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Retrofit Emission Control Devices (REC)

Proposal for a 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 Chair of the informal working group on Retrofit Emission Control devices (REC)*

The text reproduced below was prepared by the chairman of the informal working group on Retrofit Emission Control devices (REC) regarding a proposal for a new Regulation on REC.

* In accordance with the programme of work of the Inland Transport Committee for 2010–2014 (ECE/TRANS/208, para. 106 and ECE/TRANS/2010/8, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

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

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 (CI) 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 M_2, M_3 and N vehicles[1] and their CI engines, excluding those vehicles approved according to Regulation No. 83;

2.2. On CI engines having a net power higher than 18 kW but not more than 560 kW installed in non-road mobile machinery[1], operated under variable speed;

2.3. On CI engines having a net power higher than 18 kW but not more than 560 kW installed in non-road mobile machinery[1], operated under constant speed;

2.4. On CI engines having a net power higher than 18 kW but not more than 560 kW installed in category T vehicles[1].

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.

[1] As defined in the Consolidated Resolution on the Construction of Vehicles (R.E.3.), document ECE/TRANS/WP.29/78/Rev.2, para. 2. - www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29resolutions.html.

3.3. "*Application range*" means the range of engines to which a retrofit emission control device (REC) approved in accordance with this 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 NO_2 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, and which does not increase the direct tailpipe NO_2 emissions by more than the per centage specified in paragraph 8.4.2 based on the engine baseline emission NO_2 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 aftertreatment system that occurs either permanently or at least once per applicable test cycle.

3.9. "*DeNO_X system*" means an exhaust aftertreatment system designed to reduce emissions of oxides of nitrogen (NO_X) (for example, passive and active lean NO_X catalysts, NO_X absorbers, 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 aftertreatment the engine baseline emissions are equal to the engine out raw emissions. For engines with aftertreatment the engine baseline emissions are equal to the tailpipe emissions downstream of the aftertreatment 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 No. 49 or Paragraph 7 of Regulation No. 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. "*Gaseous pollutants*" means carbon monoxide, hydrocarbons (assuming a ratio of $CH_{1,85}$ for diesel), oxides of nitrogen (NO_X, expressed as NO_2 equivalent) and nitrogen dioxide (NO_2).

3.17. "*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.

3.18. "*Manufacturer*" means the person or body who is responsible to the Type Approval Authority for all aspects of the type-approval and can demonstrate that it possesses the features required and the necessary means to achieve quality assessment and 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. "*Installer*" means a person or body who is responsible for the correct and safe installation of the approved REC.

3.20. "*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.

3.21. "*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.

3.22. "*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.

3.23. "*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.

3.24. "*NRTC*" means a test cycle consisting of 1,173 second-by-second transient modes defined in, and to be applied in accordance with, the relevant series of amendments to Regulation No. 96.

3.25. "*On-board operator warning system*" means a device that detects incorrect operation or removal of the REC.

3.26. "*Parent engine*" means an engine selected from an engine family in such a way that its emissions characteristics will be representative for that engine family.

3.27. "*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.

3.28. "*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.

3.29. "*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.

3.30. "*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.

3.31. *"Particle number*" means the number of particles which is defined in the relevant series of amendments to Regulation No. 49.

3.32. "*Reagent*" means any medium that is stored on-board the vehicle in a tank and provided to the exhaust aftertreatment system (if required) upon request of the emission control system.

3.33. "*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.

3.34. "*Reduction level*" means a reduction efficiency in per cent 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.

3.35. "*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.

3.36. "*Scan-tool*" means an external test equipment used for off-board communication with the NCD system.

3.36.1. "*Generic scan-tool*" means a scan-tool, which is publicly available, and which shall be capable to read failure messages.

3.36.2. "*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.

3.37. "*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.

3.38. "*WHTC*" means a test cycle consisting of 1,800 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 4 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 shall 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 approval[2];

(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 4. 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;

[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.

(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.

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 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.

7.3. 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 paragraphs 7., 8. and 9. 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.

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

7.5. 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.

7.5.1. A particulate reduction REC shall be equipped with a monitoring device that detects incorrect operation or removal of the REC and that triggers an audible and/or visual alarm to the operator. For reagent based particulate reduction REC the monitoring device may interrupt the input of any reagent or additive, if necessary. The warning system can be based for example on the continuous measurement of the engine exhaust back-pressure

7.5.2. Specific requirements applicable to NO_X reduction RECs are provided in paragraph 7.7. and Annex 10.

7.5.2.1. 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.

7.5.3. Combined PM and NO_X reduction RECs (Class IV RECs) shall meet the provisions of paragraphs 7.5.1., 7.5.2. and 7.5.2.1.

7.6. Specific requirements for REC requiring a reagent or additive.

7.6.1. 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.

7.6.2. 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.

7.6.3. 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 shall be specified by the REC manufacturer in Annex 1.

76.4. Detailed written information fully describing the functional operation characteristics of the operator warning system defined in paragraph 4. of Annex 10 and of the operator inducement system defined in paragraph 5. of Annex 10 shall be provided to the Type Approval Authority at the time of type approval.

7.6.5. Reagent freeze protection

7.6.5.1. 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 7.6.5.2.2. A non-heated system shall meet the requirements of Annex 10, 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.

7.6.5.2. Reagent tank and dosing system

7.6.5.2.1. 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.

7.6.5.2.2. Design criteria for a heated system

7.6.5.2.2.1. 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.

7.6.5.2.2.2. After the soak period in paragraph 7.6.5.2.2.1., 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.

7.6.5.2.2.3. At the conclusion of the test procedure in paragraph 7.6.5.2.2.2., the reagent dosing system shall be fully functional.

7.6.5.2.3. 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.

7.7. Requirements on NO_X control measures for REC requiring a reagent

7.7.1. 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 1.

7.7.2. 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.

7.7.2.1. The NCD system shall be operational at

(a) Ambient temperatures between 266 K and 308 K (-7 °C and 35 °C);

(b) All altitudes below 1600 m;

(c) Engine coolant temperatures above 343 K (70 °C).

This paragraph 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).

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

7.8. Maintenance requirements

7.8.1. 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.

7.8.2. 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.

7.8.3. 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.

7.8.4. 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.

7.8.5. 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.

7.8.6. 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.

7.8.7. 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.

7.9. The approval shall be conditional upon the following sub-paragraphs.

7.9.1. The manufacturer providing written maintenance instructions to be given by the installer to the driver or operator.

7.9.2. The manufacturer providing installation documents for the REC.

7.9.3. 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.

7.9.4. The manufacturer providing a written statement to the installer, to be given to the driver or operator, on the normal operating conditions (temperature range, environmental conditions, …) within which the REC will operate correctly.

8. Performance requirements

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

(a) The emission limit values as specified in paragraph 8.2.;

(b) The reduction levels as specified in paragraph 8.3.;

(c) The NO_2 emission requirements as specified in paragraph 8.4.;

(d) The secondary emissions requirements as specified in paragraph 8.6.

8.2. Limit values

The retrofitted engine system shall not exceed the emission limits for the relevant pollutants (NO_X or PM or both as appropriate for the REC Class) of a more stringent emission stage as specified in Regulation No. 49 or No. 96 as appropriate and measured using the test procedure(s) associated with the limit values to be achieved. The retrofitted engine system shall meet at least the emission 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.

8.2.2. In the case of an engine not type-approved in accordance with the requirements of either Regulation No. 49 or Regulation No. 96, the emissions of each of the regulated pollutants (CO, HC, NO_X, and PM) in the initial condition shall not exceed the limit values for the emissions stage immediately below that for which certification of the REC is sought.

8.2.3. In the case of an engine where no more stringent category is defined in Regulation No. 49 or No. 96 (as appropriate) the requirements of paragraph 8.3. shall be applied.

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 1:

Table 1
Reduction levels

	Minimum reduction efficiency (%)	
	PM mass	*NO_X*
Reduction level 00	50	60

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 agricultural and forestry 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 1 of this Regulation shall be met.

8.3.4. The reduction efficiency shall be calculated from the measured emissions of the relevant pollutant downstream of the REC (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:

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

8.4. NO_2 emissions requirements

8.4.1. For a Class I REC, there shall be no increase in NO_2 emissions above the NO_2 baseline emissions, measured as defined in Annex 5.

8.4.2. For a Class II REC, the NO_2 incremental increase shall not be more than [30][20] per centage points greater than the level recorded when no REC is fitted (baseline). As an example, if baseline NO_2 is 10 per cent of NO_X, the maximum permitted NO_2 emission with the REC is [40][30] per cent of NO_X measured as defined in Annex 5.

8.4.3. For Class III RECs, there shall be no increase of NO_2 emissions measured in g/kWh and as defined in Annex 6.

8.4.4. For Class IV RECs, there shall be no increase of NO_2 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 No. 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.

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 M_2 and M_3 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 per cent idle, 10 per cent transient operation, 75 per cent high speed-high load operation, and 5 per cent 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:

(a) 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 when appropriate reagent or additive required by the REC device, 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 shall 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;

(b) 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 Type Approval Authority.

9.5. The REC system shall 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 3.

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 ±20 per cent of the test engine;

(ii) Method of aspiration (turbocharged or naturally-aspirated engine);

(iii) With or without EGR;

(iv) Whether a constant speed or a variable speed engine[3];

(v) Engine baseline emission stage; and

(vi) With or without an aftertreatment system.

10.4. The application range shall not be extended to engines with a baseline emission stage less stringent than the baseline emission stage of the test engine.

10.5. If the applicant can prove that a REC tested for vehicles of Category M_2, M_3 and N and their CI engines, is also designed for use in the same structural manner on CI engines for use in non-road mobile machinery or Category T vehicles and the test engine in accordance with 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 CI engines for use in non-road mobile machinery and Category T vehicles.

Extending the range of a REC that has been approved for use with CI 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.

11. Modifications to engine baseline emissions

11.1. Any modifications of engine operation parameters which might affect the engine baseline emissions must be kept within the limits specified by the original engine manufacturer (for example maximum allowable exhaust gas back pressure or limits set for impact of external devices upon the electrical or data handling systems).

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 aftertreatment 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:

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

(i) The requirements of paragraph 8.4. are met; and

(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;

(c) The installation of temperature and/or pressure measuring probes at the entrance of the NOx reduction REC system including the dosing unit.

11.4. Subject to the requirements of paragraph 11.1. being met, modifications downstream of an original aftertreatment system are permitted.

11.5. 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 per cent and 60 per cent 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 shall 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 (for example 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 No. 49 and Regulation No. 96.

13.2. If a heated chemiluminescent detector (CLD) is used for the determination of NO_2 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 No. 49 or Regulation No. 96 as appropriate, and the absolute converter efficiencies are shown to be within 3 per cent 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);

(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/m^3);

(e) Maximum volumetric concentration of catalytically active materials of the particulate reduction system including upstream catalysts (if fitted) (grams/m^3);

(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 shall be within ± 40 per cent 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 shall 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) shall be the same as those on the tested device, or shall 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 shall be within ±40 per cent 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 shall 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 shall not be considered to be in the same family as devices where the two activities are performed on separate substrates.

17. Fuel and specific 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 Type 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 2.3 and 3.3, Annex 6 paragraphs 2.3 and 3.3.) shall be not more than 4 per cent 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 vehicle[4] will be considered to fulfil this requirement.

20. Installation of a REC

20.1. The REC manufacturer shall 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;

(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.

20.3. The REC manufacturer shall demonstrate to the Type Approval Authority. The existence of adequate procedures to select, train and monitor authorised REC installers.

21. Modification and extension of approval of a REC

21.1. Every modification relevant in the context of this Regulation of the REC shall be notified to the Type Approval Authority, which granted the REC type approval. The Type Approval Authority will then assess whether or not

[4] Road vehicles, for this purpose, are category M_2, M_3 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.2), excluding those vehicles approved according to Regulation No. 83.

the REC still complies with the requirements for inclusion in the appropriate REC family.

The Type Approval Authority may require a further test report from the Technical Service responsible for conducting the tests in order to assist in its assessment.

21.2. 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.

21.3. 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.

21.4. The Type Approval 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.

22. Conformity of production

22.1. 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).

22.2. The measures taken to guarantee conformity of production shall fulfil the requirements of paragraph 2 of appendix 2 to the 1958 Agreement.

22.3. Special requirements

(a) The checks as meant in paragraph 2.2. of the appendix to the 1958 agreement include the checks on conformity with the criteria of article paragraphs 7. and 8. of this Regulation.

(b) For the application of paragraph 2.4.4. of appendix 2 to the 1958 Agreement the tests described in the paragraphs 8.2., 8.3. and 8.4.of this Regulation may be carried out.

22.4. Before type approvals can be granted, the manufacturers shall submit the following data on conformity of production for the purpose of the initial assessment:

(a) A completed and signed application form, according to a model to be provided by the Type Approval Authority;

(b) A description of the requested information, according to the application form;

(c) A copy of the ISO9001:2000 certificate, or any equivalent quality system, with a relevant scope.

22.5. Based on this information manufacturers who have a certified quality system may be admitted, to the Type Approval procedure, receiving an Initial Assessment Statement based on the appraisal of documents.

22.6. In case the manufacturer does not have a certified quality system, a company assessment is carried out based on ISO9001:2000, including Conformity of Production aspects.

22.7. At least the following aspects of ISO9001:2000 are to be described and verified:

(a) Quality management system;

(b) Responsibilities of the board;

(c) Management of resources;

(d) Realisation of the product;

(e) Measurement, analysis and improvement.

22.8. To confirm the existence of adequate measures and procedures for an effective control on Conformity of Production the manufacturer receives a Compliance Statement, at the published certificate fee.

22.9. The statement has a stated validity.

22.10. Before the expiration of the validity of both statements the Type Approval Authority will carry out a Conformity of Production audit by process control at the manufacturer, to verify the effectiveness of the applied Conformity of Production controls.

22.11. In practising its surveillance on the Conformity of production the Type Approval Authority shall take into consideration the surveillance carried out by the qualified authorities of other parties to the 1958 Agreement.

23. Penalties for non-conformity of production

23.1. The type-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 Type Approval Authority which granted the type-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 Type Approval Authorities

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 Type Approval

Authorities which grant type-approval and to which forms certifying type-approval or extension or refusal or withdrawal of type-approval, issued in other countries, are to be sent.

Annex 1

Information document

Information document No..…... of Regulation No. nnn 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 shall be supplied in appropriate scale and sufficient detail on size A4 or on a folder of A4 format. Photographs, if any, shall 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 shall 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) performance[1]:.....

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 paragraph 8.3.: .....

2.7. Is the REC intended to be compatible with OBD requirements: Yes/No[2].

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 and particulate reduction REC family

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 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 including material type, 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): .....

3.3.3.2. Physical design of the substrate: .....

3.3.3.3. Cell density, porosity, mean pore size and pore size distribution: .....

.....

[1] As defined in paragraph 8.2 of this Regulation.

[2] Strike out what does not apply.

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): .....

3.3.4.2. Physical design of the substrate: .....

3.3.4.3. Cell density: .....

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(s) or additive(s): .....

.....

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 paragraph 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 and NO_x reduction REC family

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, drawings and part lists 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 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): .....

.....

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): .....

4.3.3.2. Physical design of the substrate: .....

4.3.3.3. Cell density: .....

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): .....

4.3.4.2. Physical design of the substrate: .....

4.3.4.3. Cell density: .....

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/m^3): .....

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/m^3): .....

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

4.3.8. Volume of each active component: .....

4.4. Method or system of regeneration (if applicable) (comprehensive 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: .....

4.5.4. Control strategy (for example delay periods, reagent dosing rates, positioning and characteristics of sensors, flow characteristics and reagent introduction location): .....

4.6. Heated system (Yes/No[2])

4.6.1. Temperature control method (catalytic, thermal or electrothermal): .....

4.7. Description of NO_x control diagnostic system (in accordance with Annex 10):

.....

4.8. Description of any modifications to the original engine or emissions control system as defined in paragraph 11. of this Regulation: .....

.....

4.9. Normal operating temperature: ..... (K) and pressure range: ..... (KPa)

4.10. Use of insulation (Yes/No[2])

4.10.1. Design and characteristics of the insulation:.....

5. Characteristics of the NO_x and PM reduction REC and the NO_x and PM reduction REC family

5.1. Dimensions, shape(s) and active volume(s) 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, drawings and part lists 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.

5.3.1. 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) and of the PM reduction

active element (for example metallic or ceramic material and material type, 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): .....

5.3.3.2. Physical design of the substrate(s): .....

5.3.3.3. Working principle of the PM reduction active element (for example metallic or ceramic material including material type, barrier filtration or aerodynamic separation) .....

5.3.3.4. Cell density, porosity, mean pore size and pore size distribution of the PM reduction active element: .....

.....

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): .....

5.3.4.2. Physical design of the substrate: .....

5.3.4.3. Cell density: .....

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: .....

5.3.8. Volume of each active component: .....

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

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: .....

.....

5.5. Method and control strategy for introducing additives or reagents (if used):

.....

5.5.1. Type and concentration of reagent(s) or additive(s) (if used): .....

.....

5.5.2. Frequency of reagent(s) or additive(s) refill: .....

5.5.3. Normal operational temperature range of NO_x reduction reagent(s): ..... (K)

5.5.4. Control strategy (for example delay periods, reagent dosing rates, positioning and characteristics of sensors, flow characteristics and reagent introduction location): .....

5.6. Heated system (Yes/No[2])

5.6.1. Temperature control method (catalytic, thermal or electrothermal): .....

5.7. Description of PM reduction system monitoring (in accordance with paragraph 7.5.1.):.....

5.8. Description of NO_x control diagnostic system (in accordance with Annex 10.):

.....

5.9. Description of any modifications to the original engine or emissions control system as defined in paragraph 11. of this Regulation: .....

.....

5.10. Normal operating temperature: ..... (K) and pressure range: ..... (KPa)

5.11. Use of insulation (yes/no[2])

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

.....

.....

.....

concerning[2]: Approval granted
Approval extended
Approval refused
Approval withdrawn
Production definitively discontinued

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

Type-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:.....

.....

[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.

7.1. Has the REC demonstrated compatibility with OBD requirements: Yes/No[2]

8. Location and method of affixing of the approval mark: .....

9. Submitted for type-approval on: .....

10. Technical Service responsible for approval tests: .....

10.1. Date of test report: .....

10.2. Number of test report: .....

11. Type-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: .....

14.1. Designed for fitment to an engine meeting the emissions requirements of (Regulation and Stage): .....

14.3. The engine + REC system continues to meet the requirements of the above Regulation and Stage for other pollutants regulated by that Regulation and Stage (yes/no[2])

14.2. The engine + REC system meets the requirements of (Regulation and Stage)

..... for NO_x / PM / NO_x and PM[2].

15. Annexed to this communication is a list of documents in the type-approval file deposited at the administrative services having delivered the type-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 NO_2 emissions and of emissions of the other regulated pollutants: .....

16.6. Declaration on noise emissions: .....

.....

17. Place: .....

18. Date: .....

19. Signature: .....

Annex 3

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

(Type-approval No. ..... Extension No. .....)

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

Engine No.	*1*	*2*	*n*
Make			
Type			
Engine			
Power			
Category			

2. Test results:

3. Engine type(s) for which the REC device is qualified (application range):

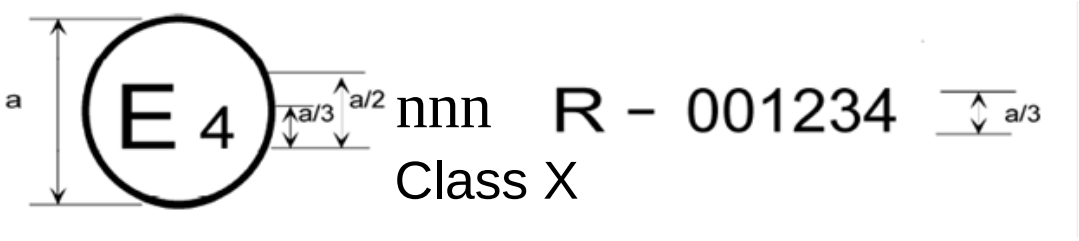
Number			
Vehicle or engine manufacturer			
Model year from/to			
Engine type			
Capacity / cylinder (cm^3)			
Capacity VH (cm^3)			
engine net power (kW with min^{-1})			
Engine baseline emissions			
Silencer replaced			
Type identification of the REC			
REC Type and Reduction Level			

Annex 4

Arrangement of the REC System Type-Approval mark

Model A

(See paragraph 5 of this Regulation)



a = 8 mm min

The above example type-approval mark affixed to a REC shows that the type concerned has been approved in the Netherlands (E4), pursuant to Regulation No. nnn under type-approval No. 001234. The first two digits of the type-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 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 NO_2 emissions:

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 and specific fuel consumption 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.

2.3. The specific fuel consumption (g/kWh) shall be established by performance of the emissions test in paragraph 2.2. of this Annex.

3. Determination of emissions, fuel consumption 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 paragraph 8.3. of this Regulation.

3.3. The specific fuel consumption (g/kWh) shall be established by performance of the emissions test in paragraph 3.2. of this Annex.

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 shall be carried out. The test cycle used shall 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, shall 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 shall present a robust technical case to the Type 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 4.6. of this Annex 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 25 per cent 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:

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

Where:

n = number of measured values

x = respective single measured value

4.4. 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 per cent and 75 per cent 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 iterations of the appropriate test cycle (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 per cent for the gaseous emissions or more than 20 per cent for the particulate mass or particle 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.

4.5. 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.

4.5.1. 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 NO_2 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 NO_2 and NO_X mass emissions is to be determined by simultaneous measurement in accordance with paragraph 13.2. of this Regulation.

4.6. 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.)

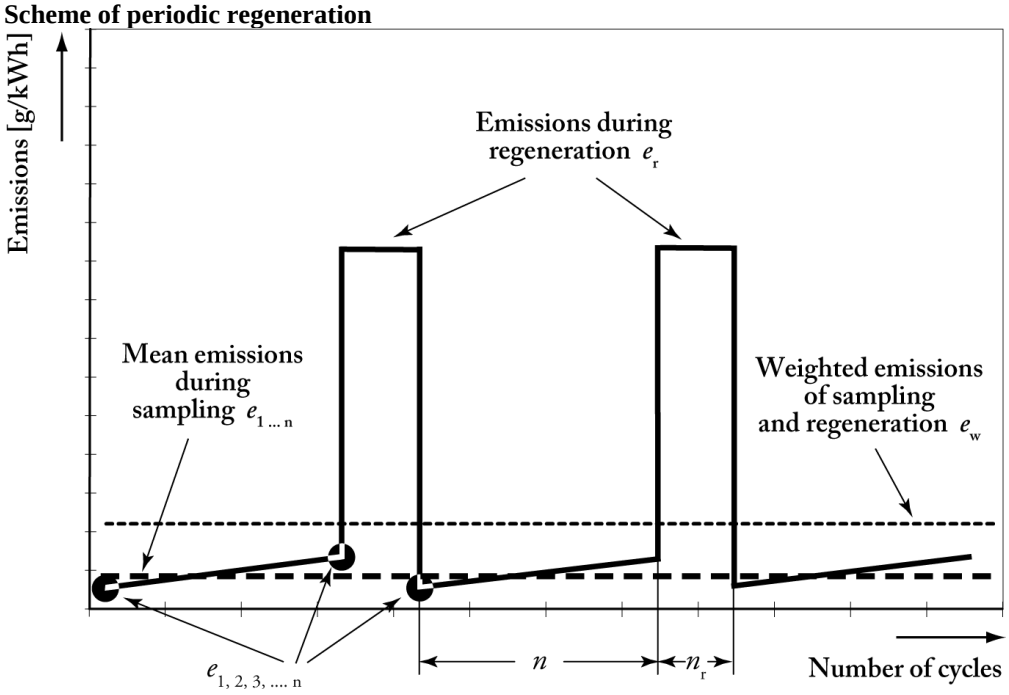
For a regeneration test, the manufacturer shall provide a particulate reduction REC system that has been loaded with particulate matter. As an option, the manufacturer may run consecutive test cycles as set out in paragraph 4.4. until the particulate reduction REC is loaded. Emissions measurement is not required on cycles run for the purposes of loading the REC with particulate matter.

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

During the regeneration test, all the data needed to detect regeneration shall be recorded (CO or NO_X emissions, temperature before and after the REC, exhaust back pressure, and any other relevant parameters). It is permissible for the applicable emission limits to be exceeded during the regeneration process. The test procedure is shown schematically in Figure 1.

Figure 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.

4.6.1. Regulated pollutants

The emissions of regulated pollutants (CO, HC, PM and NO_X) shall not exceed the limit values for the standard to which the engine was originally type approved, both in the initial condition and in the retrofitted condition. The NO_2 / 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 NO_2 and NO_X-mass emissions is to be determined by simultaneous measurement in accordance with paragraph 4.7.2. of this Annex and paragraph 13. of this Regulation.

4.6.1.1. Weighted particulate emissions

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

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

Where:

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

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

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

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

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

or

$k_{Ur} = \text{PM mass} - \text{PM mass}_{wor}$ (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 shall be taken at equal intervals and an arithmetical average taken.

4.6.1.2. Weighted gaseous emissions

The emission of gaseous components Mgas (g/kWh) for periodically regenerating systems is determined as follows.

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

Where:

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

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

Mgas_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:

$k_r = Mgas / Mgas_{wor}$ (multiplicative adjustment factor)

or

$k_{Ur} = Mgas - Mgas_{wor}$ (upward adjustment factor)

or

$k_{Dr} = Mgas - Mgas_{r}$ (downward adjustment factor)

4.7. Determination of NO_2 emissions

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

4.7.1. Selection of the particulate reduction REC for NO_2 determination.

The REC used for testing may be different from the REC used in paragraph 4.5. of this Annex. 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 charge of platinum with the maximum total charge of catalytically active material 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 125 hours.

4.7.2. Determination of NO_2 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 per cent of the mean, then an additional test cycle should be run.

The calculation of the NO_X and NO_2 emissions shall be determined for CI engines used in vehicles of category M and N over the complete WHTC cycle.

For CI 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 NO_2 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 shall 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 shall 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 shall 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 shall 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 shall 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 shall 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 and the emissions of NO_2 the appropriate test cycle is that defined in paragraph 8.3. of this Regulation.

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 NO_2 emissions:

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 and specific fuel consumption 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.

2.3. The specific fuel consumption (g/kWh) shall be established by performance of the emissions test in paragraph 2.2. of this Annex.

3. Determination of emissions, specific fuel consumption 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 paragraph 8.3. of this Regulation.

3.3. The specific fuel consumption (g/kWh) shall be established by performance of the emissions test in paragraph 3.2. of this Annex.

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. of this Regulation are met.

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.

4.2. The NO_2 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 NO_2 and NO_X mass emissions is to be determined by simultaneous measurement in accordance with paragraph 13.2. of this Regulation.

4.3. Determination of NO_2 emissions

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

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 per cent of the mean, then an additional test cycle shall be run.

The calculation of the NO_X and NO_2 emissions shall be determined for CI engines used in vehicles of category M and N over the complete WHTC cycle.

For CI 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 NO_2 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 shall 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 shall 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 shall 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 shall 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 shall 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 shall 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 and the emissions of NO_2 the appropriate test cycle is that defined in paragraph 8.3. of this Regulation.

Annex 7

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

Testing of a NO_X and PM reduction REC is performed in the following series of stages, including an assessment of the emissions of secondary pollutants and determination of the NO_2 emissions.

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 and specific fuel consumption without REC fitted

   Tests of a PM and NO_X reduction REC shall meet the relevant requirements for testing for each of the pollutants set out in paragraph 2. of Annex 5 and paragraph 2. of Annex 6 to this Regulation.

3. Determination of emissions, specific fuel consumption and reduction efficiency with the REC fitted after service accumulation run.

   Tests of a PM and NO_X reduction REC shall meet the relevant requirements for testing for each of the pollutants set out in paragraph 3. of Annex 5 and paragraph 3. of Annex 6 to this Regulation.

4. Assessment criteria for NO_X and PM reduction REC

4.1. Tests of a PM and NO_X reduction REC shall meet the relevant requirements for testing for each of the pollutants set out in paragraph 4. of Annex 5 and paragraph 4. of Annex 6 to this Regulation, except as indicated in paragraph 4.2. of this Annex.

4.2. For Class IV REC with a particulate reduction REC installed upstream of the NO_x reduction REC, paragraph 4.7.1. of Annex 5 to this Regulation shall not apply.

5. Test cycles.

5.1. Tests of PM and NO_X reduction REC shall be undertaken using the test cycles that meet all of the requirements of Annex 5 and Annex 6 to this Regulation.

Annex 8

Test sequence for particulate reduction REC

Test sequence for NO_x reduction REC

Test sequence for particulate and NO_x reduction REC

[Diagram on next page is to be revised]

Annex 9

Limit value equivalence tables

1. 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.

2. 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.

3. The efficiency requirements detailed in paragraph 8.3. of this Regulation may require that the measured emissions are lower than these limit values.

Table A9/1
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.

Table A9/2

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

Baseline[*]	*Net Power*	*Component*	*Class I / II, to the standard of*									
		g/kWh	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*P*	*Q*	*R*
E	130 ≤ P ≤ 560	PM	-	-	-	-	0,025	-	-	-	0,025	-
F	75 ≤ P < 130	PM	-	-	-	-	-	0,025	-	-	-	0,025
G	37 ≤ P < 75	PM	-	-	-	-	-	-	0,025 (1)	0.025(2)	-	0,025 (1)
D	18 ≤ P < 37	PM	-	-	-	0,6 (3)	-	-	-	-	-	-
H	130 ≤ P ≤ 560	PM	-	-	-	-	0,025	-	-	-	0,025	-
I	75 ≤ P < 130	PM	-	-	-	-	-	0.025	-	-	-	0,025
J	37 ≤ P < 75	PM	-	-	-	-	-	-	0,025 (1)	0.025(2)	-	0,025 (1)
K	19 ≤ P < 37	PM	-	-	-	-	-	-	-	-	-	-
L	130 ≤ P ≤ 560	PM	-	-	-	-	-	-	-	-	-	-
M	75 ≤ P < 130	PM	-	-	-	-	-	-	-	-	-	-
N	56 ≤ P < 75	PM	-	-	-	-	-	-	-	-	-	-
P	37 ≤ P < 56	PM	-	-	-	-	-	-	-	-	-	-

(1) Only for engines 56 ≤ P < 75

(2) Only for engines 37 ≤ P < 56

(3) Only for engines 19 ≤ P < 37. Engines 18 ≤ P <19 are to be treated as having no further stage

[*] Where the baseline corresponds to that in Regulation No. 96 revision 2.

Table A9/3
Equivalence Matrix for Regulation No. 96 / REC Class III

Baseline[*]	*Net Power*	*Component*	*Class III, to the standard of*									
		g/kWh	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*P*	*Q*	*R*
E	130 ≤ P ≤ 560	NO_X	4,0 (4)	-	-	-	2,0	-	-	-	0,4	-
F	75 ≤ P < 130	NO_X	-	4,0 (4)	-	-	-	3,3	-	-	-	0,4
G	37 ≤ P < 75	NO_X	-	-	4,7 (4)	-	-	-	3,3 (1)	4.7 (2,4)-	-	0.4 (1)-
D	18 ≤ P < 37	NO_X	-	-	-	7,5 (3,4)	-	-	-	-	-	-
H	130 ≤ P ≤ 560	NO_X (3)	-	-	-	-	2,0	-	-	-	0,4	-
I	75 ≤ P < 130	NO_X (3)	-	-	-	-	-	3,3	-	-	-	0,4)
J	37 ≤ P < 75	NO_X (3)	-	-	-	-	-	-	3,3 (1)	4.7(2,4)-	-	0,4 (1)
K	19 ≤ P < 37	NO_X (3)	-	-	-	-	-	-	-	-	-	-
L	130 ≤ P ≤ 560	NO_X	-	-	-	-	-	-	-	-	0,4	-
M	75 ≤ P < 130	NO_X	-	-	-	-	-	-	-	-	-	0,4
N	56 ≤ P < 75	NO_X	-	-	-	-	-	-	-	-	-	0,4
P	37 ≤ P < 56	NO_X	-	-	-	-	-	-	-	-	-	-

(1) Only for engines 56 ≤ P < 75
(2) Only for engines 37 ≤ P < 56
(3) Only for engines 19 ≤ P < 37. Engines 18 ≤ P <19 are to be treated as having no further stage
(4) Sum of hydrocarbons and oxides of nitrogen
[*] Where the baseline corresponds to that in Regulation No. 96 revision 2.

Table A9/4
Equivalence Matrix for Regulation No. 96 / REC Class IV

Baseline[*]	*Net Power*	*Component*	*Class IV, to the standard of*									
		g/kWh	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*P*	*Q*	*R*
E	130 ≤ P ≤ 560	PM	-	-	-	-	0,025	-	-	-	0,025	-
		NO_X	4,0 (4)	-	-	-	2,0	-	-	-	0,4	-
F	75 ≤ P < 130	PM	-	-	-	-	-	0,025	-	-	-	0,025
		NO_X	-	4,0 (4)	-	-	-	3,3	-	-	-	0,4
G	37 ≤ P < 75	PM	-	-	-	-	-	-	0,025 (1)	0,025(2)-	-	0,025 (1)
		NO_X	-	-	4,7 (4)	-	-	-	3,3 (1)	4,7(2,4)-	-	0,4 (1)
D	18 ≤ P < 37	PM	-	-	-	0,6 (3)	-	-	-	-	-	-
		NO_X	-	-	-	7,5 (3,4)	-	-	-	-	-	-
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
J	37 ≤ P < 75	PM	-	-	-	-	-	-	0,025 (1)	0,025(2)-	-	0,025 (1)
		NO_X (3)	-	-	-	-	-	-	3,3 (1)	4,7 (2,4)	-	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 56 ≤ P < 75

(2) Only for engines 37 ≤ P < 56

(3) Only for engines only for engines 19 ≤ P < 37. Engines 18 ≤ P <19 are to be treated as having no further

(4) Sum of hydrocarbons and oxides of nitrogen

[*] Where the baseline corresponds to that in Regulation No. 96 revision 2.

Annex 10

Requirements of the NO_X control diagnostic system of NO_x reduction or NO_x and particulate reduction REC requiring a reagent

1. Introduction

This Annex sets out the requirements of the NO_X control diagnostic (NCD) system for NO_x reduction or NO_x and particulate reduction RECs that rely on the use of a reagent in order to reduce NO_x 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 Type 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).

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. Failures 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 Type 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.

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 Type Approval Authority.

The manufacturer may request approval by the Type 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:

(a) The remaining time before activation of the inducement;

(b) The amount of inducement, for example the amount of time for restart;

(c) 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

(a) Activating a second lamp, whose meaning is described in the REC manual; or

(b) Display a message, for example "engine will not start after shut-off".

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 (for example 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 3.36.1. of this Regulation.

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 3.36.2. of this Regulation, 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. of this annex.

6.2.2. The operator inducement system described in paragraphs 5.3. to 5.6. 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 per cent of the capacity of the reagent tank or a higher per centage 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 per cent of the capacity of the reagent tank or a higher per centage 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:

(a) Activating a second lamp, whose meaning is described in the REC manual; or

(b) 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 5.6. of this annex shall be activated if the reagent tank is empty, or at any level below 2.5 per cent 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 CDmin, which results in tailpipe NO_X emissions not exceeding

(a) 0.9 g/kWh for retrofitted engine systems complying with the NO_x emission limit for stage Q and R of Regulation No. 96; or

(b) The NO_X emission limit + 1.5 g/kWh for all other systems.

8.2.1. The correct value of CDmin 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 CDmin.

8.2.1.2. A WHTC or NRTC preconditioning cycle or REC manufacturer defined pre-conditioning cycle may be conducted, permitting a closed loop NO_X control system to perform adaptation to the quality of the reagent with the concentration CDmin.

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 CDmin 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.

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:

(a) Disconnect reagent dosing valve;

(b) Disconnect reagent pump;

(c) Failures or disconnect of the NCD system, as described in paragraph 10.1.1. of this annex.

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:

(a) The NO_X value shall not exceed the lower threshold between:

(i) Twice the applicable REC type approval NO_X limit; or

(ii) An increase of no more than 1 g/kWh above the applicable REC type approval NO_X limit;

(b) 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 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 operator 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 Type 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 Type 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 Type 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 Type 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.

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 Type 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 Type 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 shall provide written information and installation instructions for use by retrofitters, and operation and maintenance instructions for use by owners and operators. These instructions shall:

   (a) Address the safety hazards identified in the course of the assessment undertaken in accordance with paragraph 18.3. of this Regulation 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 shall 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 shall be in clear language appropriate to the intended readership.

2.2. The REC manufacturer shall 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;

   (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 shall 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 shall also be taken into consideration.

3.3. The instructions shall state that the vehicle or machine to be retrofitted shall 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 shall 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, which 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 NO_x and PM emissions limits set out in table 1, paragraph 5.3. of the 06 series of amendments of Regulation No. 49.

2.1.2. 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.

2.1.3. The On-board diagnostic system (OBD) requirements set out in Annexes 9A and 9B to the 06 series of amendments of Regulation No. 49.

2.1.4. 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.

2.1.5. 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.

2.1.6. 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 No. 49.