution of the

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- active ingredient at least as dilute as that communicated by the manufacturer (CDmin) according to the requirements of paragraph 8.2. of this Annex
- 11.2.3. For the purpose of demonstrating the activation of the warning system, the selection shall be performed on the basis of a list of potential failures provided by the REC manufacturer to the type approval authority, and agreed by the type approval authority.
- 11.2.4. For the purpose of this demonstration, a separate test shall be performed for each of the failures considered in paragraph 11.2.1. of this Annex.
- 11.2.5. During a test, no failure shall be present other than the one addressed by the test.
- 11.2.6. Prior to starting a test, all failure messages shall have been erased.
- 11.2.7. At the request of the manufacturer, and with the agreement of the approval authority, the failures subject to testing may be simulated.
- 11.2.8. Demonstration test procedure for failures other than lack of reagent
- 11.2.8.1. Once the failure has been installed or simulated, the NCD system shall respond to the introduction of a failure within three consecutive hot WHTC or hot NRTC cycles, as applicable.
- 11.2.8.2. Each individual test cycle in the demonstration test may be separated by an engine shut-off.
- 11.2.9. Demonstration test procedure in case of lack of reagent
- 11.2.9.1. The REC system shall be operated over one or more hot WHTC or hot NRTC cycles, as applicable, at the discretion of the REC manufacturer.
- 11.2.9.2. The demonstration shall start with a level of reagent in the tank to be agreed between the REC manufacturer and the approval authority but representing not less than 10 per cent of the nominal capacity of the tank.
- 11.2.10. The demonstration of the warning system activation is deemed to be accomplished if, at the end of each demonstration test performed according to paragraphs 11.2.8. and 11.2.9. of this Annex, the warning system has been properly activated in accordance with paragraph 4 of this Annex..
- 11.2.11. The manufacturer shall be permitted to simulate, in agreement with the approval authority, the achievement of a certain number of operating hours.
- 11.3. Demonstration of the operator inducement system activation
- 11.3.1. The demonstration of the operator inducement system shall be done by tests performed on an engine test bench.
- 11.3.2. If the REC manufacturer chooses, and subject to the agreement of the approval authority, the demonstration tests may be performed on a complete vehicle or machine either by mounting the vehicle or machine on a suitable test bed or by running it on a test track under controlled conditions.
- 11.3.3. The compliance of the inducement system activation shall be demonstrated by performing two tests: lack of reagent, and one failure category considered in paragraphs 8 to 10 of this Annex.

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- 11.3.4. For the purpose of this demonstration, the failures selected for the warning system activation shall be used.
- 11.3.5. The demonstration starts when the warning system has been activated as a result of the detection of a failure selected by the type approval authority.
- 11.3.6. When the system is being checked for its reaction to the case of lack of reagent in the tank, the engine shall be run until the reagent tank is empty, or has reached the level of 2.5 per cent of the nominal full capacity of the tank or the value declared by the manufacturer in accordance with paragraph 7.3.1. of this Annex
- 11.3.6.1. The manufacturer may, with the agreement of the approval authority, simulate continuous running by extracting reagent from the tank, either whilst the engine is running or is stopped.
- 11.3.7. When the system is checked for its reaction in the case of a failure other than a lack of reagent in the tank, the engine shall be run for the relevant number of hours indicated in paragraph 5.2. of this Annex.
- 11.3.8. The manufacturer shall be permitted to simulate, in agreement with the approval authority, the achievement of a certain number of operating hours.
- 11.3.9. The demonstration of the inducement system activation is deemed to be accomplished if, at the end of each demonstration test performed according to paragraphs 11.3.4. and 11.3.5. of this Annex, the inducement system has been properly activated in accordance with paragraph 5 of this Annex.

Annex 11

Installation and Operation instructions

1. The REC manufacturer must provide written information and installation instructions for use by retrofitters, and operation and maintenance instructions for use by owners and operators. These instructions must
 - a) address the safety hazards identified in the course of the assessment undertaken in accordance with paragraph 18.3 so that, to the greatest extent possible, fitting of the REC in accordance with the instructions will eliminate those hazards and will
 - i) maintain the level of safety provided by the vehicle or machine when it was first placed on the market,
 - ii) maintain the vehicle or machine in a state of conformity with all legal health and safety requirements,
 - b) explicitly list and describe any identified safety hazards that will not be fully eliminated by following the fitting instructions and that will have to be addressed by the application of appropriate skills and good engineering judgement on the part of the retrofitter.
 - c) clearly address each of the points in paragraphs 3 and 4 of this annex.
2. Preparation and demonstration requirements
 - 2.1. The instructions and guidelines must be written in the language of the country in which the REC is sold or in which the REC is expected to be used, and must be in clear language appropriate to the intended readership.
 - 2.2. The REC manufacturer must be able to demonstrate to the type-approval authority where each of the relevant points in this annex is addressed, but may address these points in any way that meets the requirement for clarity. There is no requirement for the wording or layout of this annex to be reproduced.
 - 2.3. Technical or legal language should not be used in documents intended for readers, such as end users, who are unlikely to be familiar with it. Where the use of such language is considered essential in such documents, it should be accompanied by a clear explanation of its intent.
 - 2.3. The REC manufacturer is encouraged to consider, in the interests of clarity, the use of local idioms and usages where a language is used in more than one country or region, and the use of industry-specific terms where a REC is intended for use on vehicles or machines specific to that industry.
3. Instructions for the retrofitter
 - 3.1. The instructions for the retrofitter should include,
 - a) specific instructions related to any specific vehicle or machine application for which the REC is intended,

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- b) general instructions and guidelines, when appropriate, which will permit the REC to be properly fitted to any vehicle or machine in the range for which it is approved,
 - c) a clear indication of the range of applications for which the REC is approved, and of the range of vehicle or machine applications for which it may be safely used if that is different,
 - d) an indication of the level of skill and education required in order to perform the fitting operation,
 - e) a level of detail at least sufficient to permit an appropriately skilled and educated person to perform the work.
- 3.2. The instructions shall state that retrofitting with a REC must be performed in accordance with the installation instructions provided by the REC manufacturer, and that any additional instructions provided by the vehicle or machine manufacturer, public authorities, or other competent parties must also be taken into consideration.
- 3.3. The instructions shall state that the vehicle or machine to be retrofitted must be in a properly maintained condition, and that 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.
- 3.4. The instructions shall state that all necessary care must be taken in order to ensure that the safety in use of the vehicle or machine is not impaired by the fitting of the REC, and that it remains conformant with local laws and regulations. The instructions shall, in particular,
- a) draw attention to any additional safety hazards to operators or bystanders, such as high surface temperatures or electrical voltages, that are associated with the REC, and propose measures for reducing the risks associated with them.
 - b) warn against the installation of the REC, or any systems associated with it, in such a way as to interfere with the field of vision of the operator of a vehicle or machine, or with the visibility of any gauges or indicators, or with access to any controls.
 - c) warn that the extent of the liability of the person or company fitting the REC for any subsequent accident or failure will depend upon local laws and customs, and may extend beyond liability for failures of or directly attributable to the REC.
- 3.5. The instructions shall draw attention to the fact that any modification made to an engine enclosure or access panel may increase the noise emitted by the vehicle or machine, that increases in noise may be forbidden by local laws, and that increases in noise may have implications for the health and safety of operators and bystanders.
4. Instructions for the owner and operator
- 4.1. The instructions for the owner and operator should include both specific instructions related to any vehicle or machine application for which the REC

is intended and, when appropriate, general instructions related to its use with any vehicle or machine in the range for which it is approved.

- 4.2. The instructions shall 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.
- 4.3. The instructions shall specify whether any reagents or additives need to be refilled by the vehicle or machine operator between normal maintenance intervals, and to indicate a likely rate of reagent consumption.
- 4.4. The instructions shall specify the type and quality of any consumable reagents or additives used.
- 4.5. The instructions shall remind the owner and operator of the vehicle or machine that, where the fitting of the REC is a condition for its operation 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 constitute a breach of contract or be a criminal offence.

Annex 12

Specific requirements regarding the approval of a REC with respect to the emission limits set out in the 06 series of amendments of Regulation No. 49

1. Introduction

This Annex sets out the specific requirements for the approval of a REC fitted to an engine or engine system, for the purpose of meeting the emission limits set out in the 06 series of amendments of Regulation No. 49.
2. Specific requirements
 - 2.1. The retrofitted engine system shall meet the following specific requirements
 - 2.1.1. The limits set out in table 1, paragraph 5.3. of the 06 series of amendments of Regulation No. 49.
 - 2.1.2. The technical requirements set out in paragraphs 6.10 and 6.11 of Annex 4 to the 06 series of amendments of Regulation No. 49, regarding crankcase emissions.
 - 2.1.3. The requirements for the verification of the durability of engine systems, as lied down in Annex 7 to the 06 series of amendments of Regulation No. 49.
 - 2.1.4. The On-board diagnostic system (OBD) requirements set out in Annexes 9A and 9B to the 06 series of amendments of Regulation No. 49.
 - 2.1.5. The specific requirements to limit off-cycle emissions and in-use emissions, as lied down in Annex 10 to the 06 series of amendments of Regulation No. 49.
 - 2.1.6. The requirements to ensure the correct operation of the NO_x control measures, as lied down in Annex 11 to the 06 series of amendments of Regulation No. 49.
 - 2.1.7. Notwithstanding paragraph 8.6.2. of this regulation, for Class III and Class IV RECs, emissions of ammonia shall not exceed a mean value of 10 ppm when measured using the procedures defined in Appendix 7 to Annex 4 of the 06 series of amendments to Regulation 49.