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Report of the Working Party on Pollution and Energy (GRPE) on its seventy-sixth session

Addendum 3

Adopted draft 02 series of amendments to UN Regulation No. 120 (Net power of tractors and non-road mobile machinery)

The text reproduced below was adopted on the basis of GRPE-76-14 (see para. 33 of the report).

GE.18-03036(E)
1803036

UN Regulation No. 120

Uniform provisions concerning the approval of internal combustion engines to be installed in agricultural and forestry tractors and in non-road mobile machinery, with regard to the measurement of the net power, net torque and specific fuel consumption

Contents

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1. Scope

1.1. This Regulation applies to the representation of the curves as a function of engine speed of the power, torque and specific fuel consumption at full load, indicated by the manufacturer for internal combustion engines to be used:

1.1.1. In category T vehicles[1],

1.1.2. In non-road mobile machinery[1], operated under variable or constant speed.

1.2. The internal combustion engines belong to one of the following categories:

1.2.1. Reciprocating internal combustion engines (positive-ignition or compression-ignition), but excluding free piston engines;

1.2.2. Rotary piston engines (positive-ignition or compression-ignition).

2. Definitions

2.1. "*Approval of an engine*" means the approval of an engine type with regard to its net power measured in accordance with the procedure specified in Annex 4 to this Regulation;

2.2. "*Approval of an engine family*" means the approval of the members of an engine family with regard to their net power in accordance with the procedure specified in paragraphs 3 and 4 of this Regulation;

2.3. "*Constant-speed engine*" means an engine type-approval of which is limited to constant-speed operation, excluding engines the constant-speed governor function of which is removed or disabled; it may be provided with an idle speed that can be used during start-up or shut-down and it may be equipped with a governor that can be set to an alternative speed when the engine is stopped;

2.4. "*Constant-speed operation*" means an engine operation with a governor that automatically controls the operator demand to maintain engine speed, even under changing load;

2.5. "*DeNO_X system*" means an exhaust after-treatment system designed to reduce emissions of oxides of nitrogen (NO_X) (e.g. passive and active lean NO_X catalysts, NO_X adsorbers and selective catalytic reduction (SCR) systems);

2.6. "*Dual-fuel engine*" means an engine that is designed to simultaneously operate with a liquid fuel and a gaseous fuel, both fuels being metered separately, the consumed amount of one of the fuels relative to the other one being able to vary depending on the operation;

2.7. "*Electronically controlled engine*" means an engine using electronic control to determine both the quantity and timing of injected fuel.

2.8. "*Engine family*" means a manufacturer's grouping of engines which, through their design, fulfil the grouping criteria laid down in Annex 5 to this Regulation;

2.9. "*Engine type*" means a category of engines which do not differ in such essential engine characteristics as defined in Annex 5 to this Regulation;

[1] As defined in the Consolidated Resolution on the Construction of Vehicles (R.E.3.), document ECE/TRANS/WP.29/78/Rev.6, para. 2. - www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29resolutions.html

2.10. "*Exhaust-gas recirculation*" or "*EGR*" means a technical device that is part of the emission control system and reduces emissions by routing exhaust gases that have been expelled from the combustion chamber(s) back into the engine to be mixed with incoming air before or during combustion, except for the use of valve timing to increase the amount of residual exhaust gas in the combustion chamber(s) that is mixed with incoming air before or during combustion;

2.11. "*Gaseous fuel*" means any fuel which is wholly gaseous at standard ambient conditions (298 K, absolute ambient pressure 101.3 kPa);

2.12. "*Internal combustion engine*" or "*Engine*" means an energy converter, other than a gas turbine, designed to transform chemical energy (input) into mechanical energy (output) with an internal combustion process; it includes, where they have been installed, the emission control system and the communication interface (hardware and messages) between the engine's electronic control unit(s) and any other powertrain or category T vehicle or non-road mobile machinery control unit necessary to comply with this Regualtion;

2.13. "*λ-shift factor*" or "S_λ" means an expression that describes the required flexibility of the engine management system regarding a change of the excess-air ratio λ if the engine is fuelled with a gas composition different from pure methane;

2.14. "*Liquid fuel*" means a fuel which exists in the liquid state at standard ambient conditions (298 K, absolute ambient pressure 101.3 kPa);

2.15. "*Liquid-fuel mode*" means the normal operating mode of a dual-fuel engine during which the engine does not use any gaseous fuel for any engine operating condition;

2.16. "*Manufacturer*" means any natural or legal person who is responsible to the Type Approval Authority for all aspects of the engine approval and for ensuring conformity of engine production, whether or not they are directly involved in all stages of the design and construction of the engine which is the subject of the approval process;

2.17. "*Maximum net power*" means the highest value of the net power on the nominal full-load power curve for the engine type;

2.18. "*Maximum net power speed*" means the engine speed at which the maximum net power is obtained, as specified by the manufacturer;

2.19. "*Maximum torque*" means the highest value of the net torque measured at full engine load.

2.20. "*Maximum torque speed*" means the engine speed at which the maximum torque is obtained from the engine, as specified by the manufacturer;

2.21. "*Mechanically controlled engine*" means an engine using mechanical devices to determine the quantity and timing of the delivered fuel.

2.22. "*Net power*" means the power obtained on a test bench at the end of the crankshaft or its equivalent at the corresponding engine speed with the auxiliaries and equipment listed in Table 1 of Annex 4 to this Regulation, determined under reference atmospheric conditions;

2.23. "*Parent engine*" means an engine selected from an engine family in such a way that it complies with requirements set out in Annex 5 of this Regulation;

2.24. "*Particulate after-treatment system*" means an exhaust after-treatment system designed to reduce emissions of particulate pollutants through a mechanical, aerodynamic, diffusional or inertial separation;

2.25. "*Rated net power*" means engine net power as declared by the manufacturer at rated speed;

2.26. "*Rated speed*" means the maximum full load speed allowed by an engine's governor, as designed by the manufacturer, or, if a governor is not present, the speed at which the maximum net power is attained by the engine, as specified by the manufacturer;

2.27. "*Reagent*" means any consumable or non-recoverable medium required and used for the effective operation of the exhaust after-treatment system;

2.28. "*Reference power*" means the maximum net power for variable speed engines and the rated net power for constant speed engines

2.29. *"Reference power speed"* means the engine speed at which the reference power is obtained, as specified by the manufacturer;

2.30. "*Regeneration*" means an event during which emissions levels change while the exhaust after-treatment system's performance is being restored by design and which can be classified as continuous regeneration or infrequent (periodic) regeneration;

2.31. "*Tampering*" means inactivation, adjustment or modification of the engine control system, including any software or other logical control elements of such a system, that has the effect, whether intended or not, of changing the engine performance;

2.32. "*Variable-speed engine*" means an engine that is not a constant-speed engine;

2.33. "*Wobbe index*" or "*W*" means the ratio of the corresponding calorific value of a gas per unit volume and the square root of its relative density under the same reference conditions:

$$W = H_{gas} \times \sqrt{\frac{\rho_{air}}{\rho_{gas}}}$$

3. Application for approval

3.1. The application for approval of an engine type or an engine family with regard to the measurement of the net power shall be submitted by the manufacturer or by his duly accredited representative.

3.2. The applicant shall provide the Type Approval Authority with an information folder which includes the following:

(a) An information document, including a list of reference fuels and, where requested by the manufacturer, any other specified fuels, fuel mixtures or fuel emulsions referred to in paragraph 5.2.3 and described in accordance with Annex 7 to this Regulation.

(b) All relevant data, drawings, photographs and other information relating to the engine type or, where applicable, the parent engine;

(c) Any additional information requested by the Type Approval Authority in the context of the type-approval application procedure.

A description of the engine type and if applicable the particulars of the engine family referred to in Annex 5 of this Regulation.

3.3. The information folder may be provided in paper form or in an electronic format that is accepted by the technical service and the Type Approval Authority.

3.3.1. Applications submitted on paper shall be in triplicate. Any drawings shall be to an appropriate scale and in sufficient detail on size A4 sheets or in a folder of A4 format. Photographs (if any) shall show sufficient detail.

3.4. Manufacturers shall make available to the technical service responsible for conducting the type-approval tests defined in paragraph 5, an engine conforming to the engine type or, in the case of an engine family, to the parent engine characteristics described in Annex 5 of this Regulation.

3.5. In the case of an application for an engine family type-approval, if the Technical Service determines that, with regard to the selected parent engine, the application submitted does not fully represent the engine family described in Annex 5, manufacturers shall make available an alternative and, if necessary, an additional parent engine which is considered by the Technical Service to represent the engine family.

4. Approval

4.1. If the power of the engine submitted for approval pursuant to this Regulation meets the requirements of paragraph 5. below, approval of the engine type or family shall be granted.

4.2. An approval number shall be assigned to each engine type or family approved. Its first two digits (at present 02 for the Regulation in its 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 Contracting Party shall not assign the same number to another engine type or family.

4.3. Notice of approval or of extension or of refusal of approval of an engine type or an engine family pursuant to this Regulation shall be communicated to the Parties to the 1958 Agreement applying this Regulation by means of a form conforming to the model in Annex 2 to this Regulation.

4.4. There shall be affixed, conspicuously and in a readily accessible place as specified on the approval form, to every engine conforming to an engine type or an engine family approved under this Regulation a statutory marking consisting of:

4.4.1. A circle surrounding the letter "E" followed by the distinguishing number of the country which has granted approval[2];

[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.6/ - www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29resolutions.html

4.4.2. The number of this Regulation, followed by the letter "R", a dash and the approval number to the right of the circle prescribed in paragraph 4.4.1.

Where the statutory marking of the engine is not visible without removing parts, the vehicle manufacturer shall affix to the category T vehicle or the non-road mobile machinery, in a visible manner, a duplicate of the marking provided by the manufacturer..

4.5. If the engine conforms to an approved type or family under one or more other Regulations annexed to the Agreement, in the country which has granted approval under this Regulation, the symbol prescribed in paragraph 4.4.1. need not be repeated; in such a case the Regulation and approval numbers and the additional symbols of all the Regulations under which approval has been granted under this Regulation shall be placed in vertical columns to the right of the symbol prescribed in paragraph 4.4.1.

4.6. The statutory marking shall be placed close to or on the data plate affixed by the manufacturer to the approved type.

4.7. Annex 3 to this Regulation gives examples of arrangements of approval marks.

4.8. Every engine conforming to an engine type or an engine family approved under this Regulation must bear, in addition to the approval mark:

(a) The trademark or trade name of the manufacturer of the engine and the address at which it can be contacted;

(b) The manufacturer's engine type or engine family designation in case the engine type belongs to a family;

(c) The unique engine identification number;

5. Specifications and tests

5.1. General

The components liable to affect the power of the engine shall be so designed, constructed and assembled as to enable the engine in normal use, despite the vibrations to which it may be subjected, to comply with the provisions of this Regulation.

5.1.1. For this purpose, the engine net power measured in accordance with the test conditions and detailed technical procedures set out in Annex 4 to this Regulation, using the fuel(s) specified in paragraph 5.2.3. and corrected according to the power correction factors defined in paragraph 5 of Annex 4 of this Regulation shall not deviate by more than the tolerances specified in paragraph 5.3. from the power curves declared by the manufacturer.

5.2. Description of tests for internal combustion engines

5.2.1. The net power test shall consist of either

(a) A run at full throttle for mechanically controlled positive ignition engines a run fixed full load fuel injection pump setting for mechanically controlled compression ignition engines; or

(b) A run at the required fuel system settings to produce the manufacturer specified power for electronically controlled engines.

The engine shall be equipped as specified in Table 1 of Annex 4 to this Regulation.

5.2.2. Measurements shall be taken at a sufficient number of engine speeds to define correctly the power, torque and specific fuel consumption curves between the lowest and the highest engine speeds recommended by the manufacturer. This range of speeds must include the rotational speeds at which the engine produces its rated net power, its maximum power and its maximum torque.

5.2.3. The testing of an engine type or engine family shall be carried out by using the following reference fuels or fuel combinations described in Annex 7, as appropriate:

(a) Diesel;

(b) Petrol;

(c) Petrol/oil mixture, for two stroke SI engines;

(d) Natural gas/bio methane;

(e) Liquid petroleum gas (LPG);

(f) Ethanol.

The engine type or engine family shall, in addition, meet the requirements set out in paragraph 5.1.1. in respect of any other specified fuels, fuel mixtures or fuel emulsions included by a manufacturer in an application for type- approval and described in Annex 1 to this Regulation.

5.2.3.1. The fuel used shall be specified in the test report.

5.2.4. Measurements shall be carried out according to the provisions of Annex 4 to this Regulation.

5.2.5. The test report shall contain the results and all the calculations required to determine the net power, as listed in the appendix A.1 to Annex 2 to this Regulation together with the characteristics of the engine, as listed in Annex 1 to this Regulation.

5.3. Interpretation of Results

5.3.1. Net power

The net power declared by the manufacturer for the type of engine (or parent engine) shall be accepted if it does not differ by more than the values indicated in the table below, from the corrected values measured by the technical service on the engine submitted for testing.

Engine Type	*Reference power [%]*	*Other measurement points on the curve [%]*	*Tolerance for engine speed [%]*
General	±2	±4	±1.5
Petrol fuelled spark ignited engines with governor	±4	±6	±4
Petrol fuelled spark ignited engines without governor	±4	±10	±4

5.3.2. Reference power speed

The reference power speed declared by the manufacturer shall not deviate by more than 100 min^{-1} from the value measured by the technical service on the engine submitted for testing. For spark ignited petrol fuelled engines, the reference power speed declared by the manufacturer shall not deviate from the value measured by the technical service on the engine submitted for testing by more than 150 min^{-1} for engines provided with governor and for engines without governor 350 min^{-1} or 4 per cent, whichever is smaller.

5.3.3. Fuel consumption

The specific fuel consumption curve declared by the manufacturer for the type of engine (or parent engine) shall be accepted if it does not differ by more than ±8 per cent at all measurement points from the values measured for the same points by the technical service on the engine submitted for testing.

5.3.4. Engine family

In case of compliance of the parent engine to the conditions in paragraphs 5.3.1. and 5.3.2., the acceptance is automatically extended to all the declared curves of the family members.

5.4. Engine types and engine families shall be designed and fitted with engine control strategies in such a way as to prevent tampering to the extent possible.

6. Conformity of production

The conformity of production procedures shall comply with those set out in the Agreement, Schedule 1 (E/ECE/324 - E/ECE/TRANS/505/Rev.3), with the following requirements:

6.1. Engines approved under this Regulation shall be so manufactured as to conform to the type approved.

6.2. The minimum requirements for conformity of production control procedures set forth in Annex 6 to this Regulation shall be complied with.

7. Penalties for non-conformity of production

7.1. The approval granted in respect of an engine type or an engine family pursuant to this Regulation may be withdrawn if the requirements set forth in paragraph 6.1. above are not met or if an engine or an engine family bearing the approval mark does not conform to the type approved.

7.2. If a Contracting Party to the 1958 Agreement applying this Regulation withdraws an approval it has previously granted, it shall forthwith so notify the other Contracting Parties applying this Regulation, by means of a communication form conforming to the model in Annex 2 to this Regulation.

8. Modification and extension of approval of an engine type or engine family

8.1. Every modification of an engine type or an engine family with regard to the characteristics in Annex 1, shall be notified to the Type Approval Authority which approved the engine type or engine family. The Type Approval Authority may then either:

8.1.1. Consider that the modifications made are unlikely to have any appreciable adverse effect and that in any case the engine still complies with the requirements; or

8.1.2. Require a further test report from the Technical Service responsible for conducting the tests.

8.2. Confirmation or refusal of approval, specifying the alterations shall be communicated by the procedure specified in paragraph 4.3. above to the Parties to the Agreement applying this Regulation.

8.3. 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 this Regulation by means of a communication form conforming to the model in Annex 2 to this Regulation.

9. Production definitively discontinued

If the holder of an approval completely ceases to manufacture an engine type or an engine family approved in accordance with this Regulation, he shall so inform the authority which granted the approval. Upon receiving the relevant communication that authority shall inform thereof the other Parties to the 1958 Agreement applying this Regulation by means of a communication form conforming to the model in Annex 2 to this Regulation.

10. Names and addresses of Technical Services responsible for conducting approval tests, and of Type Approval Authorities

The Parties to the Agreement which apply this Regulation shall communicate to the United Nations Secretariat the names and addresses of the Technical Services responsible for conducting approval tests, and/or the Type Approval Authorities which grant approval, and to which forms certifying approval or extension or refusal of approval, issued in other countries, are to be sent.

Annex 1

Templates for information folder and information document

1. Information folder

The information folder referred to in paragraph 3 of this Regulation shall contain the following:

1.1. A list of contents;

1.2. Manufacturer's declaration and supporting data demonstrating that the engine control strategies fitted are designed in such a way as to prevent tampering to the extent possible, as referred to in paragraph 5.4.

1.2.1. For electronically controlled engine types and engine families that use an Electronic Control Unit (ECU) as part of the engine control system the information shall include a description of the provisions taken to prevent tampering with and modification of the ECU including the facility for updating using a manufacturer approved programme or calibration;

1.2.2. For mechanically controlled engine types and engine families the information shall include a description of the provisions taken to prevent tampering with and modification of the adjustable parameters of the engine control system. This shall include the tamper resistant components such as carburettor limiter caps or sealing of carburettor screws or special screws not adjustable by user;

1.3. A description of the overall quality-assurance management systems for conformity of production in accordance to paragraph 6. of this Regulation;

1.4. The completed information document as set out in paragraph 2 of this Annex;

1.4.1 Where the particulars appearing in the information document for an engine approval have changed, the manufacturer shall submit revised pages to the approval authority showing clearly the nature of the change(s) and the date of re-issue;

1.5. All relevant data, drawings, photographs and other information as required in the information document;

2. Information document

The information document shall have a reference number issued by the applicant.

2.1. All information documents shall contain the following:

2.1.1. the general information set out in Part A of Appendix A.1 to this Annex;

2.1.2. the information set out in Part B of Appendix A.1 to this Annex, to identify the common design parameters of all engine types within an engine family or applicable to the engine type where not part of an engine family, intended for type approval;

2.1.3. the information set out in Part C of Appendix A.1 to this Annex.

2.2. Explanatory notes on creation of information document:

2.2.1. Upon agreement of the approval authority, the information in paragraph 2.1.2 and 2.1.3 may be presented in an alternative format;

2.2.2. Reserved

2.2.3. Only those paragraphs of this Annex relevant for the particular engine family, engine types within the engine family or engine type shall be listed; in any case, the list shall adhere to the proposed numbering system,

2.2.4. Where several options separated by forward slash are given for an entry, the unused options shall be struck out, or only the used option(s) shall be shown;

2.2.5. When the same value for or description of a certain engine characteristic applies for several or all members of an engine family the corresponding cells may be merged.

2.2.6. Where a picture, diagram or detailed information is required, a reference to an appendix may be given;

2.2.7. Where a 'type' of a component is requested, the information supplied shall uniquely identify the component; this may be a list of characteristic, a manufacturers' name and part or drawing number, a drawing, or a combination of the aforementioned or other methods that achieves the same result.

2.3. Engine type designation and engine family designation

The manufacturer shall allocate to each engine type and engine family a unique alphanumeric code.

2.3.1. In the case of an engine type, the code is named engine type designation and shall clearly and unequivocally identify those engines presenting a unique combination of technical features for those items set out in Part C of Appendix A.1 to this Annex applicable to the engine type.

2.3.2. In the case of engine types within an engine family, the whole code is named Family-Type or 'FT', and is composed of two sections: the first section is named engine family designation and identifies the engine family; the second section is the engine type designation of each particular engine type within the engine family;

The engine family designation shall clearly and unequivocally identify those engines presenting a unique combination of technical features for those items set out in Parts B and C of Appendix A.1 to this Annex applicable to the particular engine family.

The FT shall clearly and unequivocally identify those engines presenting a unique combination of technical features for those items set out in Part C of Appendix A.1 to this Annex applicable to the engine type within the engine family.

2.3.2.1. The manufacturer may use the same engine family designation to identify the same engine family under two or more engine categories.

2.3.2.2. The manufacturer shall not use the same engine family designation to identify more than one engine family under the same engine category.

2.3.2.3. Display of the FT

In the FT, a space shall be left between the engine family designation and the engine type designation, as shown in the example below:

'159AF[space]0054'

2.3.3. Number of characters

The number of characters shall not exceed the following:

(a) 15 for the engine family designation;

(b) 25 for the engine type designation;

(c) 40 for the FT.

2.3.4. Characters allowed

The engine type designation and engine family designation shall be made up of Roman letters and/or Arabic numerals;

2.3.4.1. The use of brackets and hyphens is permitted provided they do not replace a letter or a numeral.

2.3.4.2. The use of variable characters is permitted; variable characters shall be denoted by a '#', where the variable character is unknown at the time of notification;

2.3.4.2.1. The reasons for using such variable characters shall be explained to the technical service and Type Approval Authority.

Annex 1 - Appendix A.1

Template for information document

Explanatory note to Appendix A.1: All the templates below have been adapted from Appendix 3 to Annex 1 to the 05 series of amendments to Regulation No. 96 and the corresponding numeration has been kept to facilitate their use by both manufacturers and Type Approval Authorities.

PART A

1.	GENERAL INFORMATION
1.1.	Make (trade name(s) of manufacturer): .....
1.2.	Commercial name(s) (if applicable): .....
1.3.	Company name and address of manufacturer: .....
1.4.	Name and address of manufacturer's authorised representative (if any): .....
1.5.	Name(s) and address(es) of assembly/manufacture plant(s): .....
1.6.	Engine type designation/engine family designation/FT: .....
1.11.	Reference power is: rated net power/maximum net power

PART B

2.	COMMON DESIGN PARAMETERS OF ENGINE FAMILY [(1)]
2.1.	Combustion Cycle: four stroke cycle/two stroke cycle/rotary/other (specify) .....
2.2.	Ignition Type: Compression ignition/spark ignition
2.3.	Configuration of the cylinders
2.3.1.	Position of the cylinders in the block: Single/V/in-line/opposed/radial/other(specify): .....
2.3.2.	Bore centre to centre dimension (mm): .....
2.4.	Combustion chamber type/design
2.4.1.	Open chamber/divided chamber/other(specify)
2.4.2.	Valve and porting configuration: .....
2.4.3.	Number of valves per cylinder: .....
2.5.	Range of swept volume per cylinder (cm^3): .....
2.6.	Main Cooling medium: Air/Water/Oil
2.7.	Method of air aspiration: naturally aspirated/pressure charged/pressure charged with charge cooler

2.8. Fuel

2.8.1. Fuel Type: Diesel (non-road gas-oil)/Ethanol for dedicated compression ignition engines (ED95)/Petrol (E10)/ Ethanol (E85)/(Natural gas/Biomethane)/Liquid Petroleum Gas (LPG)

2.8.1.1. Sub Fuel type (Natural gas/Biomethane only): Universal fuel — high calorific fuel (H-gas) and low calorific fuel (L-gas)/Restricted fuel — high calorific fuel (H-gas)/Restricted fuel — low calorific fuel (L-gas)/Fuel specific (LNG);

2.8.2. Fuelling arrangement: Liquid-fuel only/Gaseous-fuel only/Dual-fuel type 1A/Dual-fuel type 1B/Dual-fuel type 2A/Dual-fuel type 2B/Dual-fuel type 3B

2.8.3. List of additional fuels, fuel mixtures or emulsions compatible with use by the engine declared by the manufacturer in accordance with paragraph 5.2.3. of this Regulation (provide reference to recognised standard or specification): .....

2.8.4. Lubricant added to fuel: Yes/No

2.8.4.1. Specification:
.....

2.8.4.2. Ratio of fuel to oil: .....

2.8.5. Fuel supply type: Pump (high pressure) line and injector/in-line pump or distributor pump/Unit injector/ Common rail/Carburettor)/port injector/direct injector/Mixing unit/other(specify): .....

2.9. Engine management systems: mechanical/electronic control strategy ([2])

2.10. Miscellaneous devices: Yes/No (if yes provide a schematic diagram of the location and order of the devices)

2.10.1. Exhaust gas recirculation (EGR): Yes/No (if yes, complete section 3.10.1 and provide a schematic diagram of the location and order of the devices)

2.10.2. Water injection: Yes/No (if yes, complete section 3.10.2 and provide a schematic diagram of the location and order of the devices)

2.10.3. Air injection: Yes/No (if yes, complete section 3.10.3 and provide a schematic diagram of the location and order of the devices)

2.10.4. Others: Yes/No (if yes specify, complete section 3.10.4 and provide a schematic diagram of the location and order of the devices): .....

2.11. Exhaust after-treatment system: Yes/No (if yes provide a schematic diagram of the location and order of the devices)

2.11.1. Oxidation catalyst: Yes/No

(if yes, complete section 3.11.2)

2.11.2. De NO_X system with selective reduction of NO_X (addition of reducing agent): Yes/No

(if yes, complete section 3.11.3)

2.11.3. Other De NO_X systems: Yes/No

(if yes, complete section 3.11.3)

2.11.4. Three-way catalyst combining oxidation and NO_X reduction: Yes/No

(if yes, complete section 3.11.3)

2.11.5. Particulate after-treatment system with passive regeneration: Yes/No

(if yes, complete section 3.11.4)

2.11.5.1. Wall-flow/non-wall-flow

2.11.6. Particulate after-treatment system with active regeneration: Yes/No

(if yes, complete section 3.11.4)

2.11.6.1. Wall-flow/non-wall-flow

2.11.7. Other particulate after-treatment systems: Yes/No

(if yes, complete section 3.11.4)

2.11.8. Other after-treatment devices (specify): .....

(if yes, complete section 3.11.5)

PART C

Item Number	*Item Description*	*Parent engine/ engine type*	*Engine types within the engine family (if applicable)*				*Explanatory notes (not included in document)*
			type 2	*type 3*	*type …*	*type n*	
3.1.	**Engine Identification**						
3.1.1.	Engine type designation						
3.1.2.	Engine type designation shown on engine marking: yes/no						
3.1.3.	Location of the statutory marking:						
3.1.4.	Method of attachment of the statutory marking:						
3.1.5.	Drawings of the location of the engine identification number (complete example with dimensions):						
3.2.	**Performance Parameters**						
3.2.1.	Declared rated speed(s) (rpm):						
3.2.1.1.	Fuel delivery/stroke (mm^3) for diesel engine, fuel flow (g/h) for other engines, at rated net power:						
3.2.1.2.	Declared rated net power (kW):						
3.2.2.	Maximum power speed(rpm):						If different from rated speed
3.2.2.1.	Fuel delivery/stroke (mm^3) for diesel engine, fuel flow (g/h) for other engines, at maximum net power:						
3.2.2.2.	Maximum net power (kW):						If different from rated speed
3.2.3.	Declared maximum torque speed (rpm):						If applicable
3.2.3.1.	Fuel delivery/stroke (mm^3) for diesel engine, fuel flow (g/h) for other engines, at maximum torque speed:						
3.2.3.2.	Declared maximum torque (Nm):						If applicable
3.2.4.	Declared 100 % test speed:						If applicable
3.2.5.	Declared Intermediate test speed:						If applicable
3.2.6.	Idle speed (rpm)						If applicable
3.2.7.	Maximum no load speed (rpm):						If applicable

Item Number	*Item Description*	*Parent engine/ engine type*	*Engine types within the engine family (if applicable)*				*Explanatory notes (not included in document)*
			type 2	*type 3*	*type …*	*type n*	
3.2.8	Declared minimum torque (Nm)						If applicable
3.3.	**Run-in procedure**						Optional at choice of manufacturer
3.3.1.	Run-in time:						
3.3.2.	Run-in cycle:						
3.4.	**Engine test**						
3.4.1.	Specific fixture required: Yes/No						If applicable
3.4.1.1	Description, including photographs and/or drawings, of the system for mounting the engine on the test bench including the power transmission shaft for connection to the dynamometer:						
3.4.2.	Exhaust mixing chamber permitted by manufacturer: Yes/No						If applicable
3.4.2.1.	Exhaust mixing chamber description, photograph and/or drawing:						If applicable
3.5.	**Lubrication system**						
3.5.1.	Lubricant temperature						If applicable
3.5.1.1.	Minimum (°C):						
3.5.1.2.	Maximum (°C):						
3.6.	**Combustion Cylinder**						
3.6.1.	Bore(mm):						
3.6.2.	Stroke(mm):						
3.6.3.	Number of cylinders:						
3.6.4.	Engine total swept volume (cm^3):						
3.6.5.	Swept volume per cylinder as % of parent engine:						If engine family
3.6.6.	Volumetric compression ratio:						Specify tolerance
3.6.7.	Combustion system description:						
3.6.8.	Drawings of combustion chamber and piston crown:						
3.6.9.	Minimum cross sectional area of inlet and outlet ports (mm^2):						
3.6.10.	Valve timing						
3.6.10.1.	Maximum lift and angles of opening and closing in relation to dead centre or equivalent data:						
3.6.10.2.	Reference and/or setting range:						
3.6.10.3.	Variable valve timing system: Yes/No						If applicable and where intake and/or exhaust
3.6.10.3.1.	Type: continuous/(on/off)						
3.6.10.3.2.	Cam phase shift angle:						
3.6.11.	Porting configuration						2-stroke only, if applicable
3.6.11.1.	Positon, size and number:						
3.7.	**Cooling system**						Complete relevant section
3.7.1.	Liquid cooling						
3.7.1.1.	Nature of liquid:						
3.7.1.2.	Circulating pumps: Yes/No						

Item Number	*Item Description*	*Parent engine/ engine type*	*Engine types within the engine family (if applicable)*				*Explanatory notes (not included in document)*
			type 2	*type 3*	*type …*	*type n*	
3.7.1.2.1.	type(s):						
3.7.1.2.2.	Drive ratio(s):						If applicable
3.7.1.3.	Minimum coolant temperature at outlet (°C):						
3.7.1.4.	Maximum coolant temperature at outlet (°C):						
3.7.2.	Air cooling						
3.7.2.1.	fan: Yes/No						
3.7.2.1.1.	type(s):						
3.7.2.1.2.	Drive ratio(s):						If applicable
3.7.2.2.	Maximum temperature at reference point (°C):						
3.7.2.2.1.	Reference point location						
3.8.	**Aspiration**						
3.8.1.	Maximum allowable intake depression at 100% engine speed and at 100% load (kPa)						
3.8.1.1.	With clean air cleaner:						
3.8.1.2.	With dirty air cleaner:						
3.8.1.3.	Location, of measurement:						
3.8.2.	Pressure charger(s): Yes/No						
3.8.2.1.	Type(s):						
3.8.2.2.	Description and schematic diagram of the system (e.g. maximum charge pressure,-waste gate, VGT, Twin turbo, etc.):						
3.8.3.	Charge air cooler: Yes/No						
3.8.3.1.	Type: air-air/air-water/other(specify)						
3.8.3.2.	Maximum charge air cooler outlet temperature at 100% speed and 100% load (°C):						
3.8.3.3.	Maximum allowable pressure drop across charge cooler at 100% engine speed and at 100% load (kPa):						
3.8.4.	Intake throttle valve: Yes/No						
3.8.5.	Device for recycling crankcase gases: Yes/No						
3.8.5.1.	If yes, description and drawings:						
3.8.5.2.	If no, compliance with paragraph 5.7. of this Regulation: Yes/No						
3.8.6.	*Inlet path*						If applicable
3.8.6.1.	Description of inlet path, (with drawings, photographs and/or part numbers):						
3.8.7.	Air filter						If applicable
3.8.7.1.	Type:						
3.8.8.	Intake air-silencer						If applicable
3.8.8.1.	Type:						
3.9.	**Exhaust system**						
3.9.1.	Description of the exhaust system (with drawings, photos and/or part numbers as required):						If applicable
3.9.2.	Maximum exhaust temperature (°C):						
3.9.3.	Maximum permissible exhaust backpressure at 100% engine speed and at 100% load (kPa):						

Item Number	*Item Description*	*Parent engine/ engine type*	*Engine types within the engine family (if applicable)*				*Explanatory notes (not included in document)*
			type 2	*type 3*	*type …*	*type n*	
3.9.3.1.	Location of measurement:						
3.9.4.	Exhaust backpressure at loading level specified by manufacturer for variable restriction after-treatment at start of test (kPa):						
3.9.4.1.	Location and speed/load conditions:						
3.9.5.	Exhaust throttle valve: Yes/No						
3.10.	**Miscellaneous devices: Yes/No**						
3.10.1.	Exhaust gas recirculation (EGR)						
3.10.1.1.	Characteristics: cooled/uncooled, high pressure/low pressure/other (specify):						
3.10.2.	Water injection						
3.10.2.1.	Operation principle:						
3.10.3.	Air injection						
3.10.3.1.	Operation principle						
3.10.4.	Others						
3.10.4.1.	Type(s)						
3.11.	**Exhaust after-treatment system**						
3.11.1.	Location						
3.11.1.1.	Place(s) and maximum/minimum distance(s) from engine to first after-treatment device:						
3.11.1.2.	Maximum temperature drop from exhaust or turbine outlet to first after-treatment device (^{o}C) if stated:						
3.11.1.2.1.	Test conditions for measurement:						
3.11.1.3.	Minimum temperature at inlet to first after-treatment device, (^{0}C) if stated:						
3.11.1.3.1.	Test conditions for measurement:						
3.11.2.	Oxidation catalyst						
3.11.2.1.	Number of catalytic converters and elements:						
3.11.2.2.	Dimensions and volume of the catalytic converter(s):						*Or drawing*
3.11.2.3.	Total charge of precious metals (g):						
3.11.2.4.	Relative concentration of each compound (%):						
3.11.2.5.	Substrate (structure and material):						
3.11.2.6.	Cell density:						
3.11.2.7.	Type of casing for the catalytic converter(s):						
3.11.3.	Catalytic exhaust after-treatment system for NO_X or three way catalyst						
3.11.3.1.	Type:						
3.11.3.2.	Number of catalytic converters and elements:						
3.11.3.3.	Type of catalytic action:						
3.11.3.4.	Dimensions and volume of the catalytic converter(s):						*Or drawing*
3.11.3.5.	Total charge of precious metals (g):						
3.11.3.6.	Relative concentration of each compound (%):						
3.11.3.7.	Substrate (structure and material):						
3.11.3.8.	Cell density:						

Item Number	*Item Description*	*Parent engine/ engine type*	*Engine types within the engine family (if applicable)*				*Explanatory notes (not included in document)*
			type 2	*type 3*	*type …*	*type n*	
3.11.3.9.	Type of casing for the catalytic converter(s):						
3.11.3.10.	Method of regeneration:						If applicable
3.11.3.10.1.	Infrequent regeneration: Yes/No:						If yes, complete section 3.11.6.
3.11.3.11.	Normal operating temperature range (°C):						
3.11.3.12.	Consumable reagent: Yes/No						
3.11.3.12.1.	Type and concentration of reagent needed for catalytic action:						
3.11.3.12.2.	Lowest concentration of the active ingredient present in the reagent that does not activate warning system (CD_{min}) (%vol):						
3.11.3.12.3.	Normal operational temperature range of reagent:						
3.11.3.12.4.	International standard:						If applicable
3.11.3.13.	NO_X sensor(s): Yes/No						
3.11.3.13.1.	Type:						
3.11.3.13.2.	Location(s)						
3.11.3.14.	Oxygen sensor(s): Yes/No						
3.11.3.14.1.	Type:						
3.11.3.14.2.	Location(s):						
3.11.4.	Particulate after-treatment system						
3.11.4.1.	Type of filtration: wall-flow/ non-wall-flow/other (specify)						
3.11.4.2.	Type:						
3.11.4.3.	Dimensions and capacity of the particulate after-treatment system:						*Or drawing*
3.11.4.4.	Location place(s) and maximum and minimum distance(s) from engine:						
3.11.4.5.	Method or system of regeneration, description and/or drawing:						
3.11.4.5.1.	Infrequent regeneration: Yes/No						If yes, complete section 3.11.6.
3.11.4.5.2.	Minimum exhaust gas temperature for initiating regeneration procedure (°C):						
3.11.4.6.	Catalytic coating: Yes/No						
3.11.4.6.1.	Type of catalytic action:						
3.11.4.7.	Fuel borne catalyst (FBC): Yes/No						
3.11.4.8.	Normal operating temperature range (°C):						
3.11.4.9.	Normal operating pressure range (kPa)						
3.11.4.10.	Storage capacity soot/ash (g):						
3.11.4.11.	Oxygen sensor(s): Yes/No						
3.11.4.11.1.	Type:						
3.11.4.11.2.	Location(s):						
3.11.5.	Other after-treatment devices						
3.11.5.1.	Description and operation:						
3.11.6.	Infrequent Regeneration						
3.11.6.1.	Number of cycles with regeneration						

Item Number	*Item Description*	*Parent engine/ engine type*	*Engine types within the engine family (if applicable)*				*Explanatory notes (not included in document)*
			type 2	*type 3*	*type …*	*type n*	
3.11.6.2.	Number of cycles without regeneration						
3.11.7.	Other devices or features						
3.11.7.1.	Type(s)						
3.12.	**Fuel feed for liquid-fuelled CI or, where applicable, dual-fuel engines**						
3.12.1.	Feed pump						
3.12.1.1.	Pressure (kPa) or characteristic diagram:						
3.12.2.	Injection system						
3.12.2.1.	Pump						
3.12.2.1.1.	Type(s):						
3.12.2.1.2.	Rated pump speed (rpm):						
3.12.2.1.3.	mm^3 per stroke or cycle at full injection at rated pump speed:						Specify tolerance
3.12.2.1.4.	Torque peak pump speed (rpm):						
3.12.2.1.5.	mm^3 per stroke or cycle at full injection at torque peak pump speed						Specify tolerance
3.12.2.1.6.	Characteristic diagram:						As alternative to entries 3.12.2.1.1. to 3.12.2.1.5.
3.12.2.1.7.	Method used: on engine/on pump bench						
3.12.2.2.	Injection timing						
3.12.2.2.1.	Injection timing curve:						Specify tolerance, if applicable
3.12.2.2.2.	Static Timing:						Specify tolerance
3.12.2.3.	Injection piping						
3.12.2.3.1.	Length(s) (mm):						
3.12.2.3.2.	Internal diameter (mm):						
3.12.2.4.	Common rail: Yes/No						
3.12.2.4.1.	Type:						
3.12.3.	Injector(s)						
3.12.3.1.	Type(s):						
3.12.3.2.	Opening pressure (kPa):						Specify tolerance
3.12.4.	ECU: Yes/No						
3.12.4.1.	Type(s):						
3.12.4.2.	Software calibration number(s):						
3.12.4.3.	Communication standard(s) for access to data stream information: ISO 27145 with ISO 15765-4 (CAN-based)/ISO 27145 with ISO 13400 (TCP/IP-based)/SAE J1939-73						
3.12.5.	Governor						
3.12.5.1.	Type(s):						
3.12.5.2.	Speed at which cut-off starts under full load:						Specify range, if applicable
3.12.5.3.	Maximum no-load speed:						Specify range, if applicable
3.12.5.4.	Idle speed:						Specify range, if applicable
3.12.6.	Cold-start system: Yes/No						
3.12.6.1.	Type(s):						

Item Number	*Item Description*	*Parent engine/ engine type*	*Engine types within the engine family (if applicable)*				*Explanatory notes (not included in document)*
			type 2	*type 3*	*type …*	*type n*	
3.12.6.2.	Description:						
3.12.7.	Fuel temperature at the inlet to the fuel injection pump						
3.12.7.1.	Minimum (°C):						
3.12.7.2.	Maximum (°C):						
3.13.	**Fuel feed for liquid fuel spark ignition engine**						
3.13.1.	Carburettor						
3.13.1.1.	Type(s):						
3.13.2.	Port fuel injection:						
3.13.2.1.	single-point / multi-point						
3.13.2.2.	Type(s):						
3.13.3.	Direct injection:						
3.13.3.1.	Type(s):						
3.13.4.	Fuel temperature at location specified by manufacturer						
3.13.4.1.	Location:						
3.13.4.2.	Minimum (°C)						
3.13.4.3.	Maximum (°C)						
3.14.	**Fuel feed for gaseous fuel engines or where applicable, dual-fuel engines (in the case of systems laid out in a different manner, supply equivalent information)**						
3.14.1.	Fuel: LPG /NG-H/NG-L /NG-HL/LNG/Fuel specific LNG						
3.14.2.	Pressure regulator(s)/vaporiser (s)						
3.14.2.1.	Type(s)						
3.14.2.2.	Number of pressure reduction stages						
3.14.2.3.	Pressure in final stage minimum and maximum. (kPa)						
3.14.2.4.	Number of main adjustment points:						
3.14.2.5.	Number of idle adjustment points:						
3.14.3.	Fuelling system: mixing unit/gas injection/liquid injection/direct injection						
3.14.3.1.	Mixture strength regulation						
3.14.3.1.1.	System description and/or diagram and drawings:						
3.14.4.	Mixing unit						
3.14.4.1.	Number:						
3.14.4.2.	Type(s):						
3.14.4.3.	Location:						
3.14.4.4.	Adjustment possibilities:						
3.14.5.	Inlet manifold injection						
3.14.5.1.	Injection: single-point/multi-point						
3.14.5.2.	Injection: continuous/simultaneously timed/ sequentially timed						
3.14.5.3.	Injection equipment						
3.14.5.3.1.	Type(s):						

Item Number	*Item Description*	*Parent engine/ engine type*	*Engine types within the engine family (if applicable)*				*Explanatory notes (not included in document)*
			type 2	*type 3*	*type …*	*type n*	
3.14.5.3.2.	Adjustment possibilities:						
3.14.5.4.	Supply pump						If applicable
3.14.5.4.1.	Type(s):						
3.14.5.5.	Injector(s)						
3.14.5.5.1.	Type(s):						
3.14.6.	Direct injection						
3.14.6.1.	Injection pump/pressure regulator						
3.14.6.1.1.	Type(s):						
3.14.6.1.2.	Injection timing (specify):						
3.14.6.2.	Injector(s)						
3.14.6.2.1.	Type(s):						
3.14.6.2.2.	Opening pressure or characteristic diagram :						
3.14.7.	Electronic Control Unit (ECU)						
3.14.7.1.	Type(s):						
3.14.7.2.	Adjustment possibilities:						
3.14.7.3.	Software calibration number(s):						
3.14.8.	Approvals of engines for several fuel compositions						
3.14.8.1.	Self-adaptive feature: Yes/No						
3.14.8.2.	Calibration for a specific gas composition: NG-H/NG-L/NG-HL/ LNG/Fuel specific LNG						
3.14.8.3.	Transformation for a specific gas composition: NG-HT/NG-LT/NG-HLT						
3.14.9.	Fuel temperature pressure regulator final stage						
3.14.9.1.	Minimum ((°C):						
3.14.9.2.	Maximum ((°C):						
3.15.	**Ignition system**						
3.15.1.	Ignition coil(s)						
3.15.1.1.	Type(s):						
3.15.1.2.	Number:						
3.15.2.	Spark plug(s)						
3.15.2.1.	Type(s):						
3.15.2.2.	Gap setting:						
3.15.3.	Magneto						
3.15.3.1.	Type(s):						
3.15.4.	Ignition timing control: Yes/No						
3.15.4.1.	Static advance with respect to top dead centre (crank angle degrees):						
3.15.4.2.	Advance curve or map:						If applicable
3.15.4.3.	Electronic control: Yes/No						

Explanatory notes to Appendix A.1:

(Footnote markers, footnotes and explanatory notes not to be stated on the information document)

In the case of combined catalyst and particulate filter both pertinent sections shall be filled.
([1]) As defined in Annex 5 of this Regulation.
([2]) Refer to paragraph 2.3.13. in Annex 5 (engine family definition).

Annex 2

Communication

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

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

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

of an engine or engine family pursuant to Regulation No. 120

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

Reason for extension/refusal/withdrawal ([2]): .....

SECTION I

1.1. Make (trade name(s) of manufacturer): .....

1.2. Commercial name(s) (if applicable): .....

1.3. Company name and address of manufacturer: .....

1.4. Name and address of manufacturer's authorised representative (if any): .....

1.5. Name(s) and address(es) of assembly/manufacture plant(s): .....

1.6. Engine type designation/engine family designation/FT ([2]): .....

SECTION II

1. Technical service responsible for carrying out the test(s): .....

2. Date(s) of the test report(s): .....

3. Number(s) of the test report(s): .....

[1] Distinguishing number of the country which has granted/refused/withdrawn approval (see approval provisions in the Regulation).
[2] Strike out which does not apply.

SECTION III

The undersigned hereby certifies the accuracy of the manufacturer's description in the attached information document of the engine type/engine family ([2]) described above, for which one or more representative samples, selected by the approval authority, have been submitted as prototypes and that the attached test results apply to the engine type/engine family ([2]).

1. The engine type/engine family ([2]) meets/does not meet ([2]) the requirements laid down in Regulation 120, 02 series of amendments.

2. The approval is granted/extended/refused/withdrawn ([2])

Place: .....
Date: .....

Name and signature: .....

Attachments:

Information folder

Test report(s)

All other documents added by the technical services or by the Type Approval Authority to the information folder in the course of carrying out their functions.

Addendum

Approval number: .....

PART A — CHARACTERISTICS OF THE ENGINE TYPE/ENGINE FAMILY ([2])

2.	Common design parameters of the engine type/engine family [(2)]
2.1.	Combustion Cycle: four stroke cycle/two stroke cycle/rotary/other: ..... (describe) ([2])
2.2.	Ignition Type: Compression ignition/spark ignition ([2])
2.3.1.	Position of the cylinders in the block: V/in-line/radial/other(describe) ([2])
2.6	Main Cooling medium: Air/Water/Oil ([2])
2.7.	Method of air aspiration: naturally aspirated/pressure charged/pressure charged with charge cooler ([2])
2.8.1.	Fuel Type(s): Diesel (non-road gas-oil)/Ethanol for dedicated compression ignition engines (ED95)/Petrol (E10)/ Ethanol (E85)/(Natural gas/Biomethane)/Liquid Petroleum Gas (LPG) ([2])
2.8.1.1.	Sub Fuel type (Natural gas/Biomethane only): Universal fuel — high calorific fuel (H-gas) and low calorific fuel (L-gas)/Restricted fuel — high calorific fuel (H-gas)/Restricted fuel — low calorific fuel (L-gas)/Fuel specific (LNG);
2.8.2.	Fuelling arrangement: Liquid-fuel only/Gaseous-fuel only/Dual-fuel type 1A/Dual-fuel type 1B/Dual-fuel type 2A/Dual-fuel type 2B/Dual-fuel type 3B ([2])
2.8.3.	List of additional fuels compatible with use by the engine declared by the manufacturer in accordance with paragraph 5.2.3. of this Regulation (provide

reference to recognised standard or specification): .....

2.8.4. Lubricant added to fuel: Yes/No ([2])

2.8.5. Fuel supply type: Pump (high pressure) line and injector/in-line pump or distributor pump/Unit injector/ Common rail/Carburettor)/port injector/direct injector/Mixing unit/other(specify) ([2])

2.9. Engine management systems: mechanical/electronic control strategy [(2)]

2.10. Miscellaneous devices: Yes/No ([2])

2.10.1. Exhaust gas recirculation (EGR): Yes/No ([2])

2.10.2. Water injection: Yes/No ([2])

2.10.3. Air injection: Yes/No ([2])

2.10.4. Others (specify): .....

2.11. Exhaust after-treatment system: Yes/No ([2])

2.11.1. Oxidation catalyst: Yes/No ([2])

2.11.2. De NO_X system with selective reduction of NO_X (addition of reducing agent): Yes/No ([2])

2.11.3. Other De NO_X systems: Yes/No ([2])

2.11.4. Three-way catalyst combining oxidation and NOx reduction: Yes/No ([2])

2.11.5. Particulate after-treatment system with passive regeneration: Yes/No ([2])

2.11.6. Particulate after-treatment system with active regeneration: Yes/No ([2])

2.11.7. Other particulate after-treatment systems: Yes/No ([2])

2.11.8. Three-way catalyst combining oxidation and NO_X reduction: Yes/No ([2])

2.11.9. Other after-treatment devices (specify): .....

3. Essential characteristics of the engine type(s)

Item Number	**Item Description**	**Parent Engine / Engine type**	**Engine types within the family (if applicable)**		
3.1.1.	Engine Type Designation:				
3.1.2.	Engine type designation shown on engine mark: Yes/No[(2)]				
3.1.3.	Location of the manufacturer's statutory marking:				
3.2.1.	Declared rated speed (rpm):				
3.2.1.2.	Declared rated net Power (kW):				
3.2.2.	Maximum power speed (rpm):				
3.2.2.2.	Maximum net power (kW):				
3.2.3.	Declared maximum torque speed (rpm):				

Item Number	Item Description	Parent Engine / Engine type	Engine types within the family (if applicable)		
3.2.3.2.	Declared maximum torque (Nm):				
3.6.3.	Number of Cylinders:				
3.6.4.	Engine total swept volume (cm^3):				
3.8.5.	Device for recycling crankcase gases: Yes/No(2)				
3.11.3.12.	Consumable reagent: Yes/No(2)				
3.11.3.12.1.	Type and concentration of reagent needed for catalytic action:				
3.11.3.13.	NO_X sensor(s): Yes/No(2)				
3.11.3.14.	Oxygen sensor: Yes/No(2)				
3.11.4.7.	Fuel borne catalyst (FBC): Yes/No(2)				

PART B – TEST RESULTS

1. Approved data

1.1. Rated net power: .....kW, at..... min^{-1}

1.2. Maximum net power:.....kW, at..... min^{-1}

1.3. Maximum net torque: .....Nm, at..... min^{-1}

Explanatory notes to Annex 2

(Footnote markers, footnotes and explanatory notes not to be stated on the type-approval certificate)

(1) Distinguishing number of the contracting party which has granted/extended/refused/withdrawn an approval.

(2) Strike out the unused options, or only show the used option(s).

Annex 2 - Appendix A.1

Test Report

A.1.1. General requirements

One test report shall be completed for each tests required for the type-approval. Each additional (e.g. a second speed on a constant speed engine) or supplementary test (e.g. another fuel is tested) will require an additional or supplementary test report.

A.1.2. Explanatory notes on creation of a test report

A.1.2.1. A test report shall contain at least the information set out in paragraph A.1.3.

A.1.2.2. Notwithstanding paragraph A.1.2.1, only those sections or sub-sections relevant for the particular test and for the particular engine family, engine types within the engine family or engine type tested need to be stated in the test report;

A.1.2.3. The test report may contain more information than that requested in paragraph A.1.2.1 but in any case, shall adhere to the proposed numbering system;

A.1.2.4. Where several options separated by forward slash are given for an entry, the unused options shall be struck out, or only the used option(s) shall be shown;

A.1.2.5. Where a 'type' of a component is requested, the information supplied shall uniquely identify the component; this may be a list of characteristic, a manufacturers' name and part or drawing number, a drawing, or a combination of the aforementioned or other methods that achieves the same result.

A.1.2.6. The test report may be delivered on paper on in an electronic format agreed between the manufacturer, technical service and Type Approval Authority.

A.1.3 Template for the test report

TEST REPORT FOR NON-ROAD ENGINES

1. **General Information**

1.1. Make(s) (trade name(s) of manufacturer): .....

1.2. Commercial name(s) (if applicable): .....

1.3. Company name and address of manufacturer: .....

1.4. Name of technical service: .....

1.5. Address of technical service: .....

1.6. Location of test: .....

1.7. Date of test: .....

1.8. Test report number: .....

1.9. Information document reference number (if available): .....

1.10. Test report type: Primary test/additional test/supplementary test

1.10.1. Description of the purpose of the test: .....

2.	**General engine information (test engine)**
2.1.	Engine type designation/engine family designation/FT: .....
2.2.	Engine identification number: .....
3.	**Documentation and information Check list (primary test only)**
3.6.	For engine types and engine families that use an ECU as part of the engine control system anti-tampering declaration documentation reference: .....
3.7.	For engine types and engine families that use mechanical devices as part of the engine control system anti- tampering and adjustable parameters declaration and demonstration documentation reference: .....
4.	**Reference fuel(s) used for test (complete relevant subparagraph(s))**
4.1.	Liquid fuel for spark-ignition engines
4.1.1.	Make: .....
4.1.2.	Type: .....
4.1.3.	Octane number RON: .....
4.1.4.	Octane number MON: .....
4.1.5.	Ethanol content (%): .....
4.1.6.	Density at 15 °C (kg/m3): .....
4.2.	Liquid fuel for compression-ignition engines
4.2.1.	Make: .....
4.2.2.	Type: .....
4.2.3.	Cetane number: .....
4.2.4.	Fame content (%): .....
4.2.5.	Density at 15 °C (kg/m3): .....
4.3.	Gaseous fuel — LPG
4.3.1.	Make: .....
4.3.2.	Type: .....
4.3.3.	Reference fuel type: Fuel A/Fuel B
4.3.4.	Octane number MON: .....
4.4.	Gaseous fuel- Methane/biomethane
4.4.1.	Reference fuel type: GR/G23/G25/G20
4.4.2.	Source of reference gas: specific reference fuel/pipeline gas with admixture
4.4.3.	For specific reference fuel
4.4.3.1.	Make:.....
4.4.3.2.	Type:.....
4.4.4.	For pipeline gas with admixture
4.4.4.1.	Admixture(s): Carbon dioxide/Ethane/Methane/Nitrogen/Propane

4.4.4.2. The value of S_λ for the resulting fuel blend: .....

4.4.4.3. The Methane Number (MN) of the resulting fuel blend:.....

4.5. Dual-fuel engine (in addition to relevant sections above)

4.5.1. Gas energy ratio on test cycle: .....

5. **Lubricant**

5.1. Make(s): .....

5.2. Type(s): .....

5.3. SAE viscosity: .....

5.4. Lubricant and fuel are mixed: yes/no

5.4.1. Percentage of oil in mixture: .....

6. Detailed results of measurements*

Engine speed, min^{-1}			
Measured torque, Nm			
Measured power, kW			
Measured fuel flow, g/h			
Barometric pressure, kPa			
Water vapour pressure, kPa			
Inlet air temperature, K			
Power to be added for equipment and auxiliaries in excess of Table 1, kW Total, kW	No. 1 No. 2 No. 3		
Power correction factor			
Corrected power, kW			
Corrected torque, Nm			
Corrected specific fuel consumption g/(kWh)(2)			
Cooling liquid temperature at outlet, K			
Lubricating oil temperature at measuring point, K			
Air temperature after pressure-charger, K (1)			
Fuel temperature at injection pump inlet, K			
Air temperature after charge air cooler, K (1)			
Pressure after pressure-charger, kPa			
Pressure after charge air cooler, kPa			
Inlet depression, Pa			
Exhaust back-pressure, Pa			

Engine speed, min^{-1}		
Fuel delivery, mm^3/stroke or cycle (1)		

* The characteristic curves of the net power and the net torque shall be drawn as a function of the engine speed.

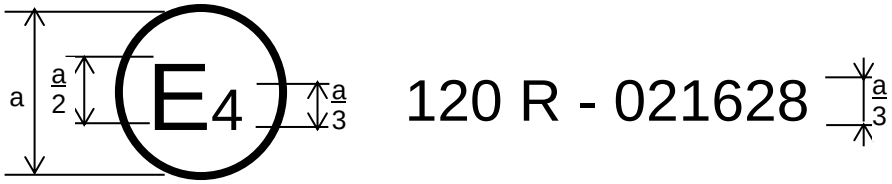
(1) Strike out what does not apply.

(2) Calculated with the net power for compression-ignition and positive-ignition engines, in the latter case multiplied by the power correction factor.

Annex 3

Arrangements of approval marks

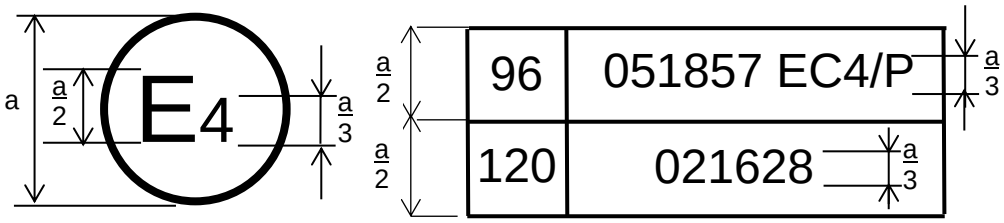
Model A
(see paragraph 4.4. of this Regulation)



a = 8 mm min.

The above approval mark affixed to an engine shows that the engine type concerned has been approved in the Netherlands (E4) with regard to the measurement of the net power, pursuant to Regulation No. 120 and under the approval number 021628. The approval number indicates that the approval was granted in accordance with the requirements of Regulation No. 120 as amended by the 02 series of amendments.

Model B
(see paragraph 4.5. of this Regulation)



a = 8 mm min.

The above approval mark affixed to an engine shows that the engine type concerned has been approved in the Netherlands (E4) pursuant to Regulations No. 120 and 96[1]. The first two digits of the approval numbers indicate that, at the dates when the respective approvals were granted, Regulation No. 120 was amended by the 02 series of amendments, and Regulation No. 96 already included the 05 series of amendments.

[1] The second number is given merely as an example.

Annex 4

Method for measuring internal combustion engine net power

1. These provisions apply to the method for determining the power curve at full load of an internal combustion engine operated under intermittent speed as a function of engine speed and the rated speed and rated net power of an internal combustion engine under constant speed.

2. Test conditions

2.1. The engine shall have been run-in according to the manufacturer's recommendations.

2.2. If the power measurement can be carried out only on an engine with the gearbox mounted, the efficiency of the gearbox shall be taken into account.

2.3. Auxiliaries and equipment

2.3.1. Auxiliaries and equipment to be fitted

During the test, the auxiliaries necessary for the engine operation in the intended application (as listed in Table 1) shall be installed on the test bench as far as possible in the same position as in the intended application.

2.3.2. Auxiliaries and equipment to be removed

Certain auxiliaries whose definition is linked with the operation of the machine and which may be mounted on the engine shall be removed for the test. The following non-exhaustive list is given as a sample:

(i) Air compressor for brakes

(ii) Power steering compressor

(iii) Suspension compressor

(iv) Air-conditioning system

Where auxiliaries cannot be removed, the power they absorb in the unloaded condition may be determined and added to the measured engine power (see note h of Table 1). If this value is greater than 3 per cent of the maximum power at the test speed it may verified by the test authority.

Table 1
Equipment and auxiliaries to be installed for the test to determine engine power

Number	*Equipment and auxiliaries*	*Fitted for emission test*
1	Inlet system	
	Inlet manifold	Yes
	Crankcase emission control system	Yes
	Air flow meter	Yes
	Air filter	Yes[a]
	Inlet silencer	Yes[a]

Number	*Equipment and auxiliaries*	*Fitted for emission test*
2	Exhaust system	
	Exhaust aftertreatment	Yes
	Exhaust manifold	Yes
	Connecting pipes	Yes[b]
	Silencer	Yes[b]
	Tail pipe	Yes[b]
	Exhaust brake	No[c]
	Pressure charging device	Yes
3	Fuel supply pump	Yes[d]
4	Carburation equipment	
	Carburettor	Yes
	Electronic control system, air flow meter, etc.	Yes
	Equipment for gas engines	
	Pressure reducer	Yes
	Evaporator	Yes
	Mixer	Yes
5	Fuel injection equipment (petrol and diesel)	
	Pre-filter	Yes
	Filter	Yes
	Pump	Yes
	High-pressure pipe	Yes
	Injector	Yes
	Electronic control system, sensors, etc.	Yes
	Governor/control system	Yes
	Automatic full-load stop for the control rack depending on atmospheric conditions	Yes
6	Liquid-cooling equipment	
	Radiator	No
	Fan	No

Number	*Equipment and auxiliaries*	*Fitted for emission test*
	Fan cowl	No
	Water pump	Yes[e]
	Thermostat	Yes[f]
7	Air cooling	
	Cowl	No[g]
	Fan or Blower	No[g]
	Temperature-regulating device	No
8	Pressure charging equipment	
	Compressor driven either directly by the engine and/or by the exhaust gases	Yes
	Charge air cooler	Yes[g, h]
	Coolant pump or fan (engine-driven)	No[g]
	Coolant flow control device	Yes
9	Auxiliary test-bed fan	Yes, if necessary
10	Anti-pollution device	Yes,
11	Starting equipment	Yes or test bed equipment[k]
12	Lubricating oil pump	Yes
13	Certain auxiliaries whose definition is linked with the operation of the non-road mobile machinery and which may be mounted on the engine shall be removed for the test. The following non-exhaustive list is given as an example: (i) air compressor for brakes (ii) power steering compressor (iii) suspension compressor (iv) air-conditioning system.	No

[a] The complete inlet system shall be fitted as provided for the intended application:
(i) Where there is a risk of an appreciable effect on the engine power;
(ii) In the case of naturally aspirated spark ignition engines.
In other cases, an equivalent system may be used and a check should be made to ascertain that the intake pressure does not differ by more than 100 Pa from the upper limit specified by the manufacturer for a clean air filter.

[b] The compete exhaust system shall be fitted as provided for the intended application:
(i) Where there is a risk of an appreciable effect on the engine power;
(ii) In the case of naturally aspirated spark ignition engines.

In other cases, an equivalent system may be installed provided the pressure measured does not differ by more than 1,000 Pa from the upper limit specified by the manufacturer.

[c] If an exhaust brake is incorporated in the engine, the throttle valve shall be fixed in the fully open position.

[d] The fuel feed pressure may be adjusted, if necessary, to reproduce the pressure existing in the particular engine application (particularly when a "fuel return" system is used).

[e] The cooling-liquid circulation shall be operated by the engine water pump only. Cooling of the liquid may be produced by an external circuit, such that the pressure loss of this circuit and the pressure at the pump inlet remain substantially the same as those of the engine cooling system.

[f] The thermostat may be fixed in the fully open position.

[g] When the cooling fan or blower is fitted for the test, the power absorbed shall be added to the results, except for engines where such auxiliaries are an integral part of the engine (i.e.: cooling fans of air cooled engines directly fitted on the crankshaft). The fan or blower power shall be determined at the speeds used for the test either by calculation from standard characteristics or by practical tests.

[h] Charge air-cooled engines shall be tested with charge air cooling, whether liquid - or air-cooled, but if the manufacturer prefers, a test bench system may replace the air cooler. In either case, the measurement of power at each speed shall be made with the maximum pressure drop and the minimum temperature drop of the engine air across the charge air cooler on the test bench system as those specified by the manufacturer.

[k] The power for electrical or other starting systems shall be provided from the test bed.

2.4. Setting conditions
The setting conditions for the test to determine the net power are indicated in Table 2.

Table 2
Setting conditions

1.	Setting of carburettor(s), evaporator/pressure regulator	In accordance with the manufacturer's production specifications, and used without further alteration for the particular application.
2.	Setting of injection pump delivery system	
3.	Ignition or injection timing (timing curve)	
4.	Governor setting	
5.	Emission control devices	
6.	Boost Control	

3. Data to be recorded

3.1. Data to be recorded are those indicated in appendix A.1 to Annex 2. Performance data shall be obtained under stabilised operating conditions with an adequate fresh air supply to the engine. Combustion chambers may contain deposits, but in limited quantity. Test conditions, such as inlet air temperature, shall be selected as near to reference conditions (see paragraph 5.2. of this annex) as possible in order to minimise the magnitude of the correction factor.

3.2. The temperature of the inlet air to the engine shall be measured within the inlet ductwork. The inlet depression measurement shall be made at the same point. The thermometer or thermocouple shall be shielded from fuel spray-back and radiant heat and located directly in the air stream. A sufficient number of locations shall be used to give a representative average of the inlet temperature.

3.3. The inlet depression shall be measured downstream of the entry ducts, air filter, inlet silencer or speed-limiting device (if fitted).

3.4. The absolute pressure at the entry to the engine downstream of the compressor and heat exchanger, if fitted, shall be measured in the inlet manifold and at any other point where pressure has to be measured to calculate correction factors.

3.5. The exhaust back pressure shall be measured at a point at least three pipe diameters downstream from the outlet flange(s) of the exhaust manifold(s) and downstream at the turbocharger(s), if fitted. The location shall be specified.

3.6. No data shall be taken until torque, speed and temperatures have been maintained substantially constant for at least one minute.

3.7. The engine speed during a run or reading shall not deviate from the selected speed by more than ±1 per cent or ±10 min, whichever is greater.

3.8. Observed brake load, fuel consumption and inlet air temperature data shall be taken simultaneously and shall be the average of two stabilised consecutive values which do not vary more than 2 per cent for the brake load.

3.9. The temperature of the coolant at the outlet from the engine shall be kept at the value specified by the manufacturer.

If no temperature is specified by the manufacturer, the temperature shall be 353 K ± 5 K. For air-cooled engines, the temperature at a point indicated by the manufacturer shall be kept within +0/-20 K of the maximum value specified by the manufacturer in the reference conditions.

3.10. For C.I. engines, the fuel temperature shall be measured at the inlet of the fuel injection pump and maintained within 306 - 316 K (33-43 °C) for positive-ignition engines the fuel temperature shall be measured as near as possible to the inlet of the carburettor or assemby of fuel injectors and maintained within 293–303 K (20-30 °C).

3.11. The temperature of the lubricating oil measured in the oil pump or at the outlet from the coil cooler, if fitted, shall be maintained within the limits established by the engine manufacturer.

3.12. An auxiliary regulating system may be used if necessary to maintain the temperatures within the limits specified in paragraphs 3.9., 3.10. and 3.11. above of this annex.

4. Accuracy of measurements

4.1. Torque: ±1 per cent of measured torque. The torque measuring system shall be calibrated to take friction losses into account. The accuracy in the lower half of the measuring range of the dynamometer bench may be ±2 per cent of measured torque.

4.2. Engine speed: 0.5 per cent of measured speed.

4.3. Fuel consumption: ±1 per cent of measured consumption.

4.4. Fuel temperature: ±2 K.

4.5. Engine inlet air temperature: ±2 K.

4.6. Barometric pressure: ±100 Pa.

4.7. Depression in inlet system: ±50 Pa.

4.8. Back-pressure in exhaust system: ±200 Pa.

5. Power correction factors

5.1. Definition

The power correction factor is the coefficient to determine the engine power under the reference atmospheric conditions specified in 5.2. below.

$$P_o = \alpha P$$

where:

P_o is the corrected power (i.e. power under reference atmospheric conditions)

α is the correction factor (α_a or α_d)

P is the measured power (test power)

5.2. Reference atmospheric conditions

5.2.1. Temperature (T_o): 298 K (25 °C)

5.2.2. Dry pressure (P_{so}): 99 kPa

The dry pressure is based on a total pressure of 100 kPa and a water vapour pressure of 1 kPa.

5.3. Test atmospheric conditions

The atmospheric conditions during the test shall be the following:

5.3.1. Temperature (T)

For positive-ignition engines: $288\ K \leq T \leq 308\ K$

For compression-ignition engines: $283\ K \leq T \leq 313\ K$

5.3.2. Pressure (p_s)

$$90\ kPa < p_s < 110\ kPa$$

5.4. Determination of correction factor α_a and α_d [1]

5.4.1. Naturally aspirated or pressure-charged positive-ignition engine

The correction factor α_a is obtained by applying the formula:

$$\alpha_a = \left(\frac{99}{p_s}\right)^{1.2} * \left(\frac{T}{298}\right)^{0.6}$$

where:

p_s is the total dry atmospheric pressure in kilopascals (kPa); i.e. the total barometric pressure minus water vapour pressure,

T is the absolute temperature in kelvins (K) of the air drawn in by the engine.

Conditions to be complied with in the laboratory

For a test to be valid, the correction factor must be such that

$$0.93 < \alpha_a < 1.07$$

If these limits are exceeded, the corrected value obtained shall be given and the test conditions (temperature and pressure) precisely stated in the test report.

5.4.2. Compression-ignition engines - factor α_d

The power correction factor (α_d) for compression-ignition engines at constant fuel rate is obtained by applying the formula:

$$\alpha_d = (f_a)^{fm}$$

where:

f_a is the atmospheric factor

[1] The tests may be carried out in air-conditioned test rooms where the atmospheric conditions may be controlled.
In the case of engines fitted with automatic air temperature control, if the device is such that at full load at 25 °C no heated air is added, the test shall be carried out with the device fully closed. If the device is still operating at 25 °C then the test is made with the device operating normally and the exponent of the temperature term in the correction factor shall be taken as zero (no temperature correction).

f_m the characteristic parameter for each type of engine and adjustment

5.4.2.1. Atmospheric factor f_a

This factor indicates the effects of environmental conditions (pressure, temperature and humidity) on the air drawn in by the engine. The atmospheric factor formula differs according to the type of engine.

5.4.2.1.1. Naturally aspirated and mechanically pressure charged engines

$$f_a = \left(\frac{99}{p_s}\right) * \left(\frac{T}{298}\right)^{0.7}$$

5.4.2.1.2. Turbocharged engines with or without charge air cooling

$$f_a = \left(\frac{99}{p_s}\right)^{0.7} * \left(\frac{T}{298}\right)^{1.5}$$

5.4.2.2. Engine factor f_m

f_m is a function of qc (fuel flow corrected) as follows:

$f_m = 0.036\ q_c - 1.14$

and

$q_c = q/r$

Where:

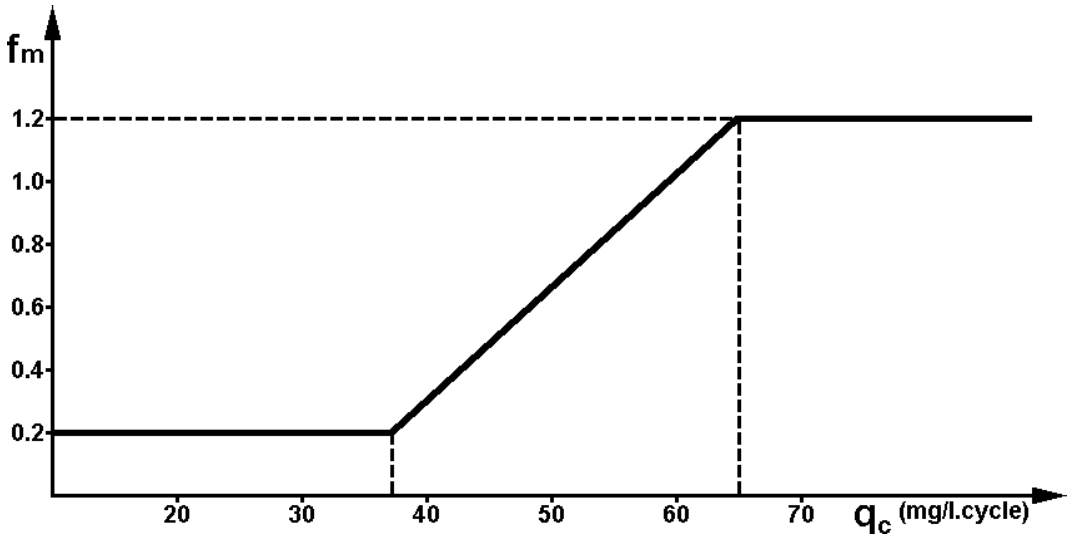
q is the fuel flow in milligram per cycle per litre of total swept volume (mg/(l.cycle))

r is the pressure ratio of compressor outlet and compressor inlet in case of multiple turbochargers r represents the total compression ratio (r = 1 for naturally aspirated engines)

This formula is valid for a value interval of q_c included between 37.2 mg/(l.cycle) and 65 mg/(l.cycle).

For q_c values lower than 37.2 mg/(l.cycle), a constant value of f_m equal to 0.2 ($f_m = 0.2$) will be taken.

For q_c values higher than 65 mg/(l.cycle), a constant value of f_m equal to 1.2 ($f_m = 1.2$) will be taken (see figure):



5.4.2.3. Conditions to be complied with in the laboratory

For a test to be valid, the correction factors α_a must be such that

$$0.93 \leq \alpha_a \leq 1.07$$

If these limits are exceeded, the corrected value obtained shall be given and the test conditions (temperature and pressure) precisely stated in the test report

Annex 5

Parameters for the definition of engine types and engine families, and their operation modes

1. Engine type

The technical features of an engine type shall be those defined in its information document drafted in accordance with the template set out in Annex 1.

1.1. Operating mode (speed operation)

An engine type may be type-approved as a constant speed engine or as a variable speed engine, as defined respectively in paragraphs 2.3. and 2.32. of this Regulation.

2. Engine family criteria

2.1. General

An engine family is characterised by design parameters. These shall be common to all engines within the engine family. The engine manufacturer may decide, which engines belong to an engine family, as long as the membership criteria listed in paragraph 2.3 of this Annex are respected. The engine family shall be approved by the Type Approval Authority.

2.2. Engine categories, operating mode (speed operation) and power range.

2.2.1. The engine family shall comprise only engine types of the same speed operation.

2.3. Parameters defining the engine family

2.3.1. Combustion cycle

(a) 2-stroke cycle;

(b) 4-stroke cycle;

(c) Rotary engine;

(d) Others.

2.3.2. Configuration of the cylinders

2.3.2.1. Position of the cylinders in the block

(a) Single

(b) V;

(c) In-line;

(d) Opposed;

(e) Radial;

(f) Others (F, W, etc.).

2.3.2.2. Relative position of the cylinders

Engines with the same block may belong to the same engine family as long as their bore centre-to-centre dimensions are the same.

2.3.3. Main cooling medium

(a) Air;

(b) Water;

(c) Oil.

2.3.4. Swept volume per cylinder

2.3.4.1. Engine with a swept volume per cylinder ≥ 750 cm^3

In order for engines with a swept volume per cylinder of ≥ 750 cm^3 to be considered to belong to the same engine family, the spread of the swept volume per cylinder shall not exceed 15 per cent of the largest swept volume per cylinder within the engine family.

2.3.4.2. Engine with a swept volume per cylinder < 750 cm^3

In order for engines with a swept volume per cylinder of < 750 cm^3 to be considered to belong to the same engine family, the spread of the swept volume per cylinder shall not exceed 30 per cent of the largest swept volume per cylinder within the engine family.

2.3.5. Method of air aspiration

(a) Naturally aspirated;

(b) Pressure charged;

(c) Pressure charged with charge cooler.

2.3.6. Fuel type

(a) Diesel (non-road gas-oil);

(b) Ethanol for dedicated compression ignition engines (ED95);

(c) Petrol (E10);

(d) Ethanol (E85);

(e) Natural gas/Biomethane:

(1) Universal fuel — high calorific fuel (H-gas) and low calorific fuel (L-gas);

(2) Restricted fuel — high calorific fuel (H-gas);

(3) Restricted fuel — low calorific fuel (L-gas);

(4) Fuel specific (LNG);

(f) Liquid Petroleum Gas (LPG);

2.3.7. Fuelling arrangement

(a) Liquid-fuel only;

(b) Gaseous-fuel only;

(c) Dual-fuel type 1A;

(d) Dual-fuel type 1B;

(e) Dual-fuel type 2A;

(f) Dual-fuel type 2B;

(g) Dual-fuel type 3B.

2.3.8. Combustion chamber type/design

(a) Open chamber;

(b) Divided chamber;

(c) Other types.

2.3.9. Ignition Type

(a) Spark ignition;

(b) Compression ignition.

2.3.10. Valves and porting

(a) Configuration;

(b) Number of valves per cylinder.

2.3.11. Fuel supply type

(a) Pump, (high pressure) line and injector;

(b) In-line pump or distributor pump;

(c) Unit injector;

(d) Common rail;

(e) Carburettor;

(f) Port injector;

(g) Direct injector;

(h) Mixing unit;

(i) Other.

2.3.12. Miscellaneous devices

(a) Exhaust gas recirculation (EGR);

(b) Water injection;

(c) Air injection;

(d) Others.

2.3.13. Electronic control strategy

The presence or absence of an ECU on the engine is regarded as a basic parameter of the engine family.

The electronic governing of speed does not need to be in a different engine family from those with mechanical governing. The need to separate electronic engines from mechanical engines should only apply to the fuel injection characteristics, such as timing, pressure, rate shape, etc.

2.3.14. Exhaust after-treatment systems

The function and combination of the following devices are regarded as membership criteria for an engine family:

(a) Oxidation catalyst;

(b) $DeNO_X$ system with selective reduction of NO_X (addition of reducing agent);

(c) Other $DeNO_X$ systems;

(d) Particulate after-treatment system with passive regeneration:

(1) wall-flow;

(2) non-wall-flow;

(e) Particulate after-treatment system with active regeneration:

(1) wall-flow;

(2) non-wall-flow;

(f) Other particulate after-treatment systems;

(g) Other devices.

2.3.15. Dual-fuel engines

All engine types within a dual-fuel engine family shall belong to the same type of dual-fuel engines as defined in paragraph 2 of Annex 7 of 05 series of amendments to Regulation No. 96, and operate with the same types of fuel or when appropriate with fuels declared according to this Regulation as being of the same range(s).

3. Choice of the parent engine

3.1. General

3.1.1. Once the engine family has been agreed by the Type Approval Authority, the parent engine of the engine family shall be selected using the primary criterion of the highest fuel delivery per stroke per cylinder at the declared maximum torque speed. In the event that two or more engines share this primary criterion, the parent engine shall be selected using the secondary criterion of highest fuel delivery per stroke at rated speed.

Annex 6

Checks on conformity of production

1. General

These requirements are consistent with tests to be held to check conformity of production (COP), according to paragraph 6.2. of this Regulation.

2. Test procedures

The methods of testing and measuring instruments shall be those described in Annex 4 to this Regulation.

3. Collection of samples

3.1. Case of an engine type

One engine has to be chosen. If after the test of paragraph 4. below, the engine is not considered as conforming to the requirements of this Regulation, two more engines have to be tested.

3.2. Case of a family of engines

In case of an approval granted to a family of engines the COP shall be run on one member of the family, which is not the parent engine. In case of failure of the COP test, the two more engines shall be of the same member type.

4. Measurement criteria

4.1. Net power and specific fuel consumption of internal combustion engine

Measurements shall be taken at a sufficient number of engine speeds to define correctly the power, torque and specific fuel consumption curves between the lowest and the highest engine speeds recommended by the manufacturer.

The corrected values measured for the engine sampled shall not differ by more than the values indicated in the table below and ±10 per cent for the specific fuel consumption.

Engine type	*Reference power (torque) [%]*	*Other measurement points on the curve [%]*	*Tolerance for engine speed [%]*
General	±5	±10	±5
Petrol fuelled spark ignited engines with governor	±8	±12	±8
Petrol fuelled spark ignited engines without governor	±8	±20	±8

5. Evaluation of results

If the net power and fuel consumption figures of the second and/or third engine of paragraph 3. do not fulfil the requirements of paragraph 4. above, the production shall be considered not to conform to the requirements of this Regulation and the provision of paragraph 7. of this Regulation shall be put into effect.

Annex 7

Technical characteristics of reference fuels prescribed for approval tests and to verify conformity of production

1. Technical data on fuels for testing compression-ignition engines

1.1. Type: Diesel (non-road gas-oil)

Parameter	*Unit*	*Limits*[1]	*Test Method*	
		minimum	*maximum*	
Cetane number[2]		45	56.0	EN-ISO 5165
Density at 15 °C	kg/m^3	833	865	EN-ISO 3675
Distillation:				
50 per cent point	°C	245	-	EN-ISO 3405
95 per cent point	°C	345	350	EN-ISO 3405
Final boiling point	°C	-	370	EN-ISO 3405
Flash point	°C	55	-	EN 22719
CFPP	°C	-	–5	EN 116
Viscosity at 40 °C	mm^2/s	2.3	3.3	EN-ISO 3104
Polycyclic aromatic hydrocarbons	% m/m	2.0	6.0	IP 391
Sulphur content[3]	mg/kg	-	10	ASTM D 5453
Copper corrosion		-	class 1	EN-ISO 2160
Conradson carbon residue (10 % DR)	% m/m	-	0.2	EN-ISO 10370
Ash content	% m/m	-	0.01	EN-ISO 6245
Total contamination	mg/kg	-	24	EN 12662
Water content	% m/m	-	0.02	EN-ISO 12937
Neutralisation (strong acid) number	mg KOH/g	-	0.10	ASTM D 974
Oxidation stability[3]	mg/ml	-	0.025	EN-ISO 12205
Lubricity (HFRR wear scar diameter at 60 °C)	µm	-	400	CEC F-06-A-96
Oxidation stability at 110 °C[3]	H	20.0	-	EN 15751
FAME	% v/v	-	7.0	EN 14078

[1] The values quoted in the specifications are "true values". In establishment of their limit values the terms of ISO 4259 "Petroleum products – Determination and application of precision data in relation to methods of test" have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility).

Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels should nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify the questions as to whether a fuel meets the requirements of the specifications, the terms of ISO 4259 should be applied.

[2] The range for the cetane number is not in accordance with the requirements of a minimum range of 4R. However, in the case of a dispute between fuel supplier and fuel user, the terms of ISO 4259 may be used to resolve such disputes provided replicate measurements, of sufficient number to archive the necessary precision, are made in preference to single determinations.

[3] Even though oxidation stability is controlled, it is likely that shelf life will be limited. Advice should be sought from the supplier as to storage conditions and life.

1.2. Type: Ethanol for dedicated compression ignition engines (ED95)[1]

Parameter	*Unit*	*Limits*[2]		*Test method*[3]
		Minimum	*Maximum*	
Total alcohol (Ethanol incl. content on higher saturated alcohols)	per cent m/m	92.4		EN 15721
Other higher saturated mono-alcohols (C_3-C_5)	per cent m/m		2.0	EN 15721
Methanol	per cent m/m		0.3	EN 15721
Density 15ºC	kg/m^3	793.0	815.0	EN ISO 12185
Acidity, calculated as acetic acid	per cent m/m		0.0025	EN 15491
Appearance		Bright and clear		
Flashpoint	ºC	10		EN 3679
Dry residue	mg/kg		15	EN 15691
Water content	per cent m/m		6.5	EN 15489[4] EN-ISO 12937 EN15692
Aldehydes calculated as acetaldehyde	per cent m/m		0.0050	ISO 1388-4
Esters calculated as ethylacetat	per cent m/m		0.1	ASTM D1617
Sulphur content	mg/kg		10.0	EN 15485 EN 15486
Sulphates	mg/kg		4.0	EN 15492
Particulate contamination	mg/kg		24	EN 12662
Phosphorus	mg/l		0.20	EN 15487
Inorganic chloride	mg/kg		1.0	EN 15484 or EN 15492
Copper	mg/kg		0.100	EN 15488
Electrical Conductivity	µS/cm		2.50	DIN 51627-4 or prEN 15938

[1] Additives, such as cetane improver as specified by the engine manufacturer, may be added to the ethanol fuel, as long as no negative side effects are known. If these conditions are satisfied, the maximum allowed amount is 10 per cent m/m.

[2] The values quoted in the specifications are "true values". In establishment of their limit values the terms of ISO 4259 Petroleum products – Determination and application of precision data in relation to methods of test have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility). Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.

[3] Equivalent EN/ISO methods will be adopted when issued for properties listed above.

[4] Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of EN 15489 shall be applied.

2. Technical data on fuels for testing spark ignition engines

2.1. Type: Petrol (E10)

Parameter	*Unit*	*Limits*[1]		*Test method*[2]
		Minimum	*Maximum*	
Research octane number, RON		91.0	98.0	EN ISO 5164:2005[3]
Motor octane number, MON		83.0	89.0	EN ISO 5163:2005[3]
Density at 15 °C	kg/m^3	743	756	EN ISO 3675 EN ISO 12185
Vapour pressure	kPa	45.0	60.0	EN ISO 13016-1 (DVPE)
Water content			Max 0.05 per cent v/v Appearance at -7°C: clear and bright	EN 12937
Distillation:				
- evaporated at 70 °C	per cent v/v	18.0	46.0	EN-ISO 3405
- evaporated at 100 °C	per cent v/v	46.0	62.0	EN-ISO 3405
- evaporated at 150 °C	per cent v/v	75.0	94.0	EN-ISO 3405
- final boiling point	°C	170	210	EN-ISO 3405
Residue	per cent v/v	—	2.0	EN-ISO 3405
Hydrocarbon analysis:				
- olefins	per cent v/v	3.0	18.0	EN 14517 EN 15553
- aromatics	per cent v/v	19.5	35.0	EN 14517 EN 15553
- benzene	per cent v/v	—	1.0	EN 12177 EN 238, EN 14517
- saturates	per cent v/v	Report		EN 14517 EN 15553
Carbon/hydrogen ratio		Report		
Carbon/oxygen ratio		Report		
Induction period[4]	minutes	480		EN-ISO 7536
Oxygen content[5]	per cent m/m	3.3[8]	3.7	EN 1601 EN 13132

				EN 14517
Existent gum	mg/ml	—	0.04	EN-ISO 6246
Sulphur content[6]	mg/kg	—	10	EN ISO 20846 EN ISO 20884
Copper corrosion (3h at 50 °C)	rating	—	Class 1	EN-ISO 2160
Lead content	mg/l	—	5	EN 237
Phosphorus content[7]	mg/l	—	1.3	ASTM D 3231
Ethanol[4]	per cent v/v	9.0[8]	10.2[8]	EN 22854

Notes:

1 The values quoted in the specifications are "true values". In establishment of their limit values the terms of ISO 4259 Petroleum products - Determination and application of precision data in relation to methods of test have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility). Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.

2 Equivalent EN/ISO methods will be adopted when issued for properties listed above.

3 A correction factor of 0.2 for MON and RON shall be subtracted for the calculation of the final result in accordance with EN 228:2008.

4 The fuel may contain oxidation inhibitors and metal deactivators normally used to stabilise refinery gasoline streams, but detergent/dispersive additives and solvent oils shall not be added.

5 Ethanol meeting the specification of EN 15376 is the only oxygenate that shall be intentionally added to the reference fuel.

6 The actual sulphur content of the fuel used for the Type 1 test shall be reported.

7 There shall be no intentional addition of compounds containing phosphorus, iron, manganese, or lead to this reference fuel.

8 The ethanol content and corresponding oxygen content may be zero for engines of category SMB at the choice of the manufacturer. In this case all testing of the engine family, or engine type where no family exists, shall be conducted using petrol with zero ethanol content.

2.2. Type: Ethanol (E85)

Parameter	*Unit*	*Limits*[1]		*Test method*
		Minimum	*Maximum*	
Research octane number, RON		95.0	—	EN ISO 5164
Motor octane number, MON		85.0	—	EN ISO 5163
Density at 15 °C	kg/m^3	Report		ISO 3675
Vapour pressure	kPa	40.0	60.0	EN ISO 13016-1 (DVPE)
Sulphur content[2]	mg/kg	—	10	EN 15485 or EN 15486
Oxidation stability	Minutes	360		EN ISO 7536
Existent gum content (solvent washed)	mg/100ml	—	5	EN-ISO 6246
Appearance This shall be determined at ambient temperature or 15°C whichever is higher		Clear and bright, visibly free of suspended or precipitated contaminants		Visual inspection
Ethanol and higher alcohols[3]	per cent v/v	83	85	EN 1601 EN 13132 EN 14517 E DIN 51627-3
Higher alcohols (C_3-C_8)	per cent v/v	—	2.0	E DIN 51627-3
Methanol	per cent v/v		1.00	E DIN 51627-3
Petrol[4]	per cent v/v	Balance		EN 228
Phosphous	mg/l	0.20[5]		EN 15487
Water content	per cent v/v		0.300	EN 15489 or EN 15692
Inorganic chloride content	mg/l		1	EN 15492
pHe		6.5	9.0	EN 15490
Copper strip corrosion (3h at 50°C)	Rating	Class 1		EN ISO 2160
Acidity, (as acetic acid CH_3COOH)	per cent m/m (mg/l)	—	0.0050 (40)	EN 15491

Electric Conductivity	µS/cm	1.5	DIN 51627-4 or prEN 15938
Carbon/hydrogen ratio		Report	
Carbon/oxygen ration		Report	

Notes:

[1] The values quoted in the specifications are "true values". In establishment of their limit values the terms of ISO 4259 Petroleum products - Determination and application of precision data in relation to methods of test have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility). Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.

[2] The actual sulphur content of the fuel used for the emission tests shall be reported.

[3] Ethanol to meet specification of EN 15376 is the only oxygenate that shall be intentionally added to this reference fuel.

[4] The unleaded petrol content can be determined as 100 minus the sum of the per cent content of water, alcohols, MTBE and ETBE.

[5] There shall be no intentional addition of compounds containing phosphorus, iron, manganese, or lead to this reference fuel.

3. Technical data on gaseous fuels for single-fuel and dual-fuel engines

3.1. Type: LPG

Parameter	*Unit*	*Fuel A*	*Fuel B*	*Test method*
Composition:				EN 27941
C_3-content	per cent v/v	30 ± 2	85 ± 2	
C_4-content	per cent v/v	Balance[1]	Balance[1]	
$< C_3$, $> C_4$	per cent v/v	Maximum 2	Maximum 2	
Olefins	per cent v/v	Maximum 12	Maximum 15	
Evaporation residue	mg/kg	Maximum 50	Maximum 50	EN 15470
Water at 0 °C		Free	Free	EN 15469
Total sulphur content including odorant	mg/kg	Maximum 10	Maximum 10	EN 24260, ASTM D 3246, ASTM 6667
Hydrogen sulphide		None	None	EN ISO 8819
Copper strip corrosion (1h at 40 °C)	Rating	Class 1	Class 1	ISO 6251[2]
Odour		Characteristic	Characteristic	
Motor octane number[3]		Minimum 89.0	Minimum 89.0	EN 589 Annex B

Notes:

[1] Balance shall be read as follows: balance = 100 - C_3 - $<C_3$ - $>C_4$.

[2] This method may not accurately determine the presence of corrosive materials if the sample contains corrosion inhibitors or other chemicals which diminish the corrosivity of the sample to the copper strip. Therefore, the addition of such compounds for the sole purpose of biasing the test method is prohibited.

[3] At the request of the engine manufacturer, a higher MON could be used to perform the type approval tests.

3.2. Type: Natural Gas/ Biomethane

3.2.1. Specification for reference fuels supplied with fixed properties (eg from a sealed container)

As an alternative to the reference fuels set out in this paragraph, the equivalent fuels in paragraph 3.2.2. of this Annex may be used

Characteristics	*Units*	*Basis*	*Limits*		*Test method*
			minimum	*maximum*	
Reference fuel G_R					
Composition:					
Methane		87	84	89	
Ethane		13	11	15	
Balance[1]	per cent mole	—	—	1	ISO 6974
Sulphur content	mg/m^3 [2]	—		10	ISO 6326-5
Notes: [1] Inerts + C_{2+} [2] Value to be determined at standard conditions 293.2 K (20 °C) and 101.3 kPa.					
Reference fuel G_{23}					
Composition:					
Methane		92.5	91.5	93.5	
Balance[1]	per cent mole	—	—	1	ISO 6974
N_2	per cent mole	7.5	6.5	8.5	
Sulphur content	mg/m^3 [2]	—	—	10	ISO 6326-5
Notes: [1] Inerts (different from N_2) + C_2+ C_{2+} [2] Value to be determined at 293.2 K (20 °C) and 101.3 kPa.					
Reference fuel G_{25}					
Composition:					
Methane	per cent mole	86	84	88	
Balance[1]	per cent mole	—	—	1	ISO 6974
N_2	per cent mole	14	12	16	
Sulphur content	mg/m^3 [2]	—	—	10	ISO 6326-5
Notes: [1] Inerts (different from N_2) + C_2+ C_{2+} [2] Value to be determined at 293.2 K (20 °C) and 101.3 kPa.					

Reference fuel G_{20}					
Composition:					
Methane	per cent mole	100	99	100	ISO 6974
Balance (1)	per cent mole	—	—	1	ISO 6974
N_2	per cent mole				ISO 6974
Sulphur content	mg/m^3 (2)	—	—	10	ISO 6326-5
Wobbe Index (net)	MJ/m^3 (3)	48.2	47.2	49.2	

(1) Inerts (different from N_2) + C_2 + C_2+.
(2) Value to be determined at 293.2 K (20 °C) and 101.3 kPa.
(3) Value to be determined at 273.2 K (0 °C) and 101.3 kPa.

3.2.2. Specification for reference fuel supplied from a pipeline with admixture of other gases with gas properties determined by on-site measurement

As an alternative to the reference fuels in this paragraph the equivalent reference fuels in paragraph 3.2.1. of this Annex may be used.

3.2.2.1. The basis of each pipeline reference fuel (G_R, G_{20}, …) shall be gas drawn from a utility gas distribution network, blended, where necessary to meet the corresponding lambda-shift (S_λ) specification in Table A.7-1, with an admixture of one or more of the following commercially (the use of calibration gas for this purpose shall not be required) available gases:

(a) Carbon dioxide;

(b) Ethane;

(c) Methane;

(d) Nitrogen;

(e) Propane.

3.2.2.2. The value of S_λ of the resulting blend of pipeline gas and admixture gas shall be within the range specified in Table A.7-1 for the specified reference fuel.

Table A.7-1
Required range of S_λ for each reference fuel

Reference fuel	*Minimum S_λ*	*Maximum S_λ*
G_R[2]	0.87	0.95
G_{20}	0.97	1.03
G_{23}	1.05	1.10
G_{25}	1.12	1.20

[1] The engine shall not be required to be tested on a gas blend with a Methane Number (MN) less than 70. In the case that the required range of S_λ for G_R would result in an MN less than 70 the value of S_λ for G_R may be adjusted as necessary until a value of MN no less than 70 is attained.

3.2.2.3. The engine test report for each test run shall include the following:

(a) The admixture gas(es) chosen from the list in paragraph 3.2.2.1. of this Annex;

(b) The value of S_λ for the resulting fuel blend;

(c) The Methane Number (MN) of the resulting fuel blend.

3.2.2.4. The requirements of Appendices A.1 and A.2 shall be met in respect to determination of the properties of the pipeline and admixture gases, the determination of S_λ and MN for the resulting gas blend, and the verification that the blend was maintained during the test.

Annex 7 - Appendix A.1

Supplementary requirements for conducting engine testing using gaseous reference fuels comprising pipeline gas with admixture of other gases

A.1.1. Method of gas analysis and gas flow measurement

A.1.1.1. For the purpose of this Appendix, where required the composition of the gas shall be determined by analysis of the gas using gas chromatography according to EN ISO 6974, or by an alternative technique that achieves at least a similar level of accuracy and repeatability.

A.1.1.2. For the purpose of this Appendix, where required the measurement of gas flow shall be performed using a mass-based flowmeter.

A.1.2. Analysis and flowrate of incoming utility gas supply

A.1.2.1. The composition of the utility gas supply shall be analysed prior to the admixture blending system.

A.1.2.2. The flowrate of the utility gas entering the admixture blending system shall be measured.

A.1.3. Analysis and flowrate of admixture

A.1.3.1. When an applicable certificate of analysis is available for an admixture (for example issued by the gas supplier) this may be used as the source of that admixture composition. In this case the on-site analysis of that admixture composition shall be permitted but shall not be required.

A.1.3.2. Where an applicable certificate of analysis is not available for an admixture the composition of that admixture shall be analysed.

A.1.3.3. The flowrate of each admixture entering the admixture blending system shall be measured.

A.1.4. Analysis of blended gas

A.1.4.1. The analysis of the composition of the gas supplied to the engine after leaving the admixture blending system shall be permitted in addition to, or as an alternative to the analysis required by paragraphs A.1.2.1. and A.1.3.1., but shall not be required.

A.1.5. Calculation of S_λ and MN of the blended gas

A.1.5.1. The results of the gas analysis according to paragraphs A.1.2.1., A.1.3.1. or A.1.3.2. and, where applicable, paragraph A.1.4.1., combined with the mass flowrate of gas measured according to paragraphs A.1.2.2. and A.1.3.3., shall be used to calculate the MN according to EN16726:2015. The same set of data shall be used to calculate S_λ according to the procedure set out in Appendix A.2 to this Annex.

A.1.6. Control and verification of gas blend during the test

A.1.6.1. The control and verification of the gas blend during the test shall be performed using either an open loop or closed loop control system.

A.1.6.2. Open loop blend control system

A.1.6.2.1. In this case the gas analysis, flow measurements and calculations set out in paragraphs A.1.1., A.1.2., A.1.3. and A.1.4. shall be performed prior to the emission test.

A.1.6.2.2. The proportion of utility gas and admixture(s) shall be set to ensure that the S_λ is within the permitted range for the relevant reference fuel in Table A.7-1.

A.1.6.2.3. When the relative proportions have been set they shall be maintained throughout the engine test. Adjustments to individual flow rates to maintain the relative proportions shall be permitted.

A.1.6.2.4. When the engine test has been completed the analysis of gas composition, flow measurements and calculations set out in paragraphs A.1.2., A.1.3., A.1.4. and A.1.5. shall be repeated. In order for the test to be considered valid the value of S_λ shall remain within the specified range for the respective reference fuel given in Table A.7-1.

A.1.6.3. Closed loop blend control system

A.1.6.3.1. In this case the analysis of gas composition, flow measurements and calculations set out in paragraphs A.1.2., A.1.3., A.1.4. and A.1.5. shall be performed at intervals during the emission test. The intervals shall be chosen taking into consideration the frequency capability of the gas chromatograph and corresponding calculation system.

A.1.6.3.2 The results from the periodic measurements and calculations shall be used to adjust the relative proportions of utility gas and admixture in order to maintain the value of S_λ within the range specified in Table A.7-1 for the respective reference fuel. The frequency of adjustment shall not exceed the frequency of measurement.

A.1.6.3.3. In order for the test to be considered valid the value of S_λ shall be within the range specified in Table A.7-1 for the respective reference fuel for at least 90 per cent of the measurement points.

Annex 7 - Appendix A.2

Calculation of λ-Shift factor (S_λ)

A.2.1. Calculation

The λ-shift factor (S_λ)[7] shall be calculated by means of equation (A.7-1):

$$S_\lambda = \frac{2}{\left(1-\frac{\text{inert\%}}{100}\right)\left(n+\frac{m}{4}\right)-\frac{O_2^*}{100}} \qquad \text{(A.7-1)}$$

Where:

S_λ = λ-shift factor;

inert per cent = per cent by volume of inert gases in the fuel (i.e. N_2, CO_2, He, etc.);

O_2^* = per cent by volume of original oxygen in the fuel;

n and m = refer to average C_nH_m representing the fuel hydrocarbons, i.e:

$$n = \frac{1\times\left[\frac{CH_4\%}{100}\right]+2\times\left[\frac{C_2\%}{100}\right]+3\times\left[\frac{C_3\%}{100}\right]+4\times\left[\frac{C_4\%}{100}\right]+5\times\left[\frac{C_5\%}{100}\right]+..}{\frac{1-\text{diluent }\%}{100}} \qquad \text{(A.7-2)}$$

$$m = \frac{4\times\left[\frac{CH_4\%}{100}\right]+4\times\left[\frac{C_2H_4\%}{100}\right]+6\times\left[\frac{C_2H_6\%}{100}\right]+...8\times\left[\frac{C_3H_8\%}{100}\right]+..}{\frac{1-\text{diluent }\%}{100}} \qquad \text{(A.7-3)}$$

Where:

CH_4 = per cent by volume of methane in the fuel;

C_2 = per cent by volume of all C_2 hydrocarbons (e.g.: C_2H_6, C_2H_4, etc.) in the fuel;

C_3 = per cent by volume of all C_3 hydrocarbons (e.g.: C_3H_8, C_3H_6, etc.) in the fuel;

C_4 = per cent by volume of all C_4 hydrocarbons (e.g.: C_4H_{10}, C_4H_8, etc.) in the fuel;

C_5 = per cent by volume of all C_5 hydrocarbons (e.g.: C_5H_{12}, C_5H_{10}, etc.) in the fuel;

diluent = per cent by volume of dilution gases in the fuel (i.e.: O_2*, N_2, CO_2, He, etc.).

[7] Stoichiometric Air/Fuel ratios of automotive fuels - SAE J1829, June 1987. John B. Heywood, Internal combustion engine fundamentals, McGraw-Hill, 1988, Chapter 3.4 "Combustion stoichiometry" (pp. 68 to 72).

A.2.2. Examples for the calculation of the λ-shift factor S_λ:

Example 1: G_{25}: CH_4 = 86 per cent, N_2 = 14 per cent (by volume)

$$n = \frac{1\times\left[\frac{CH_4\%}{100}\right] + 2\times\left[\frac{C_2\%}{100}\right] + ..}{\frac{1-\text{diluent}\%}{100}} = \frac{1\times 0.86}{1-\frac{14}{100}} = \frac{0.86}{0.86} = 1$$

$$m = \frac{4\times\left[\frac{CH_4\%}{100}\right] + 4\times\left[\frac{C_2H_4\%}{100}\right] + ..}{\frac{1-\text{diluent}\%}{100}} = \frac{4\times 0.86}{0.86} = 4$$

$$S_\lambda = \frac{2}{\left(1-\frac{\text{inert}\%}{100}\right)\left(n+\frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1-\frac{14}{100}\right)\times\left(1+\frac{4}{4}\right)} = 1.16$$

Example 2: G_R: CH_4 = 87 per cent, C_2H_6 = 13 per cent (by vol)

$$n = \frac{1\times\left[\frac{CH_4\%}{100}\right] + 2\times\left[\frac{C_2\%}{100}\right] + ..}{\frac{1-\text{diluent}\%}{100}} = \frac{1\times 0.87 + 2\times 0.13}{1-\frac{0}{100}} = \frac{1.13}{} = 1.13$$

$$m = \frac{4\times\left[\frac{CH_4\%}{100}\right] + 4\times\left[\frac{C_2H_4\%}{100}\right] + ..}{\frac{1-\text{diluent}\%}{100}} = \frac{4\times 0.87 + 6\times 0.13}{1} = 4.26$$

$$S_\lambda = \frac{2}{\left(1-\frac{\text{inert}\%}{100}\right)\left(n+\frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1-\frac{0}{100}\right)\times\left(1.13+\frac{4.26}{4}\right)} = 0.911$$

Example 3: CH_4 = 89 per cent, C_2H_6 = 4,5 per cent, C_3H_8 = 2,3 per cent, C_6H_{14} = 0,2 per cent, O_2 = 0,6 per cent, N_2 = 4 per cent

$$n = \frac{1\times\left[\frac{CH_4\%}{100}\right] + 2\times\left[\frac{C_2\%}{100}\right] + ..}{\frac{1-\text{diluent}\%}{100}} = \frac{1\times 0.89 + 2\times 0.045 + 3\times 0.023 + 4\times 0.002}{1-\frac{0.64+4}{100}} = 1.11$$

$$m = \frac{4\times\left[\frac{CH_4\%}{100}\right] + 4\times\left[\frac{C_2H_4\%}{100}\right] + 6\times\left[\frac{C_2H_6\%}{100}\right] + \;..\; + 8\times\left[\frac{C_3H_8\%}{100}\right]}{1-\frac{\text{diluent}\%}{100}} =$$

$$= \frac{4\times 0.89 + 4\times 0.045 + 8\times 0.023 + 14\times 0.002}{1-\frac{0.6+4}{100}} = 4{,}24$$

$$S_\lambda = \frac{2}{\left(1-\frac{\text{inert\%}}{100}\right)\left(n+\frac{m}{4}\right)-\frac{O_2^*}{100}} = \frac{2}{\left(1-\frac{4}{100}\right)\times\left(1.11+\frac{4.24}{4}\right)-\frac{0.6}{100}} = 0.96$$

As an alternative to the above equation, S_λ may be calculated from the ratio of the stoichiometric air demand of pure methane to the stoichiometric air demand of the fuel blend supplied to the engine, as specified below.

Lambda-shift factor (S_λ) expresses the oxygen demand of any fuel blend in relation to oxygen demand of pure methane. Oxygen demand means the amount of oxygen to oxidise methane in a stoichiometric composition of reaction partners to products of complete combustion (i.e. carbon-dioxide and water).

For the combustion of pure methane the reaction is as set out in equation (A.7-4):

$$1 \times CH_4 + 2 \times O_2 \rightarrow 1 \times CO_2 + 2 \times H_2O \qquad \text{(A.7-4)}$$

In this case the ratio of molecules in stoichiometric composition of reaction partners is exactly 2:

$\frac{n_{O2}}{n_{CH4}} = 2$

Where:

n_{O2} = number of molecules of oxygen

n_{CH4} = number of molecules of methane

The oxygen demand for pure methane is therefore:

$n_{O2} = 2 \cdot n_{CH4}$ with a reference value of $[n_{CH4}]$= 1kmol

The value of S_λ may be determined from the ratio of the stoichiometric composition of oxygen and methane to the ratio of the stoichiometric composition of oxygen and the fuel blend supplied to the engine, as set out in equation (A.6-5):

$$S_\lambda = \frac{\left(\frac{n_{O2}}{n_{CH4}}\right)}{\left(\frac{n_{O2}}{n_{blend}}\right)} = \frac{2}{(n_{O2})_{blend}} \qquad \text{(A.7-5)}$$

Where:

n_{blend} = number of molecules of the fuel blend

$(n_{O2})_{blend}$ = the ratio of the molecules in the stoichiometric composition of oxygen and the fuel blend supplied to the engine

Because air contains 21per cent oxygen the stoichiometric air demand L_{st} of any fuel shall be calculated by means of equation (A.6-6):

$$L_{st,fuel} = \frac{n_{O2,\ fuel}}{0.21} \qquad \text{(A.7-6)}$$

Where:

$L_{st,fuel}$ = the stoichiometric air demand for the fuel

$n_{O2,\ fuel}$ = the stoichiometric oxygen demand for the fuel

Consequently the value of S_λ may also be determined from the ratio of the stoichiometric composition of air and methane to the ratio of the stoichiometric composition of air and the fuel blend supplied to the engine, i.e. the ratio of the stoichiometric air demand of methane to that of the fuel blend supplied to the engine, as set out in equation (A.6-7):

$$S_\lambda = \frac{\left(\frac{n_{O2}}{n_{CH4}}\right)/0.21}{\left(\frac{n_{O2}}{n_{blend}}\right)/0.21} = \frac{\left(\frac{n_{O2}}{0.21}\right)_{CH4}}{\left(\frac{n_{O2}}{0.21}\right)_{blend}} = \frac{L_{st,CH4}}{L_{st,blend}} \qquad \text{(A.7-7)}$$

Therefore, any calculation that specifies the stoichiometric air demand may be used to express the Lambda-shift factor.