Proposal for a Directive of the European Parliament and of the Council amending Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery

(2001/C 180 E/05)

(Text with EEA relevance)

COM(2000) 840 final — 2000/0336(COD)

(Submitted by the Commission on 18 December 2000)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 95 thereof,

Having regard to the proposal from the Commission,

Having regard to the opinion of the Economic and Social Committee,

Having regard to the opinion of the Committee of the Regions,

Acting in accordance with the procedure laid down in Article 251 of the Treaty

Whereas:

(1) The Auto Oil II programme was a programme to identify cost effective strategies to meet the air quality objectives of the Community. The Commission Communication Review on the Auto Oil II programme (¹) concluded that there is a need for measures, especially to address the issues of ozone and particulate emissions. Recent work on the development of national emissions ceilings has shown that further measures are needed to meet the air quality objectives decided upon in the Community legislation.

(2) Stringent standards on emissions from vehicles on highways have been gradually introduced. It has already been decided that those standards should be strengthened. The relative contribution of pollutants from non-road mobile machinery thus will be more predominant in the future.

(3) Directive 97/68/EC of the European Parliament and of the Council (²) introduced emission limit values for gaseous

and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery.

(4) Although Directive 97/68/EC initially applied only to certain compression ignition engines, recital (5) of that Directive envisages the extension of its scope to include gasoline engines.

(5) The emissions from small spark ignition engines (gasoline engines) in different types of machinery contribute significantly to identified air quality problems, both current and future, especially ozone formation.

(6) Emissions from small spark ignition engines are subject to strict environmental standards in the USA showing that it is technically possible to significantly reduce the emissions.

(7) The absence of Community legislation means it is possible to import engines with old-fashioned technology from an environmental point of view, thereby jeopardising the air quality objectives in the Community or to implement national legislation in this field, with the potential to create barriers to trade.

(8) Directive 97/68/EC is closely aligned with the corresponding US legislation and continuing alignment will have benefits for industry as well as for the environment.

(9) A certain lead time is necessary for the European industry, especially for those manufacturers that are not yet operating on a global basis, to be able to meet the emission standards.

(10) A two-step approach is used in Directive 97/68/EC for compression ignition engines as well as in the US regulations on spark ignition engines. Although it might have been possible to adopt a one-step approach in the Community legislation, this would have left the field unregulated for another 4-5 years, thereby creating a market for engines with high emissions.

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(¹) COM(2000) 626 final.
(²) OJ L 59, 27.2.1998, p. 1.

(11) A system of averaging, banking and trading is an important element of stage II of the US regulations. Such a system means that a manufacturer can compensate emissions above the standards for one engine family by lower emissions from another as long as the average emissions of the engines sold is below the standard, banking credits from one year to another to achieve the averaging goal and buying and selling those credits to other manufacturers. The averaging and banking parts of the system, in particular, are essential when trying to align the US and Community legislation. A similar system of banking and trading is included in this Directive, to be used on a voluntary basis.

(12) Averaging and banking has never before been used in the Community legislation in this field. Differences in the administrative systems between the Community and the USA create some uncertainties about the details of the averaging and banking systems; the Commission will review the details of the included averaging and banking systems and, where necessary, propose changes or amendments before the scheduled date of entry into force.

(13) Provisions of Directive 97/68/EC concerning the Committee procedure should be adapted to take account of Council Decision 1999/468/EC of 28 June 1999 laying down the procedures for the exercise of implementing powers conferred on the Commission ([1]).

(14) Directive 97/68/EC should be amended accordingly,

HAVE ADOPTED THIS DIRECTIVE:

Article 1

Directive 97/68/EC is amended as follows:

1. In Article 2, the following indents are added:

    '— "replacement engines" shall mean a newly built engine to replace an engine in a machine, and which has been supplied for this purpose only,

    — "handheld engine" shall mean an engine that meets at least one of the following requirements:

    (a) the engine must be used in a piece of equipment that is carried by the operator throughout the performance of its intended function(s).

    (b) the engine must be used in a piece of equipment that must operate multipositionally, such as upside down or sideways, to complete its intended function(s).

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([1]) OJ L 184, 17.7.1999, p. 23.

(c) the engine must be used in a piece of equipment for which the combined engine and equipment dry weight is under 20 kilograms and at least one of the following attributes is also present:

    (i) the operator must alternatively provide support or carry the equipment throughout the performance of its intended function(s)

    (ii) the operator must provide support or attitudinal control for the equipment throughout the performance of its intended function(s)

    (iii) the engine must be used in a generator or a pump,

— "non-handheld engine" shall mean an engine which does not fall under the definition of a handheld engine,

— "emission durability period" shall mean the number of hours indicated in Annex IV Appendix 4 used to determine the deterioration factors,

— "small volume engine family manufacturer of SI engines" shall mean a manufacturer with a total production of less than 5 000 units of one and the same class,

— "small volume engine manufacturer of SI engines" shall mean a manufacturer with a total production of less than 25 000 units.'

2. In Article 3, the following paragraph 4 is added:

    '4. A manufacturer may, for SI engines with a power output of not more than 19 kW for stage II, on a voluntary basis, use the alternative type approval procedure described in Annex XII to this Directive.'

3. Article 4 is amended as follows:

a) Paragraph 2 is amended as follows:

    (i) in the first sentence 'Annex VI' is replaced by 'Annex VII';

    (ii) in the second sentence 'Annex VII' is replaced by 'Annex VIII';

(b) Paragraph 4 is amended as follows:

    (i) in point (a) 'Annex VIII' is replaced by 'Annex IX';

    (ii) in point (b) 'Annex IX' is replaced by 'Annex X';

(c) In paragraph 5, 'Annex X' is replaced by 'Annex XI'.

(d) The following paragraph 6 is added:

'6. If a manufacturer has chosen to use the voluntary type approval procedure described in Annex XII, sections 8, 9 and 10 of that Annex shall apply by way of derogation from paragraphs 1 to 2 and paragraph 4 of this Article'.

4. In Article 6 the following paragraph 5 is added:

'5. If a manufacturer has chosen to use the voluntary averaging and banking procedure described in Annex XII, section 10 of that Annex shall apply by way of derogation from paragraphs 3 and 4 of this Article.'

5. In Article 7, the following paragraph 3 is added:

'3. Type-approvals according to Directive 88/77/EEC which are in compliance with stages A, B1, B2 or C, provided for in Article 2 and section 6.2.1 of Annex 1 to Directive 1999/96/EC of the European Parliament and of the Council ([1]), and, where applicable, the pertaining approval marks shall be accepted for Stage II provided for in Article 9(3) of this Directive.

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([1]) OJ L 44, 16.2.2000, p. 1.'

6. In Article 8, the first sentence of paragraph 5 is replaced by the following:

'With regard to the control of the identification numbers, the manufacturer or his agents established in the Community shall without delay give, on request, to the responsible approval authority all the information needed related to his/their purchasers together with the identification numbers of the engines reported as produced in accordance with Article 6(3) or section 10 of Annex XII.'

7. Article 9 is amended as follows:

(a) The heading 'Timetable' is replaced by the heading 'Timetable — Compression ignition engines';

(b) In point 1, 'Annex VI' is replaced by 'Annex VII';

(c) Point 2 is amended as follows:

(i) 'Annex VI' is replaced by 'Annex VII';

(ii) 'section 4.2.1 of Annex I' is replaced by 'section 4.1.2.1 of Annex I';

(d) Point 3 is amended as follows:

(i) 'Annex VI' is replaced by 'Annex VII';

(ii) 'section 4.2.3 of Annex I' is replaced by 'section 4.1.2.3 of Annex I';

(e) In point 4, first paragraph, the word 'new' is deleted.

8. The following Article 9a is inserted:

'_Article 9a_

Timetable — Spark ignition engines

1. DIVIDING INTO CLASSES

For the purpose of this Directive Spark Ignition Engines shall be divided into the following classes.

Main class S: Small engines with a net power ≤ 19 kW

The main class S shall be divided into two categories

H: Engines for handheld machinery

N: Engines for non-handheld machinery

Class/category	Displacement (cubic cm)
Handheld engines	
Class SH:1	< 20
Class SH:2	≥ 20 to < 50
Class SH:3	≥ 50
Non-handheld engines	
Class SN:1	< 66
Class SN:2	≥ 66 < 100
Class SN:3	≥ 100 < 225
Class SN:4	≥ 225

2. GRANT OF TYPE APPROVALS

After dd/mm/yy, Member States may not refuse to grant type-approval for an SI engine type or engine family or to issue the document as described in Annex VII, and may not impose any other type-approval requirements with regard to air-polluting emissions for non-road mobile machinery in which an engine is installed, if the engine meets the requirements specified in this Directive as regards the emissions of gaseous pollutants.

3. TYPE-APPROVALS STAGE I

Member States shall refuse to grant type-approval for an engine type or engine family and to issue the documents as described in Annex (VI), and shall refuse to grant any other type-approval for non-road mobile machinery in which an engine is installed after (18) months from the date of entry into force of this Directive, if the engine fails to meet the requirements specified in this Directive and where the emissions of gaseous pollutants from the engine do not comply with the limit values as set out in the table in section 4.2.2.1 of Annex I.

4. TYPE-APPROVALS STAGE II

Member States shall refuse to grant type-approval for an engine type or engine family and to issue the documents as described in Annex (VI), and shall refuse to grant any other type-approval for non-road mobile machinery in which an engine is installed:

after 1 August 2004 for engine classes SN:1 and SN:2

after 1 August 2006 for engine class SN:4

after 1 August 2008 for engine classes SH1, SH 2 and SN:3

after 1 August 2010 for engine class SH:3,

if the engine fails to meet the requirements specified in this Directive and where the emissions of gaseous pollutants from the engine do not comply with the limit values as set out in the table in section 4.2.2.2 of Annex 1.

5. PLACING ON THE MARKET:

ENGINE PRODUCTION DATES

Six months after the dates for the relevant category of engine in paragraphs 3 and 4, with the exception of machinery and engines intended for export to third countries, Member States shall permit placing on the market of engines, whether or not already installed in machinery, only if they meet the requirements of this Directive.

Nevertheless, for each category, Member States may postpone the dates in paragraphs 3 and 4 for two years in respect of engines with a production date prior to those dates.'

9. Article 10 is amended as follows:

(a) Paragraph 1 is replaced by the following:

'1. The requirements of Article 8(1) and (2), Article 9(4) and Article 9a (5) shall not apply to:

— engines for use by the armed services,

— engines exempted in accordance with paragraphs 1a and 2;'

(b) The following paragraph 1a is inserted:

'1a. A replacement engine shall comply with the limit values that the engine to be replaced had to meet when originally placed on the market.

The text "Replacement engine" shall be attached to a label on the engine or inserted into the owner's manual.'

(c) The following paragraphs 3 and 4 are added:

'3. The requirements of Article 9a (4) shall be postponed by three years for small volume engine manufacturers.

4. The requirements of Article 9a(4) shall be replaced by the corresponding stage I requirements for a small volume engine family manufacturer for the class or classes for which the manufacturer can show a yearly production less than 5 000 units.'

10. Articles 14 and 15 are replaced by the following:

'*Article 14*

Adaptation to technical progress

Any amendments which are necessary in order to adapt the Annexes to this Directive, with the exception of the requirements specified in section 1, sections 2.1 to 2.8 and section 4 of Annex I, to take account of technical progress shall be adopted by the Commission in accordance with the procedure referred to in Article 15(2).

Article 15

Committee

1. The Commission shall be assisted by the committee established by Article 13 of Council Directive 70/156/EEC (¹) composed of representatives of the Member States and chaired by the representative of the Commission.

2. Where reference is made to this article, the regulatory procedure laid down in Article 5 of Council Decision 1999/468/EC (²) shall apply, in compliance with Article 7 [and Article 8 If codecision] thereof.

3. The period provided for in Article 5(6) of Decision 1999/468/EC shall be 3 months.

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(¹) OJ L 42, 23.2.1970, p. 1.
(²) OJ L 184, 17.7.1999, p. 23.'

11. The following list of annexes is added:

'**List of Annexes**

ANNEX I: SCOPE, DEFINITIONS . . .

ANNEX II: INFORMATION DOCUMENTS

Appendix 1: Essential characteristics of the (parent) engine

Appendix 2: Essential characteristics of the engine family

Appendix 3: Essential characteristics of engine type within family

ANNEX III: TEST PROCEDURE — COMPRESSION IGNITION ENGINES

Appendix 1: Measurement and sampling procedures

Appendix 2: Calibration of the analytical instruments

Appendix 3: Data evaluation and calculations

ANNEX IV: TEST PROCEDURE — SPARK IGNITION ENGINES

Appendix 1: Measurement and sampling procedures

Appendix 2: Calibration of the analytical instruments

Appendix 3: Data evaluation and calculations

Appendix 4: Deterioration factors

ANNEX V: TECHNICAL CHARACTERISTICS OF REFERENCE FUEL

ANNEX VI: ANALYTICAL AND SAMPLING SYSTEM

ANNEX VII: TYPE APPROVAL CERTIFICATE

Appendix 1: Test result for CI engines

Appendix 2: Test result for SI engines

Appendix 3: Equipment and auxiliaries to be installed for the test to determine engine power

ANNEX VIII: APPROVAL CERTIFICATE NUMBERING SYSTEM

ANNEX IX: LIST OF ENGINE/ENGINE FAMILY TYPE-APPROVALS ISSUED

ANNEX X: LIST OF ENGINES PRODUCED

ANNEX XI: DATA SHEET OF TYPE APPROVED ENGINES

ANNEX XII: PROCEDURE FOR VOLUNTARY AVERAGING AND BANKING'

12. The Annexes are amended in accordance with the Annex to this Directive.

Article 2

1. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by dd/mm/yy at the latest. They shall forthwith inform the Commission thereof.

When Member States adopt those provisions, they shall contain a reference to this Directive or be accompanied by such a reference on the occasion of their official publication. Member States shall determine how such reference is to be made.

2. Member States shall communicate to the Commission the texts of the main provisions of the national law that they adopt in the field governed by this Directive.

Article 3

This Directive shall enter into force on the twentieth day following that of its publication in the *Official Journal of the European Communities*.

Article 4

This Directive is addressed to the Member States.

ANNEX

1. Annex I is amended as follows:

   (a) The first sentence of Section 1 'SCOPE' shall be replaced by the following:

   'This Directive applies to all engines to be installed in non-road mobile machinery and to secondary engines fitted into vehicles intended for passenger or goods transport on the road.'

   (b) In paragraph 1A the first sentence is amended as follows:

   'A. intended and suited, to move, or to be moved on the ground with or without road and with either

        (a) a C.I. engine having a net power in accordance with section 2.4 that is higher than 18 kW but not more than 560 kW (⁴) and that is operated under intermittent speed rather than a single constant speed.

           Machinery, the engines . . .

           (remains unchanged)

           — . . .

           — mobile cranes;

           or

        (b) a C.I. engine for irrigation pumps or generating sets with intermittent load.

           Machinery, the engines of which are covered under this definition, includes but is not limited to:

           — gas compressors,

           — generating sets with intermittent load including refrigerating units and welding sets,

           — irrigation pumps,

           — turf care, chippers, snow removal equipment, sweepers;

           or

        (c) a petrol fuelled S.I. engine having a net power in accordance with section 2.4 of not more than 19 kW.

           Machinery, the engines of which are covered under this definition, includes but is not limited to:

           — lawn mowers,

           — chain saws,

           — generators,

           — water pumps,

           — bush cutters.

   The Directive is not applicable for the following applications:

   B. ships;

   C. railway locomotives;

   D. aircraft;

      E. recreational vehicles;

      F. generating sets with C.I. engines for stage I and for stage II until 31 December 2006.'

(c) Section 2 is amended as follows:

   — The following words shall be added to footnote 2 in section 2.4:

      '. . . except for engines where such an auxiliary is an integral part of the engine (see Appendix 3 of Annex VII).'

   — The following new indent shall be added to section 2.8:

      '— for engines to be tested on cycle G1, the intermediate speed shall be 85 % of the maximum rated speed (see section 3.5.1.2 of Annex IV).'

   — The following new sections shall be added:

      '2.9.   *adjustable parameter* shall mean any physically adjustable device, system or element of design which may affect emission or engine performance during emission testing or normal operation;

      2.10.   *after-treatment* shall mean the passage of exhaust gases through a device or system whose purpose is chemically or physically to alter the gases prior to release to the atmosphere;

      2.11.   *spark ignition (S.I.) engine* shall mean an engine which works on the spark-ignition principle;

      2.12.   *auxiliary emission control device* shall mean any device that senses engine operation parameters for the purpose of adjusting the operation of any part of the emission control system;

      2.13.   *emission control system* shall mean any device, system or element of design which controls or reduces emissions;

      2.14.   *fuel system* shall mean all components involved in the metering and mixture of the fuel;

      2.15.   *secondary engine* shall mean an engine installed in or on a motor vehicle, but not providing motive power to the vehicle.'

   — Section 2.9 becomes a new section 2.16 and current sections 2.9.1 to 2.9.3 become new sections 2.16.1 to 2.16.3.

(d) Section 3 is amended as follows:

   — Section 3.1 is replaced by the following:

      '3.1.   Compression ignition engines approved in accordance with this Directive must bear:'

   — Section 3.1.3 is amended as follows:

      Annex VII is replaced by Annex VIII.

   — A new section 3.2 is inserted as follows:

      '3.2.   Spark ignition engines approved in accordance with this Directive must bear:

      3.2.1.   the trade mark or trade name of the manufacturer of the engine;

      3.2.2.   the EC type-approval number as defined in Annex VIII;

      3.2.3.   the averaging scheme approval number if the engine is included in an emission averaging system as provided for in Annex XII.'

   — Sections 3.2 to 3.6 become new sections 3.3 to 3.7.

   — Section 3.7 is amended as follows: Annex VI is replaced by Annex VII.

(e) Section 4 is amended as follows:

— The following new heading shall be inserted: '4.1. CI engines.'

— Current section 4.1 shall become section 4.1.1.

— Current section 4.2 shall become section 4.1.2 and is amended as follows: Annex V is replaced by Annex VI.

— Current section 4.2.1 shall become new section 4.1.2.1; current section 4.2.2 shall become new section 4.1.2.2 and the reference to section 4.2.1 shall be replaced by a reference to section 4.1.2.1; current sections 4.2.3 and 4.2.4 shall become new sections 4.1.2.3 and 4.1.2.4.

(f) The following new paragraph shall be added:

'4.2.   SI engines

4.2.1.   General

The components liable to affect the emission of gaseous pollutants 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 Directive.

The technical measures taken by the manufacturer must be such as to ensure that the mentioned emissions are effectively limited, pursuant to this Directive, throughout the normal life of the engine and under normal conditions of use in accordance with Annex IV, Appendix 4.

4.2.2.   Specifications concerning the emissions of pollutants.

The gaseous components emitted by the engine submitted for testing shall be measured by the methods described in Annex VI (and shall include any after-treatment device).

Other systems or analysers may be accepted if they yield equivalent results to the following reference systems:

— for gaseous emissions measured in the raw exhaust, the system shown in Figure 2 of Annex VI,

— for gaseous emissions measured in the dilute exhaust of a full flow dilution system, the system shown in Figure 3 of Annex VI.

4.2.2.1.   The emissions of carbon monoxide, the emissions of hydrocarbons, the emissions of oxides of nitrogen and the sum of hydrocarbons and oxides of nitrogen obtained shall for stage I not exceed the amount shown in the table below:

Stage I

Class	Class Carbon monoxide (CO) (g/kWh)	Hydrocarbons (HC) (g/kWh)	Oxides of nitrogen (NO$_x$) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (g/kWh) HC + NO$_x$
SH:1	805	295	5,36	
SH:2	805	241	5,36	
SH:3	603	161	5,36	
SN:1	519			50
SN:2	519			40
SN:3	519			16,1
SN:4	519			13,4

4.2.2.2. The emissions of carbon monoxide and the emissions of the sum of hydrocarbons and oxides of nitrogen obtained shall for stage II not exceed the amount shown in the table below:

Stage II

Class	Class Carbon monoxide (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (g/kWh)
		HC + NO$_x$
SH:1	805	50
SH:2	805	50
SH:3	603	72
SN:1	610	50,0
SN:2	610	40,0
SN:3	610	16,1
SN:4	610	12,1

The NO$_x$ emissions for all engine classes must not exceed 10 g/kWh.

4.2.2.3. Notwithstanding the definition of "handheld engine" in Article 2 of this Directive two-stroke engines used to power snowthrowers may meet SH:1, SH:2 or SH:3 standards.'

(g) Sections 6.3 to 6.9 are replaced by the following:

'6.3. Individual cylinder displacement, within 85 % and 100 % of the largest displacement within the engine family.

6.4. Method of air aspiration

6.5. Fuel type

— diesel

— petrol

6.6. Combustion chamber type/design

6.7. Valve and porting — configurations, size and number

6.8. Fuel system:

for diesel

— pump-line injector

— in-line pump

— distributor pump

— single element

— unit injector

for petrol

— carburettor

— port fuel injection

— direct injection

6.9. Miscellaneous features

— exhaust gas recirculation

— water injection/emulsion

— air injection

     — charge cooling system

     — ignition type (compression, spark)

   6.10.   Exhaust after-treatment'

2.   Annex II is amended as follows:

  (a) In Appendix 2 the text in the table is amended as follows:

    'Fuel delivery per stroke (mm^3)' in lines 3 and 6 shall be replaced by

    'Fuel delivery per stroke (mm^3) for diesel engines,

    fuel flow (g/h) for petrol engines'.

  (b) Appendix 3 is amended as follows:

    — The heading of section 3 shall be replaced by 'Fuel feed for diesel engines'

    — The following new sections shall be inserted:

      '4.   Fuel feed for petrol engines

      4.1.   Carburettor

      4.1.1. Make(s): . . .

      4.1.2. Type(s): . . .

      4.2.   Port fuel injection: single-point or multi-point

      4.2.1. Make(s): . . .

      4.2.2. Type(s): . . .

      4.3.   Direct injection

      4.3.1. Make(s): . . .

      4.3.2 Type(s): . . .

      4.4.   Fuel flow [g/h] and air/fuel ratio at rated speed and wide open throttle'

    — Current section 4 becomes section 5 and shall be amended as follows:

      '5.3.   Variable valve timing system (if applicable and where intake and/or exhaust)

      5.3.1. Type: continuous or on/off

      5.3.2. Cam phase shift angle'

    — The following new section shall be added:

      '6.   Porting configuration

      6.1.   Position, size and number'

    — The following new section shall be added:

      '7.   Ignition system

      7.1.   Ignition coil

      7.1.1. Make(s): . . .

      7.1.2. Type(s): . . .

      7.1.3. Number: . . .

7.2.   Spark plug(s)

7.2.1. Make(s): . . .

7.2.2. Type(s): . . .

7.3.   Magneto

7.3.1. Make(s): . . .

7.3.2. Type(s): . . .

7.4.   Ignition timing

7.4.1. Static advance with respect to top dead centre [crank angle degrees]

7.4.2. Advance curve, if applicable: . . .'

3.   Annex III is amended as follows:

(a) The heading is replaced by the following:

'Test procedure for CI engines'

(b) Section 2.7 is amended as follows:

Annex VI is replaced by Annex VII and Annex IV is replaced by Annex V.

(c) Section 3.6. is amended as follows:

— Sections 3.6.1 and 3.6.1.1. are amended as follows:

'3.6.1.   Test cycle of machinery according to Section 1 of Annex I:

3.6.1.1. The following 8-mode cycle (1) shall be followed by specification A of machinery in dynamometer operation on the test engine: . . .

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(1) Identical with C1 cycle of the draft ISO 8178-4 standard.'

— A new section 3.6.1.2. is added as follows:

'3.6.1.2. The following 5-mode cycle (1) shall be followed by specification (b) of machinery in dynamometer operation on the test engine:

Mode number	Engine speed	Load %	Weighting factor
1	Rated	100	0,05
2	Rated	75	0,25
3	Rated	50	0,3
4	Rated	25	0,3
5	Rated	10	0,1

The load figures are percentage values of the torque corresponding to the prime power rating defined as the maximum power available during a variable power sequence, which may be run for an unlimited number of hours per year, between stated maintenance intervals and under the stated ambient conditions, the maintenance being carried out as prescribed by the manufacturer (2).

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(1) Identical with D2 cycle of the ISO 8168-4: 1996(E) standard.
(2) For a better illustration of the prime power definition, see Figure 2 of ISO 8528-1: 1993(E) standard.'

— Section 3.6.3 is amended as follows:

'3.6.3.   Test sequence

The test sequence shall be started. The test shall be performed in ascending order of mode numbers as set out above for the test cycles.

During each mode of the given test cycle . . .'

(d) Appendix 1, section 1 is amended as follows:

In section 1 and 1.4.3. Annex V is replaced by Annex VI.

4. The following new annex is added:

'ANNEX IV

TEST PROCEDURE FOR SPARK IGNITION ENGINES

1.   INTRODUCTION

1.1.   This Annex describes the method of determining emissions of gaseous pollutants from the engines to be tested.

1.2.   The test shall be carried out with the engine mounted on a test bench and connected to a dynamometer.

2.   TEST CONDITIONS

2.1.   Engine test conditions

The absolute temperature (T_a) of the engine air at the inlet to the engine, expressed in Kelvin, and the dry atmospheric pressure (p_s), expressed in kPa, shall be measured and the parameter f_a shall be determined according to the following provisions:

$$f_a = \left(\frac{99}{p_s} \right) \times \left(\frac{T_a}{298} \right)^{0,7}$$

2.1.1.   Test validity

For a test to be recognised as valid, the parameter f_a shall be such that:

$$0,96 \leq f_a \leq 1,06$$

2.1.2.   Engines with charge air-cooling

The temperature of the cooling medium and the temperature of the charge air have to be recorded.

2.2.   Engine air inlet system

The test engine shall be equipped with an air inlet system presenting an air inlet restriction within 10 % of the upper limit specified by the manufacturer for a new air cleaner at the engine operating conditions, as specified by the manufacturer, which result in maximum air flow in the respective engine application.

For small spark ignition engines (< 1 000 cm³ displacement) a system representative of the installed engine shall be used.

2.3.   Engine exhaust system

The test engine shall be equipped with an exhaust system presenting an exhaust back pressure within 10 % of the upper limit specified by the manufacturer for the engine operating conditions which result in the maximum declared power in the respective engine application.

For small spark ignition engines (< 1 000 cm³ displacement) a system representative of the installed engine shall be used.

2.4. Cooling system

An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures prescribed by the manufacturer shall be used. This provision shall apply to units which have to be detached in order to measure the power, such as with a blower where the blower (cooling) fan has to be disassembled to get access to the crankshaft.

2.5. Lubricating oil

Lubricating oil that meets the engine manufacturer's specifications for a particular engine and intended usage shall be used. Manufacturers must use engine lubricants representative of commercially available engine lubricants.

The specifications of the lubricating oil used for the test shall be recorded at section 1.2 of Annex VII, Appendix 2 for SI engines and presented with the results of the test.

2.6. Adjustable carburettors

Engines with limited adjustable carburettors shall be tested at both extremes of the adjustment.

2.7. Test fuel

The fuel shall be the reference fuel specified in Annex V.

The octane number and the density of the reference fuel used for test shall be recorded at section 1.1.1 of Annex VII, Appendix 2 for SI engines.

For two-stroke engines, the fuel/oil mixture ratio must be the ratio which is recommended by the manufacturer. The percentage of oil in the fuel/lubricant mixture feeding the two-stroke engines and the resulting density of the fuel shall be recorded at section 1.1.4 of Annex VII, Appendix 2 for SI engines.

2.8. Determination of dynamometer settings

Emissions measurements shall be based on uncorrected brake power. Auxiliaries necessary only for the operation of the machine and which may be mounted on the engine shall be removed for the test. Where auxiliaries have not been removed, the power absorbed by them shall be determined in order to calculate the dynamometer settings except for engines where such auxiliaries form an integral part of the engine (e.g. cooling fans for air cooled engines).

The settings of inlet restriction and exhaust pipe backpressure shall be adjusted, for engines where it is possible to perform such an adjustment, to the manufacturer's upper limits, in accordance with sections 2.2 and 2.3. The maximum torque values at the specified test speeds shall be determined by experimentation in order to calculate the torque values for the specified test modes. For engines which are not designed to operate over a speed range on a full load torque curve, the maximum torque at the test speeds shall be declared by the manufacturer. The engine setting for each test mode shall be calculated using the formula:

$$S = \left[(P_M + P_{AE}) \times \frac{L}{100} \right] - P_{AE}$$

where:

S   is the dynamometer setting (kW)

P_M is the maximum observed or declared power at the test speed under the test conditions (see Appendix 2 of Annex VII) (kW)

P_{AE} is the declared total power absorbed by any auxiliary fitted for the test (kW) and not required by Appendix 3 of Annex VII

L   is the percent torque specified for the test mode.

If the ratio

$$\frac{P_{AE}}{P_M} \geq 0.03$$

the value of P_{AE} may be verified by the technical authority granting type approval.

3.   TEST RUN

3.1.   Installation of the measuring equipment

The instrumentation and sampling probes shall be installed as required. When using a full flow dilution system for exhaust gas dilution, the tailpipe shall be connected to the system.

3.2.   Starting the dilution system and engine

The dilution system and the engine shall be started and warmed up until all temperatures and pressures have stabilised at full load and rated speed (section 3.5.2.).

3.3.   Adjustment of the dilution ratio

The total dilution ratio shall not be less than four.

For CO_2 or NO_x concentration controlled systems, the CO_2 or NO_x content of the dilution air must be measured at the beginning and at the end of each test. The pre- and post-test background CO_2 or NO_x concentration measurements of the dilution air must be within 100 ppm or 5 ppm of each other, respectively.

When using a dilute exhaust gas analysis system, the relevant background concentrations shall be determined by sampling dilution air into a sampling bag over the complete test sequence.

Continuous (non-bag) background concentration may be taken at the minimum of three points, at the beginning, at the end, and a point near the middle of the cycle and averaged. At the manufacturer's request background measurements may be omitted.

3.4.   Checking the analysers

The emission analysers shall be set at zero and spanned.

3.5.   Test cycle

3.5.1.   Specification (c) of machinery according to section 1 of Annex I.

The following test cycles shall be followed in dynamometer operation on the test engine according to the given type of machinery:

cycle D [1]: generating sets with intermittent load;

cycle G1: non-handheld intermediate speed applications;

cycle G2: non-handheld rated speed applications;

cycle G3: handheld rated speed applications.

3.5.1.1.   Test modes and weighting factors

Cycle D											
Mode number	1	2	3	4	5						
Engine speed	Rated speed					Intermediate				Low-idle speed	
Load (*) %	100	75	50	25	10						
Weighting factor	0,05	0,25	0,3	0,3	0,1						

_____

[1] Identical with D2 cycle of the ISO 8168-4: 1996(E) standard.

Cycle G1

Mode number						1	2	3	4	5	6
Engine speed	Rated speed					Intermediate speed					Low-idle speed
Load %						100	75	50	25	10	0
Weighting factor						0,09	0,2	0,29	0,3	0,07	0,05

Cycle G2

Mode number	1	2	3	4	5						6
Engine speed	Rated speed					Intermediate speed					Low-idle speed
Load %	100	75	50	25	10						0
Weighting factor	0,09	0,2	0,29	0,3	0,07						0,05

Cycle G3

Mode number	1										2
Engine speed	Rated speed					Intermediate speed					Low-idle speed
Load %	100										0
Weighting factor	0,85 (**)										0,15 (**)

(*) The load figures are percentage values of the torque corresponding to the prime power rating defined as the maximum power available during a variable power sequence, which may be run for an unlimited number of hours per year, between stated maintenance intervals and under the stated ambient conditions, the maintenance being carried out as prescribed by the manufacturer. For a better illustration of the prime power definition, see Figure 2 of ISO 8528-1: 1993(E) standard.

(**) For phase 4, 0.90 and 0.10 may be used instead of 0.85 and 0.15 respectively.

3.5.1.2. Definitions

The mode length is the time between leaving the speed and/or torque of the previous mode or the preconditioning phase and the beginning of the following mode. It includes the time during which speed and/or torque are changed and the stabilisation at the beginning of each mode.

The rated speed is the engine speed at which, according to the statement of the engine manufacturer, the rated power is delivered.

The intermediate speed shall be 85 % of the maximum rated speed for engines to be tested on test cycle G1.

3.5.1.3. Choosing an appropriate test cycle

If the primary end use of an engine model is known then the test cycle may be chosen based on the examples given in section 3.5.1.4. If the primary end use of an engine is uncertain then the appropriate test cycle should be chosen based upon the engine specification.

3.5.1.4. Examples (the list is not exhaustive):

Typical examples are for:

Cycle D:

Generating sets with intermittent load including generating sets on board ships and trains (not for propulsion), refrigerating units, welding sets;

Gas compressors.

Cycle G1:

Front or rear engines riding lawn mowers;

Golf carts;

Lawn sweepers;

Pedestrian-controlled rotary or cylinder lawn mowers;

Snow removal equipment;

Waste disposers.

Cycle G2:

Portable generators, pumps, welders and air compressors;

May also include lawn and garden equipment, which operate at engine rated speed.

Cycle G3:

Blowers;

Chain saws;

Hedge trimmers;

Portable saw mills;

Rotary tillers;

Sprayers;

String trimmers;

Vacuum equipment.

3.5.2. Conditioning of the engine

Warming up of the engine and the system shall be at maximum speed and torque in order to stabilise the engine parameters according to the recommendations of the manufacturer.

Note: The conditioning period should also prevent the influence of deposits from a former test in the exhaust system. There is also a required period of stabilisation between test points which has been included to minimise point to point influences.

3.5.3. Test sequence

Test cycles G1, G2 or G3 shall be performed in ascending order of mode number of the cycle in question. When only gaseous emissions are measured each mode sampling time shall be at least 180 s. The gaseous exhaust emission concentration values shall be measured and recorded for the last 120 s of the respective sampling time. For each measuring point, the mode length shall be of sufficient duration to achieve thermal stability of the engine prior to the start of sampling. The mode length shall be recorded and reported.

(a) For engines tested with the dynamometer speed control test configuration:

During each mode of the test cycle after the initial transition period, the specified speed shall be held to within ± 1 % of rated speed or ± 3 min^{-1} whichever is greater except for low idle which shall be within the tolerances declared by the manufacturer. The specified torque shall be held so that the average over the period during which the measurements are being taken is within ± 2 % of the maximum torque at the test speed.

(b) For engines tested with the dynamometer load control test configuration:

During each mode of the test cycle after the initial transition period, the specified speed shall be within ± 2 % of rated speed or ± 3 min^{-1} whichever is greater, but shall in any case be held within ± 5 %, except for low idle which shall be within the tolerances declared by the manufacturer.

During each mode of the test cycle where the prescribed torque is 50 % or greater of the maximum torque at the test speed the specified average torque over the data acquisition period shall be held within ± 5 % of the prescribed torque. During modes of the test cycle where the prescribed torque is less than 50 % of the maximum torque at the test speed the specified average torque over the data acquisition period shall be held within ± 10 % of the prescribed torque or ± 0,27 Nm whichever is greater.

3.5.4. Analyser response

The output of the analysers shall be recorded on a strip chart recorder or measured with an equivalent data acquisition system with the exhaust gas flowing through the analysers at least during the last three minutes of each mode. If bag sampling is applied for the diluted CO and CO_2 measurement (see Appendix 1, section 1.4.4), a sample shall be bagged during the last 180 s of each mode, and the bag sample analysed and recorded.

3.5.5. Engine conditions

The engine speed and load, intake air temperature and fuel flow shall be measured for each mode once the engine has been stabilised. Any additional data required for calculation shall be recorded (see Appendix 3, sections 1.1 and 1.2).

3.6. Rechecking the analysers

After the emission test a zero gas and the same span gas shall be used for re-checking. The test shall be considered acceptable if the difference between the two measuring results is less than 2 %.

Appendix 1

1. MEASUREMENT AND SAMPLING PROCEDURES

Gaseous components emitted by the engine submitted for testing shall be measured by the methods described in Annex VI. The methods of Annex VI describe the recommended analytical systems for the gaseous emissions (section 1.1).

1.1. Dynamometer specification

An engine dynamometer with adequate characteristics to perform the test cycles described in Annex IV, section 3.5.1 shall be used. The instrumentation for torque and speed measurement shall allow the measurement of the shaft power within the given limits. Additional calculations may be necessary.

The accuracy of the measuring equipment must be such that the maximum tolerances of the figures given in section 1.3 are not exceeded.

1.2. Fuel flow and total diluted flow

Fuel flow meters with the accuracy defined in section 1.3 shall be used to measure the fuel flow that will be used to calculate emissions (Appendix 3). When using a full flow dilution system, the total flow of the dilute exhaust (G_{TOTW}) shall be measured with a PDP or CFV — Annex VI, section 1.2.1.2. The accuracy shall conform to the provisions of Annex III, Appendix 2, section 2.2.

1.3.   Accuracy

The calibration of all measuring instruments shall be traceable to national (international) standards and comply with the requirements given in tables 2 and 3.

Table 2

Permissible deviations of instruments for engine-related parameters

No.	Item	Permissible deviation
1	Engine speed	± 2 % of the reading or ± 1 % of engine's max value whichever is larger
2	Torque	± 2 % of the reading or ± 1 % of engine's max value whichever is larger
3	Fuel consumption (a)	± 2 % of engine's max value
4	Air consumption (a)	± 2 % of the reading or ± 1 % of engine's max value whichever is larger

(a) The calculations of the exhaust emissions as described in this Directive are, in some cases, based on different measurement and/or calculation methods. Because of limited total tolerances for the exhaust emission calculation, the allowable values for some items, used in the appropriate equations, must be smaller than the allowed tolerances given in ISO 3046-3.

Table 3

Permissible deviations of instruments for other essential parameters

No.	Item	Permissible deviation
1	Temperatures ≤ 600 K	± 2 K absolute
2	Temperatures ≥ 600 K	± 1 % of reading
3	Exhaust gas pressure	± 0,2 kPa absolute
4	Inlet manifold depressions	± 0,05 kPa absolute
5	Atmospheric pressure	± 0,1 kPa absolute
6	Other pressures	± 0,1 kPa absolute
7	Relative humidity	± 3 % absolute
8	Absolute humidity	± 5 % of reading
9	Dilution air flow	± 2 % of reading
10	Diluted exhaust gas flow	± 2 % of reading

1.4.   Determination of the gaseous components

1.4.1.   General analyser specifications

The analysers shall have a measuring range appropriate for the accuracy required for measuring the concentrations of the exhaust gas components (section 1.4.1.1). It is recommended that the analysers be operated such that the measured concentration falls between 15 % and 100 % of full scale.

If the full scale value is 155 ppm (or ppm C) or less or if read-out systems (computers, data loggers) that provide sufficient accuracy and resolution below 15 % of full scale are used, concentrations below 15 % of full scale are also acceptable. In this case, additional calibrations are to be made to ensure the accuracy of the calibration curves — Appendix 2, section 1.5.5.2 of this annex.

The electromagnetic compatibility (EMC) of the equipment shall be on a level as to minimise additional errors.

1.4.1.1. Accuracy

The analyser shall not deviate from the nominal calibration point by more than ± 2 % of the reading over the whole measurement range except zero, and ± 0,3 % of full scale at zero. The accuracy shall be determined according to the calibration requirements laid down in section 1.3.

1.4.1.2. Repeatability

The repeatability shall be such that 2.5 times the standard deviation of 10 repetitive responses to a given calibration or span gas is not greater than ± 1 % of full scale concentration for each range used above 100 ppm (or ppm C) or ± 2 % of each range used below 100 ppm (or ppm C).

1.4.1.3. Noise

The analyser peak-to-peak response to zero and calibration or span gases over any 10 s period shall not exceed 2 % of full scale on all ranges used.

1.4.1.4. Zero drift

Zero response is defined as the mean response, including noise, to a zero gas during a 30-s time interval. The drift of the zero response during a one-hour period shall be less than 2% of full scale on the lowest range used.

1.4.1.5. Span drift

Span response is defined as the mean response, including noise, to a span gas during a 30-s time interval. The drift of the span response during a one-hour period shall be less than 2% of full scale on the lowest range used.

1.4.2. Gas drying

Exhaust gases may be measured wet or dry. Any gas-drying device, if used, must have a minimal effect on the concentration of the measured gases. Chemical dryers are not an acceptable method of removing water from the sample.

1.4.3. Analysers

Sections 1.4.3.1 to 1.4.3.5 of this Appendix describe the measurement principles to be used. A detailed description of the measurement systems is given in Annex VI.

The gases to be measured shall be analysed with the following instruments. For non-linear analysers, the use of linearising circuits is permitted.

1.4.3.1. Carbon monoxide (CO) analysis

The carbon monoxide analyser shall be of the non-dispersive infrared (NDIR) absorption type.

1.4.3.2. Carbon dioxide (CO_2) analysis

The carbon dioxide analyser shall be of the non-dispersive infrared (NDIR) absorption type.

1.4.3.3. Oxygen (O_2) analysis

Oxygen analysers shall be of the paramagnetic detector (PMD), zirconium dioxide (ZRDO) or electro-chemical sensor (ECS) types.

Note: Zirconium dioxide sensors are not recommended when HC and CO concentrations are high such as for lean-burn spark ignited engines. Electrochemical sensors shall be compensated for CO_2 and NO_X interference.

1.4.3.4. Hydrocarbon (HC) analysis

For direct gas sampling the hydrocarbon analyser shall be of the heated flame ionisation detector (HFID) type with detector, valves, pipework, etc., heated so as to maintain a gas temperature of 463 K ± 10 K (190 °C ± 10 °C).

For diluted gas sampling the hydrocarbon analyser shall be either the heated flame ionisation detector (HFID) type or the flame ionisation detector (FID) type.

1.4.3.5. Oxides of nitrogen (NO_x) analysis

The oxides of nitrogen analyser shall be of the chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) type with a NO_2/NO converter, if measured on a dry basis. If measured on a wet basis, an HCLD with converter maintained above 328 K (55 °C) shall be used, provided the water quench check (Annex III, Appendix 2, section 1.9.2.2) is satisfied. For both CLD and HCLD, the sampling path shall be maintained at a wall temperature of 328 K to 473 K (55 °C to 200 °C) up to the converter for dry measurement, and up to the analyser for wet measurement.

1.4.4. Sampling for gaseous emissions

If the composition of the exhaust gas is influenced by any exhaust aftertreatment system, the exhaust sample shall be taken downstream of this device.

The exhaust sampling probe should be in a high pressure side of the muffler, but as far from the exhaust port as possible. To ensure complete mixing of the engine exhaust before sample extraction, a mixing chamber may be optionally inserted between the muffler outlet and the sample probe. The internal volume of the mixing chamber must be not less than 10 times the cylinder displacement of the engine under test and should be roughly equal dimensions in height, width and depth, being similar to a cube. The mixing chamber size should be kept as small as practicable and should be coupled as close as possible to the engine. The exhaust line leaving the mixing chamber of muffler should extend at least 610 mm beyond the sample probe location and be of sufficient size to minimize back pressure. The temperature of the inner surface of the mixing chamber must be maintained above the dew point of the exhaust gases and a minimum temperature of 338 K (65 °C) is recommended.

All components may optionally be measured directly in the dilution tunnel, or by sampling into a bag and subsequent measurement of the concentration in the sampling bag.

Appendix 2

1. CALIBRATION OF THE ANALYTICAL INSTRUMENTS

1.1. Introduction

Each analyser shall be calibrated as often as necessary to fulfil the accuracy requirements of this standard. The calibration method that shall be used is described in this paragraph for the analysers indicated in Appendix 1, section 1.4.3.

1.2. Calibration gases

The shelf life of all calibration gases must be respected.

The expiry date of the calibration gases stated by the manufacturer shall be recorded.

1.2.1. Pure gases

The required purity of the gases is defined by the contamination limits given below. The following gases must be available for operation:

— purified nitrogen (contamination ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0,1 ppm NO)

— purified oxygen (purity > 99,5 % vol O_2)

— hydrogen-helium mixture (40 ± 2 % hydrogen, balance helium); contamination ≤ 1 ppm C, ≤ 400 ppm CO_2

— purified synthetic air (contamination ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0,1 ppm NO) (oxygen content between 18-21 % vol)

1.2.2. Calibration and span gases

Mixture of gases having the following chemical compositions shall be available:

— C_3H_8 and purified synthetic air (see section 1.2.1.);

— CO and purified nitrogen;

— NO_x and purified nitrogen (the amount of NO_2 contained in this calibration gas must not exceed 5 % of the NO content);

— CO_2 and purified nitrogen;

— CH_4 and purified synthetic air;

— C_2H_6 and purified synthetic air.

Note: Other gas combinations are allowed provided the gases do not react with one another.

The true concentration of a calibration and span gas shall be within ± 2 % of the nominal value. All concentrations of calibration gas shall be given on a volume basis (volume percent or volume ppm).

The gases used for calibration and span may also be obtained by means of precision blending devices (gas dividers), diluting with purified N_2 or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the diluted calibration gases is accurate to within ± 1,5 %. This accuracy implies that primary gases used for blending must be known to an accuracy of at least ± 1 %, traceable to national or international gas standards. The verification shall be performed at between 15 and 50 % of full scale for each calibration incorporating a blending device.

Optionally, the blending device may be checked with an instrument, which by nature is linear, e.g. using NO gas with a CLD. The span value of the instrument shall be adjusted with the span gas directly connected to the instrument. The blending device shall be checked at the used settings and the nominal value shall be compared with the measured concentration of the instrument. This difference shall in each point be within ± 0,5 % of the nominal value.

1.2.3. Oxygen interference check

Oxygen interference check gases shall contain propane with 350 ppm C ± 75 ppm C hydrocarbon. The concentration value shall be determined to calibration gas tolerances by chromatographic analysis of total hydrocarbons plus impurities or by dynamic blending. Nitrogen shall be the predominant diluent with the balance oxygen. Blend required for gasoline-fuelled engine testing is as follows:

— O_2 interference concentration: Balance

— 10 (9 to 11): Nitrogen

— 5 (4 to 6): Nitrogen

— 0 (0 to 1): Nitrogen

1.3. Operating procedure for analysers and sampling system

The operating procedure for analysers shall follow the start-up and operating instructions of the instrument manufacturer. The minimum requirements given in sections 1.4 to 1.9 shall be included. For laboratory instruments such as GC and High Performance Liquid Chromatography (HPLC) only section 1.5.4 shall apply.

1.4. Leakage test

A system leakage test shall be performed. The probe shall be disconnected from the exhaust system and the end plugged. The analyser pump shall be switched on. After an initial stabilisation period all flow meters should read zero. If not, the sampling lines shall be checked and the fault corrected.

The maximum allowable leakage rate on the vacuum side shall be 0.5 % of the in-use flow rate for the portion of the system being checked. The analyser flows and bypass flows may be used to estimate the in-use flow rates.

Alternatively, the system may be evacuated to a pressure of at least 20 kPa vacuum (80 kPa absolute). After an initial stabilisation period the pressure increase δp (kPa/min) in the system shall not exceed:

$$\delta p = p/V_{syst} \times 0,005 \times fr$$

Where:

V_{syst} = system volume [l]

fr   = system flow rate [l/min]

Another method is the introduction of a concentration step change at the beginning of the sampling line by switching from zero to span gas. If after an adequate period of time the reading shows a lower concentration compared with the introduced concentration, this points to calibration or leakage problems.

1.5.   Calibration procedure

1.5.1.   Instrument assembly

The instrument assembly shall be calibrated and calibration curves checked against standard gases. The same gas flow rates shall be used as when sampling exhaust gas.

1.5.2.   Warming-up time

The warming-up time should be according to the recommendations of the manufacturer. If not specified, a minimum of two hours is recommended for warming-up the analysers.

1.5.3.   NDIR and HFID analyser

The NDIR analyser shall be tuned, as necessary, and the combustion flame of the HFID analyser shall be optimised (section 1.9.1).

1.5.4.   GC and HPCL

Both instruments shall be calibrated according to good laboratory practice and the recommendations of the manufacturer.

1.5.5.   Establishment of the calibration curves

1.5.5.1. General guidelines

(a) Each normally used operating range shall be calibrated.

(b) Using purified synthetic air (or nitrogen), the CO, CO_2, NO_x and HC analysers shall be set at zero.

(c) The appropriate calibration gases shall be introduced to the analysers, the values recorded, and the calibration curves established.

(d) For all instrument ranges except for the lowest range, the calibration curve shall be established by at least 10 calibration points (excluding zero) equally spaced. For the lowest range of the instrument, the calibration curve shall be established by at least 10 calibration points (excluding zero) spaced so that half of the calibration points are placed below 15 % of the analyser's full scale and the rest are placed above 15 % of full scale. For all ranges the highest nominal concentration must be equal to or higher than 90 % of full scale.

(e) The calibration curve shall be calculated by the method of least squares. A best-fit linear or non-linear equation may be used.

(f) The calibration points must not differ from the least-squares best-fit line by more than ± 2 % of reading or ± 0,3 % of full scale whichever is larger.

(g) The zero setting shall be rechecked and the calibration procedure repeated, if necessary.

1.5.5.2. Alternative methods

If it can be shown that alternative technology (e.g. computer, electronically controlled range switch, etc.) can give equivalent accuracy, then these alternatives may be used.

1.6. Verification of the calibration

Each normally used operating range shall be checked prior to each analysis in accordance with the following procedure.

The calibration is checked by using a zero gas and a span gas whose nominal value is more than 80 % of full scale of the measuring range.

If, for the two points considered, the value found does not differ by more than ± 4 % of full scale from the declared reference value, the adjustment parameters may be modified. Should this not be the case, the span gas shall be verified or a new calibration curve shall be established in accordance with section 1.5.5.1.

1.7. Calibration of tracer gas analyser for exhaust flow measurement

The analyser for measurement of the tracer gas concentration shall be calibrated using the standard gas.

The calibration curve shall be established by at least 10 calibration points (excluding zero) spaced so that half of the calibration points are placed between 4 % to 20 % of the analyser's full scale and the rest are in between 20 % and 100 % of the full scale. The calibration curve shall be calculated by the method of least squares.

The calibration curve must not differ by more than ± 1 % of the full scale from the nominal value of each calibration point, in the range from 20 % to 100 % of the full scale. It also must not differ by more than ± 2 % of reading from the nominal value in the range from 4 % to 20 % of the full scale. The analyser shall be set at zero and spanned prior to the test run using a zero gas and a span gas whose nominal value is more than 80 % of the analyser full scale.

1.8. Efficiency test of the NO_x converter

The efficiency of the converter used for the conversion of NO_2 into NO is tested as given in sections 1.8.1 to 1.8.8 (Figure 1 of Annex III, Appendix 2).

1.8.1. Test set-up

Using the test set-up as shown in Figure 1 of Annex III and the procedure below, the efficiency of converters can be tested by means of an ozonator.

1.8.2. Calibration

The CLD and the HCLD shall be calibrated in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which must amount to about 80 % of the operating range and the NO_2 concentration of the gas mixture to less than 5 % of the NO concentration). The NO_x analyser must be in the NO mode so that the span gas does not pass through the converter. The indicated concentration has to be recorded.

1.8.3. Calculation

The efficiency of the NO_x, converter is calculated as follows:

$$\text{Efficiency (\%)} = \left(1 + \frac{a-b}{c-d}\right) \times 100$$

Where:

a = NO_x concentration according to section 1.8.6;

b = NO_x concentration according to section 1.8.7;

c = NO concentration according to section 1.8.4;

d = NO concentration according to section 1.8.5.

1.8.4. Adding of oxygen

Via a T-fitting, oxygen or zero air is added continuously to the gas flow until the concentration indicated is about 20 % less than the indicated calibration concentration given in section 1.8.2. (The analyser is in the NO mode.)

The indicated concentration (c) shall be recorded. The ozonator is kept deactivated throughout the process.

1.8.5. Activation of the ozonator

The ozonator is now activated to generate enough ozone to bring the NO concentration down to about 20 % (minimum 10 %) of the calibration concentration given in section 1.8.2. The indicated concentration (d) shall be recorded. (The analyser is in the NO mode.)

1.8.6. NO_x mode

The NO analyser is then switched to the NO_x mode so that the gas mixture (consisting of NO, NO_2, O_2 and N_2) now passes through the converter. The indicated concentration (a) shall be recorded. (The analyser is in the NO_x mode.)

1.8.7. Deactivation of the ozonator

The ozonator is now deactivated. The mixture of gases described in section 1.8.6 passes through the converter into the detector. The indicated concentration (b) shall be recorded. (The analyser is in the NO_x mode.)

1.8.8. NO mode

Switched to NO mode with the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NO_x reading of the analyser shall not deviate by more than ± 5 % from the value measured according to section 1.8.2. (The analyser is in the NO mode.)

1.8.9. Test interval

The efficiency of the converter must be checked monthly.

1.8.10. Efficiency requirement

The efficiency of the converter shall not be less than 90 %, but a higher efficiency of 95 % is strongly recommended.

Note: If, with the analyser in the most common range, the ozonator cannot give a reduction from 80 % to 20 % according to section 1.8.5, then the highest range which will give the reduction shall be used.

1.9. Adjustment of the FID

1.9.1. Optimisation of the detector response

The HFID must be adjusted as specified by the instrument manufacturer. A propane in air span gas should be used to optimise the response on the most common operating range.

With the fuel and airflow rates set at the manufacturer's recommendations, a 350 ± 75 ppm C span gas shall be introduced to the analyser. The response at a given fuel flow shall be determined from the difference between the span gas response and the zero gas response. The fuel flow shall be incrementally adjusted above and below the manufacturer's specification. The span and zero response at these fuel flows shall be recorded. The difference between the span and zero response shall be plotted and the fuel flow adjusted to the rich side of the curve. This is the initial flow rate setting, which may need further optimisation depending on the results of the hydrocarbon response factor and the oxygen interference check according to sections 1.9.2 and 1.9.3.

If the oxygen interference or the hydrocarbon response factors do not meet the following specifications, the airflow shall be incrementally adjusted above and below the manufacturer's specifications, sections 1.9.2 and 1.9.3 should be repeated for each flow.

1.9.2. Hydrocarbon response factors

The analyser shall be calibrated using propane in air and purified synthetic air, according to section 1.5.

Response factors shall be determined when introducing an analyser into service and after major service intervals. The response factor (R_f) for a particular hydrocarbon species is the ratio of the FID C1 reading to the gas concentration in the cylinder expressed by ppm C1.

The concentration of the test gas must be at a level to give a response of approximately 80 % of full scale. The concentration must be known to an accuracy of ± 2 % in reference to a gravimetric standard expressed in volume. In addition, the gas cylinder must be preconditioned for 24 hours at a temperature of 298 K (25 °C) ± 5 K.

The test gases to be used and the recommended relative response factor ranges are as follows:

— methane and purified synthetic air: $1,00 \leq R_f \leq 1,15$

— propylene and purified synthetic air: $0,90 \leq R_f \leq 1,1$

— toluene and purified synthetic air: $0,90 \leq R_f \leq 1,10$

These values are relative to the response factor (R_f) of 1,00 for propane and purified synthetic air.

1.9.3. Oxygen interference check

The oxygen interference check shall be determined when introducing an analyser into service and after major service intervals. A range shall be chosen where the oxygen interference check gases will fall in the upper 50 %. The test shall be conducted with the oven temperature set as required. The oxygen interference gases are specified in section 1.2.3.

(a) The analyser shall be zeroed.

(b) The analyser shall be spanned with the 0 % oxygen blend for gasoline fuelled engines.

(c) The zero response shall be rechecked. If it has changed more than 0,5 % of full scale, subsections (a) and (b) of this section shall be repeated.

(d) The 5 % and 10 % oxygen interference check gases shall be introduced.

(e) The zero response shall be rechecked. If it has changed more than ± 1 % of full scale, the test shall be repeated.

(f) The oxygen interference (% O_2I) shall be calculated for each mixture in step (d) as follows:

$$O_2I = \frac{(B - C)}{B} \times 100 \qquad ppm\ C = \frac{A}{D}$$

Where:

A = hydrocarbon concentration (ppm C) of the span gas used in subsection (b)

B = hydrocarbon concentration (ppm C) of the oxygen interference check gases used in subsection (d)

C = analyser response

D = percent of full scale analyser response due to A

(g) The % of oxygen interference (% O_2I) shall be less than ± 3 % for all required oxygen interference check gases prior to testing.

(h) If the oxygen interference is greater than ± 3 %, the air flow above and below the manufacturer's specifications shall be incrementally adjusted, repeating section 1.9.1 for each flow.

(i) If the oxygen interference is greater than ± 3 %, after adjusting the air flow, the fuel flow and thereafter the sample flow shall be varied, repeating section 1.9.1. for each new setting.

(j) IIf the oxygen interference is still greater than ± 3 %, the analyser, FID fuel, or burner air shall be repaired or replaced prior to testing. This section shall then be repeated with the repaired or replaced equipment or gases.

1.10. Interference effects with CO, CO_2, NO_x and O_2 analysers

Gases other than the one being analysed can interfere with the reading in several ways. Positive interference occurs in NDIR and PMD instruments where the interfering gas gives the same effect as the gas being measured, but to a lesser degree. Negative interference occurs in NDIR instruments by the interfering gas broadening the absorption band of the measured gas, and in CLD instruments by the interfering gas quenching the radiation. The interference checks in sections 1.10.1 and 1.10.2 shall be performed prior to an analyser's initial use and after major service intervals, but at least once per year.

1.10.1. CO analyser interference check

Water and CO_2 can interfere with the CO analyser performance. Therefore a CO_2 span gas having a concentration of 80 to 100 % of full scale of the maximum operating range used during testing shall be bubbled through water at room temperature and the analyser response recorded. The analyser response must not be more than 1 % of full scale for ranges equal to or above 300 ppm or more than 3 ppm for ranges below 300 ppm.

1.10.2. NO_x analyser quench checks

The two gases of concern for CLD (and HCLD) analysers are CO_2 and water vapour. Quench responses of these gases are proportional to their concentrations, and therefore require test techniques to determine the quench at the highest expected concentrations experienced during testing.

1.10.2.1. CO_2 quench check

A CO_2 span gas having a concentration of 80 to 100% of full scale of the maximum operating range shall be passed through the NDIR analyser and the CO_2 value recorded as A. It shall then be diluted approximately 50% with NO span gas and passed through the NDIR and (H)CLD with the CO_2 and NO values recorded as B and C, respectively. The CO_2 shall be shut off and only the NO span gas is passed through the (H)CLD and the NO value recorded as D.

The quench, which shall not be greater than 3 % full scale, shall be calculated as follows:

$$\% \ CO_2 \ \text{quench} = \left[1 - \left(\frac{(C \times A)}{(D \times A) - (D \times B)} \right) \right] \times 100$$

Where:

A: undiluted CO_2 concentration measured with NDIR %

B: diluted CO_2 concentration measured with NDIR %

C: diluted NO concentration measured with CLD ppm

D: undiluted NO concentration measured with CLD ppm

Alternative methods of diluting and quantifying CO_2 and NO span gas values, such as dynamic/mixing/blending, can be used.

1.10.2.2. Water quench check

This check applies to wet gas concentration measurements only. Calculation of water quench must consider dilution of the NO span gas with water vapour and scaling of water vapour concentration of the mixture to that expected during testing.

A NO span gas having a concentration of 80 to 100 % of full scale to the normal operating range shall be passed through the (H)CLD and the NO value recorded as D. The NO span gas shall then be bubbled through water at room temperature and passed through the (H)CLD and the NO value recorded as C. The water temperature shall be determined and recorded as F. The mixture's saturation vapour pressure that corresponds to the bubbler water temperature (F) shall be determined and recorded as G. The water vapour concentration (in %) of the mixture shall be calculated as follows:

$$H = 100 \times \left(\frac{G}{p_B} \right)$$

and recorded as H. The expected diluted NO span gas (in water vapour) concentration shall be calculated as follows:

$$D_e = D \times \left(1 - \frac{H}{100} \right)$$

and recorded as D_e.

The water quench shall not be greater than 3 % and shall be calculated as follows:

$$\% \ H_2O \ quench \ = 100 \times \left(\frac{D_e - C}{D_e} \right) \times \left(\frac{H_m}{H} \right)$$

Where:

D_e: expected diluted NO concentration (ppm)

C: diluted NO concentration (ppm)

H_m: maximum water vapour concentration

H: actual water vapour concentration (%)

Note: It is important that the NO span gas contains minimal NO_2 concentration for this check, since absorption of NO_2 in water has not been accounted for in the quench calculations.

1.10.3. O_2 analyser interference

Instrument response of a PMD analyser caused by gases other than oxygen is comparatively slight. The oxygen equivalents of the common exhaust gas constituents are shown in Table 1.

Table 1

Oxygen equivalents

Gas	O_2 equivalent %
Carbon dioxide (CO_2)	− 0,623
Carbon monoxide (CO)	− 0,354
Nitrogen oxide (NO)	+ 44,4
Nitrogen dioxide (NO_2)	+ 28,7
Water (H_2O)	− 0,381

The observed oxygen concentration shall be corrected by the following formula if high precision measurements are to be done:

$$Interference = \frac{(Equivalent \ \% \ O_2 \ \times \ Obs. \ conc.)}{100}$$

1.11. Calibration intervals

The analysers shall be calibrated according to section 1.5 at least every three months or whenever a system repair or change is made that could influence calibration.

Appendix 3

1. DATA EVALUATION AND CALCULATIONS

1.1. Gaseous emissions evaluation

For the evaluation of the gaseous emissions, the chart reading for a minimum of the last 120 s of each mode shall be averaged, and the average concentrations (conc) of HC, CO, NO_x and CO_2 during each mode shall be determined from the average chart readings and the corresponding calibration data. A different type of recording can be used if it ensures an equivalent data acquisition.

The average background concentration ($conc_d$) may be determined from the bag readings of the dilution air or from the continuous (non-bag) background reading and the corresponding calibration data.

1.2. Calculation of the gaseous emissions

The finally reported test results shall be derived through the following steps.

1.2.1. Dry/wet correction

The measured concentration, if not already measured on a wet basis, shall be converted to a wet basis:

$$conc \, (wet) = k_w \times conc \, (dry)$$

For the raw exhaust gas:

$$k_w = k_{w,r} = \frac{1}{1 + \alpha \times 0,005 \times (\% \, CO \, [dry] + \% \, CO_2 \, [dry]) - 0,01 \times \% \, H_2 \, [dry] + k_{w2}}$$

Where a is the hydrogen to carbon ratio in the fuel.

The H_2 concentration in the exhaust shall be calculated:

$$H_2 \, [dry] = \frac{0,5 \times \alpha \times \% \, CO \, [dry] \times (\% \, CO \, [dry] + \% \, CO_2 \, [dry])}{\% \, CO \, [dry] + (3 \times \% \, CO_2 \, [dry])}$$

The factor k_{w2} shall be calculated:

$$k_{w2} = \frac{1,608 \times H_a}{1 \, 000 + (1,608 \times H_a)}$$

with H_a absolute humidity of the intake air, g of water per kg of dry air.

For the diluted exhaust gas:

For wet CO_2 measurement::

$$k_w = k_{w,e,1} = \left(1 - \frac{\alpha \times \% \, CO_2 \, [wet]}{200}\right) - k_{w1}$$

Or, for dry CO_2 measurement:

$$k_w = k_{w,e,2} = \left(\frac{(1 - k_{w1})}{1 + \frac{\alpha \times \% \, CO_2 \, [dry]}{200}}\right)$$

Where α is the hydrogen to carbon ratio in the fuel.

The factor k_{w1} shall be calculated from the following equations:

$$k_{w1} = \left(\frac{1{,}608 \times [H_d \times (1 - 1/DF) + H_a \times (1/DF)]}{1\,000 + 1{,}608 \times [H_d \times (1 - 1/DF) + H_a \times (1/DF)]} \right)$$

Where:

H_d = absolute humidity of the dilution air, g of water per kg of dry air

H_a = absolute humidity of the intake air, g of water per kg of dry air

$$DF = \frac{13{,}4}{\%\ conc_{CO_2} + (ppm\ conc_{CO} + ppm\ conc_{HC}) \times 10^{-4}}$$

For the dilution air:

$$k_{w,d} = 1 - k_{w1}$$

The factor k_{w1} shall be calculated from the following equations:

$$k_{w1} = \left(\frac{1{,}608 \times [H_d \times (1 - 1/DF) + H_a \times (1/DF)]}{1\,000 + 1{,}608 \times [H_d \times (1 - 1/DF) + H_a \times (1/DF)]} \right)$$

Where:

H_d = absolute humidity of the dilution air, g of water per kg or dry air

H_a = absolute humidity of the intake air, g of water per kg of dry air

$$DF = \frac{13{,}4}{\%\ conc_{CO_2} + (ppm\ conc_{CO} + ppm\ conc_{HC}) \times 10^{-4}}$$

For the intake air (if different from the dilution air):

$$k_{w,a} = 1 - k_{w2}$$

The factor k_{w2} shall be calculated from the following equations:

$$k_{w2} = \frac{1{,}608 \times H_a}{1\,000 + (1{,}608 \times H_a)}$$

with H_a absolute humidity of the intake air, g of water per kg of dry air.

1.2.2. Humidity correction for NO_x

As the NO_x emission depends on ambient air conditions, the NO_x concentration shall be multiplied by the factor K_H taking into account humidity:

with H_a absolute humidity of the intake air as g of water per kg of dry air

$K_H = 0{,}6272 + 44{,}030 \times 10^{-3} \times H_a - 0{,}862 \times 10^{-3} \times H_a^2$ (for 4 stroke engines)

$K_H = 1$ (for 2 stroke engines)

with H_a absolute humidity of the intake air as g of water per kg of dry air

1.2.3. Calculation of emission mass flow rate

The emission mass flow rates Gas_{mass} [g/h] for each mode shall be calculated as follows.

(a) For the raw exhaust gas [1]:

$$\text{Gas}_{\text{mass}} = \frac{MW_{\text{Gas}}}{MW_{\text{FUEL}}} \times \frac{1}{\{(\% \; CO_2 \; [\text{wet}] - \% \; CO_{2\text{AIR}}) + \% \; CO \; [\text{wet}] + \% \; HC \; [\text{wet}]\}} \times \% \; \text{conc} \times G_{\text{FUEL}} \times 1 \; 000$$

Where:

G_{FUEL} [kg/h] is the fuel mass flow rate;

MW_{Gas} [kg/kmole] is the molecular weight of the individual gas shown in Table 1;

Table 1

Molecular weights

Gas	MW_{Gas} [kg/kmole]
NO_x	46,01
CO	28,01
HC	$MW_{HC} = MW_{\text{FUEL}}$
CO_2	44,01

$MW_{\text{FUEL}} = 12{,}011 + \alpha \times 1{,}00794 + \beta \times 15{,}9994$ [kg/kmole] is the fuel molecular weight with α hydrogen to carbon ratio and β oxygen to carbon ratio of the fuel [2];

$CO_{2\text{AIR}}$ is the CO_2 concentration in the intake air (that is assumed equal to 0,04 % if not measured).

(b) For the diluted exhaust gas [3]:

$$\text{Gas}_{\text{mass}} = u \times \text{conc}_c \times G_{\text{TOTW}}$$

Where

G_{TOTW} [kg/h] is the diluted exhaust gas mass flow rate on wet basis that, when using a full flow dilution system, shall be determined according to Annex III, Appendix 1, section 1.2.4;

conc_c is the background corrected concentration:

$$\text{conc}_c = \text{conc} - \text{conc}_d \times (1 - 1/DF)$$

with $DF = \dfrac{13{,}4}{\% \; \text{conc}_{CO_2} + (\text{ppm} \; \text{conc}_{CO} + \text{ppm} \; \text{conc}_{HC}) \times 10^{-4}}$

The u coefficient is shown in Table 2.

Table 2

Values of u coefficient

Gas	u	conc
NO_x	0,001587	ppm
CO	0,000966	ppm
HC	0,000478	ppm
CO_2	15,19	%

---

[1] In the case of NO_x the concentration has to be multiplied by the humidity correction factor K_H (humidity correction factor for NO_x).

[2] In the ISO 8178-1 a more complete formula of the fuel molecular weight is quoted (formula 50 of Chapter 13.5.1 (b). The formula takes into account not only the hydrogen to carbon ratio and the oxygen to carbon ratio but also other possible fuel components such as sulphur and nitrogen. However, as the s.i. engines of the Directive are tested with a petrol (quoted as a reference fuel in Annex V) containing usually only carbon and hydrogen, the simplified formula is considered.

[3] In the case of NO_x the concentration has to be multiplied by the humidity correction factor K_H (humidity correction factor for NO_x).

Values of the u coefficient are based upon a molecular weight of the dilute exhaust gases equal to 29 [kg/kmole]; the value of u for HC is based upon an average carbon to hydrogen ratio of 1:1,85.

1.2.4. Calculation of specific emissions

The specific emission (g/kWh) shall be calculated for all individual components:

$$\text{Individual gas} = \frac{\sum\limits_{i=1}^{n}(\text{Gas}_{\text{mass}_i} \times \text{WF}_i)}{\sum\limits_{i=1}^{n}(P_i \times \text{WF}_i)}$$

Where $P_i = P_{M,i} + P_{AE,i}$

When auxiliaries, such as cooling fan or blower, are 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. The fan or blower power shall be determined at the speeds used for the tests either by calculation from standard characteristics or by practical tests (Appendix 3 of Annex VII).

The weighting factors and the number of the n modes used in the above calculation are shown in Annex IV, section 3.5.1.1.

2. EXAMPLES

2.1. Raw exhaust gas data from a 4-stroke s.i. engine

With reference to the experimental data (Table 3), calculations are carried out first for mode 1 and then are extended to other test modes using the same procedure.

Table 3

Experimental data of a 4-stroke s.i. engine

Mode		1	2	3	4	5	6
Engine speed	m^{-1}	2 550	2 550	2 550	2 550	2 550	1 480
Power	kW	9,96	7,5	4,88	2,36	0,94	0
Load percent	%	100	75	50	25	10	0
Weighting factors	—	0,090	0,200	0,290	0,300	0,070	0,050
Barometric pressure	kPa	101,0	101,0	101,0	101,0	101,0	101,0
Air temperature	°C	20,5	21,3	22,4	22,4	20,7	21,7
Air relative humidity	%	38,0	38,0	38,0	37,0	37,0	38,0
Air absolute humidity	g_{H20}/kg_{air}	5,696	5,986	6,406	6,236	5,614	6,136
CO dry	ppm	60 995	40 725	34 646	41 976	68 207	37 439
NO_x wet	ppm	726	1 541	1 328	377	127	85
HC wet	ppm C1	1 461	1 308	1 401	2 073	3 024	9 390
CO_2 dry	% Vol.	11,4098	12,691	13,058	12,566	10,822	9,516
Fuel mass flow	kg/h	2,985	2,047	1,654	1,183	1,056	0,429
Fuel H/C ratio α	—	1,85	1,85	1,85	1,85	1,85	1,85
Fuel O/C ratio β		0	0	0	0	0	0

2.1.1. The dry/wet correction factor k_w

The dry/wet correction factor k_w shall be calculated for converting dry CO and CO_2 measurements on a wet basis:

$$k_w = k_{w,r} = \frac{1}{1 + \alpha \times 0,005 \times (\% \, CO \, [dry] + \% \, CO_2 \, [dry]) - 0,01 \times \% \, H_2 \, [dry] + k_{w2}}$$

Where:

$$H_2 \, [dry] = \frac{0,5 \times \alpha \times \% \, CO \, [dry] \times (\% \, CO \, [dry] + \% \, CO_2 \, [dry])}{\% \, CO \, [dry] + (3 \times \% \, CO_2 \, [dry])}$$

and

$$k_{w2} = \frac{1,608 \times H_a}{1\,000 + (1,608 \times H_a)}$$

$$H_2 \, [dry] = \frac{0,5 \times 1,85 \times 6,0995 \times (6,0995 + 11,4098)}{6,0995 + (3 \times 11,4098)} = 2,450 \, \%$$

$$k_{w2} = \frac{1,608 \times 5,696}{1\,000 + (1,608 \times 5,696)} = 0,009$$

$$k_w = k_{w,r} = \frac{1}{1 + 1,85 \times 0,005 \times (6,0995 + 11,4098) - 0,01 \times 2,450 + 0,009} = 0,872$$

$CO \, [wet] = CO \, [dry] \times k_w = 60\,995 \times 0,872 = 53\,198$ ppm

$CO_2 \, [wet] = CO_2 \, [dry] \times k_w = 11,410 \times 0,872 = 9,951 \, \%$ Vol

Table 4

CO and CO_2 wet values according to different test modes

Mode		1	2	3	4	5	6
H_2 dry	%	2,450	1,499	1,242	1,554	2,834	1,422
K_{w2}	—	0,009	0,010	0,010	0,010	0,009	0,010
K_w	—	0,872	0,870	0,869	0,870	0,874	0,894
CO wet	ppm	53 198	35 424	30 111	36 518	59 631	33 481
CO_2 wet	%	9,951	11,039	11,348	10,932	9,461	8,510

2.1.2. HC emissions

$$HC_{mass} = \frac{MW_{HC}}{MW_{FUEL}} \times \frac{1}{\{(\% \, CO_2 \, [wet] - \% \, CO_{2AIR}) + \% \, CO \, [wet] + \% \, HC \, [wet]\}} \times \% \, conc \times G_{FUEL} \times 1\,000$$

where

$MW_{HC} = MW_{FUEL}$

$MW_{FUEL} = 12,011 + \alpha \times 1,00794 = 13,876$

$$HC_{mass} = \frac{13,876}{13,876} \times \frac{1}{(9,951 - 0,04 + 5,3198 + 0,1461)} \times 0,1461 \times 2,985 \times 1\,000 = 28,361 \, g/h$$

Table 5

HC emissions (g/h) according to different test modes

Mode	1	2	3	4	5	6
HC_{mass}	28,361	18,248	16,026	16,625	20,357	31,578

2.1.3. NO_x emissions

At first the humidity correction factor K_H of NO_x emissions shall be calculated:

$K_H = 0,6272 + 44,030 \times 10^{-3} \times H_a - 0,862 \times 10^{-3} \times H_a^2$

$K_H = 0,6272 + 44,030 \times 10^{-3} \times 5,696 - 0,862 \times 10^{-3} \times (5,696)^2 = 0,850$

Table 6

Humidity correction factor K_H of NO_x emissions according to different modes

Mode	1	2	3	4	5	6
K_H	0,850	0,860	0,874	0,868	0,847	0,865

Then NO_{xmass} [g/h] shall be calculated:

$$NO_{xmass} = \frac{MW_{NOx}}{MW_{FUEL}} \times \frac{1}{\left\{ (\% \ CO_2 \ [wet] - \% \ CO_{2AIR}) + \% \ CO \ [wet] + \% \ HC \ [wet] \right\}} \times \% \ conc \times K_H \times G_{FUEL} \times 1\ 000$$

$$NO_{xmass} = \frac{46,01}{13,876} \times \frac{1}{(9,951 - 0,04 + 5,3198 + 0,1461)} \times 0,073 \times 0,85 \times 2,985 \times 1\ 000 = 39,717 \ g/h$$

Table 7

NO_x emissions (g/h) according to the different test modes

Mode	1	2	3	4	5	6
NO_{xmass}	39,717	61,291	44,013	8,703	2,401	0,820

2.1.4. CO emissions

$$CO_{mass} = \frac{MW_{CO}}{MW_{FUEL}} \times \frac{1}{\left\{ (\% \ CO_2 \ [wet] - \% \ CO_{2AIR}) + \% \ CO \ [wet] + \% \ HC \ [wet] \right\}} \times \% \ conc \times G_{FUEL} \times 1\ 000$$

$$CO_{2mass} = \frac{44,01}{13,876} \times \frac{1}{(9,951 - 0,04 + 5,3198 + 0,1461)} \times 9,951 \times 2,985 \times 1\ 000 = 6\ 126,806 \ g/h$$

Table 8

CO emissions (g/h) according to different test modes

Mode	1	2	3	4	5	6
CO_{mass}	2 084,588	997,638	695,278	591,183	810,334	227,285

2.1.5. CO_2 emissions

$$CO_{2mass} = \frac{MW_{CO2}}{MW_{FUEL}} \times \frac{1}{\left\{ (\% \ CO_2 \ [wet] - \% \ CO_{2AIR}) + \% \ CO \ [wet] + \% \ HC \ [wet] \right\}} \times \% \ conc \times G_{FUEL} \times 1\ 000$$

$$CO_{2mass} = \frac{44,01}{13,876} \times \frac{1}{(9,951 - 0,04 + 5,3198 + 0,1461)} \times 9,951 \times 2,985 \times 1\ 000 = 6\ 126,806 \ g/h$$

Table 9

CO_2 emissions (g/h) according to different test modes

Mode	1	2	3	4	5	6
CO_{2mass}	6 126,806	4 884,739	4 117,202	2 780,662	2 020,061	907,648

2.1.6. Specific emissions

The specific emission (g/kWh) shall be calculated for all individual components:

$$\text{Individual gas} = \frac{\sum\limits_{i=1}^{n}(\text{Gas}_{\text{mass}_i} \times \text{WF}_i)}{\sum\limits_{i=1}^{n}(P_i \times \text{WF}_i)}$$

Table 10

Emissions (g/h) and weighting factors according to the test modes

Mode		1	2	3	4	5	6
HC_{mass}	g/h	28,361	18,248	16,026	16,625	20,357	31,578
NO_{xmass}	g/h	39,717	61,291	44,013	8,703	2,401	0,820
CO_{mass}	g/h	2 084,588	997,638	695,278	591,183	810,334	227,285
CO_{2mass}	g/h	6 126,806	4 884,739	4 117,202	2 780,662	2 020,061	907,648
Power P_I	KW	9,96	7,50	4,88	2,36	0,94	0
Weighting factors WF_I	—	0,090	0,200	0,290	0,300	0,070	0,050

$$HC = \frac{28,361 \times 0,090 + 18,248 \times 0,200 + 16,026 \times 0,290 + 16,625 \times 0,300 + 20,357 \times 0,070 + 31,578 \times 0,050}{9,96 \times 0,090 + 7,50 \times 0,200 + 4,88 \times 0,290 + 2,36 \times 0,300 + 0,940 \times 0,070 + 0 \times 0,050} = 4,11 \ \text{g/kWh}$$

$$NO_x = \frac{39,717 \times 0,090 + 61,291 \times 0,200 + 44,013 \times 0,290 + 8,703 \times 0,300 + 2,401 \times 0,070 + 0,820 \times 0,050}{9,96 \times 0,090 + 7,50 \times 0,200 + 4,88 \times 0,290 + 2,36 \times 0,300 + 0,940 \times 0,070 + 0 \times 0,050} = 6,85 \ \text{g/kWh}$$

$$CO = \frac{2\ 084,59 \times 0,090 + 997,64 \times 0,200 + 695,28 \times 0,290 + 591,18 \times 0,300 + 810,33 \times 0,070 + 227,29 \times 0,050}{9,96 \times 0,090 + 7,50 \times 0,200 + 4,88 \times 0,290 + 2,36 \times 0,300 + 0,940 \times 0,070 + 0 \times 0,050} = 181,93 \ \text{g/kWh}$$

$$CO_2 = \frac{6\ 126,81 \times 0,090 + 4\ 884,74 \times 0,200 + 4\ 117,20 \times 0,290 + 2\ 780,66 \times 0,300 + 2\ 020,06 \times 0,070 + 907,65 \times 0,050}{9,96 \times 0,090 + 7,50 \times 0,200 + 4,88 \times 0,290 + 2,36 \times 0,300 + 0,940 \times 0,070 + 0 \times 0,050} = 816,36 \ \text{g/kWh}$$

2.2. Raw exhaust gas data from a 2-stroke s.i. engine

With reference to the experimental data (Table 11), calculations shall be carried out first for mode 1 and then extended to the other test mode using the same procedure.

Table 11

Experimental data of a 2-stroke s.i. engine

Mode		1	2
Engine speed	m^{-1}	9 500	2 800
Power	kW	2,31	0
Load percent	%	100	0
Weighting factors	—	0,9	0,1
Barometric pressure	kPa	100,3	100,3
Air temperature	°C	25,4	25
Air relative humidity	%	38,0	38,0
Air absolute humidity	g_{H2O}/kg_{air}	7,742	7,558
CO dry	ppm	37 086	16 150
NO_x wet	ppm	183	15
HC wet	ppm C1	14 220	13 179
CO_2 dry	% Vol.	11,986	11,446
Fuel mass flow	kg/h	1,195	0,089
Fuel H/C ratio α	—	1,85	1,85
Fuel/C ratio β		0	0

2.2.1. Dry/wet correction factor k_w

The dry/wet correction factor k_w shall be calculated for converting dry CO and CO_2 measurements on a wet basis:

$$k_w = k_{w,r} = \frac{1}{1 + \alpha \times 0{,}005 \times (\% \ CO \ [dry] + \% \ CO_2 \ [dry]) - 0{,}01 \times \% \ H_2 \ [dry] + k_{w2}}$$

Where:

$$H_2 \ [dry] = \frac{0{,}5 \times \alpha \times \% \ CO \ [dry] \times (\% \ CO \ [dry] + \% \ CO_2 \ [dry])}{\% \ CO \ [dry] + (3 \times \% \ CO_2 \ [dry])}$$

$$H_2 \ [dry] = \frac{0{,}5 \times 1{,}85 \times 3{,}7086 \times (3{,}7086 + 11{,}986)}{3{,}7086 + (3 \times 11{,}986)} = 1{,}357 \ \%$$

$$k_{w2} = \frac{1{,}608 \times H_a}{1 \ 000 + (1{,}608 \times H_a)}$$

$$k_{w2} = \frac{1{,}608 \times 7{,}742}{1 \ 000 + (1{,}608 \times 7{,}742)} = 0{,}012$$

$$k_w = k_{w,r} = \frac{1}{1 + 1{,}85 \times 0{,}005 \times (3{,}7086 + 11{,}986) - 0{,}01 \times 1{,}357 + 0{,}012} = 0{,}874$$

CO [wet] = CO [dry] $\times k_w$ = 37 086 $\times$ 0,874 = 32 420 ppm

CO_2 [wet] = CO_2 [dry] $\times k_w$ = 11,986 $\times$ 0,874 = 10,478 % Vol

Table 12

CO and CO_2 wet values according to different test modes

Mode		1	2
H_2 dry	%	1,357	0,543
k_{w2}	—	0,012	0,012
k_w	—	0,874	0,887
CO wet	ppm	32 420	14 325
CO_2 wet	%	10,478	10,153

2.2.2. HC emissions

$$HC_{mass} = \frac{MW_{HC}}{MW_{FUEL}} \times \frac{1}{\{(\% \ CO_2 \ [wet] - \% \ CO_{2AIR}) + \% \ CO \ [wet] + \% \ HC \ [wet]\}} \times \% \ conc \times G_{FUEL} \times 1 \ 000$$

Where:

$MW_{HC} = MW_{FUEL}$

$MW_{FUEL} = 12{,}011 + \alpha \times 1{,}00794 = 13{,}876$

$$HC_{mass} = \frac{13{,}876}{13{,}876} \times \frac{1}{(10{,}478 - 0{,}04 + 3{,}2420 + 1{,}422)} \times 1{,}422 \times 1{,}195 \times 1 \ 000 = 112{,}520 \ g/h$$

Table 13

HC emissions (g/h) according to test modes

Mode	1	2
HC_{mass}	112,520	9,119

2.2.3. NO_x emissions

The factor K_H for the correction of the NO_x emissions is equal to 1 for two-stroke engines:

$$NO_{xmass} = \frac{MW_{NO_x}}{MW_{FUEL}} \times \frac{1}{\{(\% \ CO_2 \ [wet] - \% \ CO_{2AIR}) + \% \ CO \ [wet] + \% \ HC \ [wet]\}} \times \% \ conc \times K_H \times G_{FUEL} \times 1 \ 000$$

$$NO_{xmass} = \frac{46{,}01}{13{,}876} \times \frac{1}{(10{,}478 - 0{,}04 + 3{,}2420 + 1{,}422)} \times 0{,}0183 \times 1 \times 1{,}195 \times 1 \ 000 = 4{,}800 \ g/h$$

Table 14

NO_x emissions (g/h) according to test modes

Mode	1	2
NO_{xmass}	4,800	0,034

2.2.4. CO emissions

$$CO_{mass} = \frac{MW_{CO}}{MW_{FUEL}} \times \frac{1}{\{(\% \, CO_2 \, [wet] - \% \, CO_{2AIR}) + \% \, CO \, [wet] + \% \, HC \, [wet]\}} \times \% \, conc \times G_{FUEL} \times 1\,000$$

$$CO_{mass} = \frac{28,01}{13,876} \times \frac{1}{(10,478 - 0,04 + 3,2420 + 1,422)} \times 3,2420 \times 1,195 \times 1\,000 = 517,851 \ g/h$$

Table 15

CO emissions (g/h) according to test modes

Mode	1	2
CO_{mass}	517,851	20,007

2.2.5. CO_2 emissions

$$CO_{2mass} = \frac{MW_{CO_2}}{MW_{FUEL}} \times \frac{1}{\{(\% \, CO_2 \, [wet] - \% \, CO_{2AIR}) + \% \, CO \, [wet] + \% \, HC \, [wet]\}} \times \% \, conc \times G_{FUEL} \times 1\,000$$

$$CO_{2mass} = \frac{44,01}{13,876} \times \frac{1}{(10,478 - 0,04 + 3,2420 + 1,422)} \times 10,478 \times 1,195 \times 1\,000 = 2\,629,658 \ g/h$$

Table 16

CO_2 emissions (g/h) according to test modes

Mode	1	2
CO_{2mass}	2 629,658	222,799

2.2.6. Specific emissions

The specific emission (g/kWh) shall be calculated for all individual components in the following way:

$$\text{Individual gas} = \frac{\sum_{i=1}^{n}(Gas_{mass_i} \times WF_i)}{\sum_{i=1}^{n}(P_i \times WF_i)}$$

Table 17

Emissions (g/h) and weighting factors in two test modes

Mode		1	2
HC_{mass}	g/h	112,520	9,119
NO_{xmass}	g/h	4,800	0,034
CO_{mass}	g/h	517,851	20,007
CO_{2mass}	g/h	2 629,658	222,799
Power P_{II}	kW	2,31	0
Weigthing factors WF_i	—	0,85	0,15

$$HC = \frac{112,52 \times 0,85 + 9,119 \times 0,15}{2,31 \times 0,85 + 0 \times 0,15} = 49,4 \ g/kWh$$

$$NO_x = \frac{4,800 \times 0,85 + 0,034 \times 0,15}{2,31 \times 0,85 + 0 \times 0,15} = 2,08 \ g/kWh$$

$$CO = \frac{517,851 \times 0,85 + 20,007 \times 0,15}{2,31 \times 0,85 + 0 \times 0,15} = 225,71 \ g/kWh$$

$$CO_2 = \frac{2\ 629,658 \times 0,85 + 222,799 \times 0,15}{2,31 \times 0,85 + 0 \times 0,15} = 1\ 155,4 \ g/kWh$$

2.3.   Diluted exhaust gas data from a 4-stroke s.i. engine

With reference to the experimental data (Table 18), calculations shall be carried out first for mode 1 and then extended to other test modes using the same procedure.

Table 18

Experimental data of a 4-stroke s.i. engine

Mode		1	2	3	4	5	6
Engine speed	m^{-1}	3 060	3 060	3 060	3 060	3 060	2 100
Power	kW	13,15	9,81	6,52	3,25	1,28	0
Load percent	%	100	75	50	25	10	0
Weighting factors	—	0,090	0,200	0,290	0,300	0,070	0,050
Barometric pressure	kPa	980	980	980	980	980	980
Intake air temperature	°C	25,3	25,1	24,5	23,7	23,5	22,6
Intake air relative humidity	%	19,8	19,8	20,6	21,5	21,9	23,2
Intake air absolute humidity	g$_{H20}$/kg$_{air}$	4,08	4,03	4,05	4,03	4,05	4,06
CO dry	ppm	3 681	3 465	2 541	2 365	3 086	1 817
NO$_x$ wet	ppm	85,4	49,2	24,3	5,8	2,9	1,2
HC wet	ppm C1	91	92	77	78	119	186
CO$_2$ dry	% Vol.	1,038	0,814	0,649	0,457	0,330	0,208
CO dry (background)	ppm	3	3	3	2	2	3
NO$_x$ wet (background)	ppm	0,1	0,1	0,1	0,1	0,1	0,1
HC wet (background)	ppm C1	6	6	5	6	6	4
CO$_2$ dry (background)	% Vol.	0,042	0,041	0,041	0,040	0,040	0,040
Dil. exh. gas mass flow G$_{TOTW}$	kg/h	625,722	627,171	623,549	630,792	627,895	561,267
Fuel H/C ratio α	—	1,85	1,85	1,85	1,85	1,85	1,85
Fuel H/C ratio β		0	0	0	0	0	0

2.3.1.   Dry/wet correction factor k_w

The dry/wet correction factor k_w shall be calculated for converting dry CO and CO$_2$ measurements on a wet basis.

For the diluted exhaust gas:

$$k_w = k_{w,e,2} = \left(\frac{(1 - k_{w1})}{1 + \dfrac{\alpha \times \% \ CO_2 \ [dry]}{200}} \right)$$

Where:

$$k_{w1} = \left(\frac{1{,}608 \times [H_d \times (1 - 1/DF) + H_a \times (1/DF)]}{1\ 000 + 1{,}608 \times [H_d \times (1 - 1/DF) + H_a \times (1/DF)]} \right)$$

$$DF = \frac{13{,}4}{\% \ conc_{CO_2} + (ppm \ conc_{CO} + ppm \ conc_{HC}) \times 10^{-4}}$$

$$DF = \frac{13{,}4}{1{,}038 + (3\ 681 + 91) \times 10^{-4}} = 9{,}465$$

$$k_{w1} = \left(\frac{1{,}608 \times [4{,}08 \times (1 - 1/9{,}465) + 4{,}08 \times (1/9{,}465)]}{1\ 000 + 1{,}608 \times [4{,}08 \times (1 - 1/9{,}465) + 4{,}08 \times (1/9{,}465)]} \right) = 0{,}007$$

$$k_w = k_{w,e,2} = \left(\frac{(1 - 0{,}007)}{1 + \dfrac{1{,}85 \times 1{,}038}{200}} \right) = 0{,}984$$

$$CO \ [wet] = CO \ [dry] \times k_w = 3\ 681 \times 0{,}984 = 3\ 623 \ ppm$$

$$CO_2 [wet] = CO_2 \ [dry] \times k_w = 1{,}038 \times 0{,}984 = 1{,}0219 \ \%$$

Table 19

CO and CO$_2$ wet values for the diluted exhaust gas according to test modes

Mode		1	2	3	4	5	6
DF	—	9,465	11,454	14,707	19,100	20,612	32,788
k_{w1}	—	0,007	0,006	0,006	0,006	0,006	0,006
k_w	—	0,984	0,986	0,988	0,989	0,991	0,992
CO wet	ppm	3 623	3 417	2 510	2 340	3 057	1 802
CO$_2$ wet	%	1,0219	0,8028	0,6412	0,4524	0,3264	0,2066

For the dilution air:

$$k_{w,d} = 1 - k_{w1}$$

Where the factor k_{w1} is the same as that already calculated for the diluted exhaust gas.

$$k_{w,d} = 1 - 0{,}007 = 0{,}993$$

$$CO \ [wet] = CO \ [dry] \times k_w = 3 \times 0{,}993 = 3 \ ppm$$

$$CO_2 \ [wet] = CO_2 \ [dry] \times k_w = 0{,}042 \times 0{,}993 = 0{,}042 \ \% \ Vol$$

Table 20

CO and CO$_2$ wet values for the dilution air according to test modes

Mode		1	2	3	4	5	6
K_{w1}	—	0,007	0,006	0,006	0,006	0,006	0,006
K_w	—	0,993	0,994	0,994	0,994	0,994	0,994
CO wet	ppm	3	3	3	2	2	3
CO$_2$ wet	%	0,0421	0,0405	0,0403	0,0398	0,0394	0,0401

2.3.2. HC emissions

$$HC_{mass} = u \times conc_c \times G_{TOTW}$$

Where:

u = 0,000478 from Table 2

$conc_c = conc - conc_d \times (1 - 1/DF)$

$conc_c = 91 - 6 \times (1 - 1/9,465) = 86$ ppm

$HC_{mass} = 0,000478 \times 86 \times 625,722 = 25,666$ g/h

Table 21

HC emissions (g/h) according to test modes

Mode	1	2	3	4	5	6
HC_{mass}	25,666	25,993	21,607	21,850	34,074	48,963

2.3.3. NO_x emissions

The factor K_H for the correction of the NO_x emissions shall be calculated from:

$K_H = 0,6272 + 44,030 \times 10^{-3} \times H_a - 0,862 \times 10^{-3} \times H_a^2$

$K_H = 0,6272 + 44,030 \times 10^{-3} \times 4,08 - 0,862 \times 10^{-3} \times (4,08)^2 = 0,79$

Table 22

Humidity correction factor K_H of NO_x emissions according to test modes

Mode	1	2	3	4	5	6
K_H	0,793	0,791	0,791	0,790	0,791	0,792

$NO_{xmass} = u \times conc_c \times K_H \times G_{TOTW}$

Where:

u = 0,001587 from Table 2

$conc_c = conc - conc_d \times (1 - 1/DF)$

$conc_c = 85 - 0 \times (1 - 1/9,465) = 85$ ppm

$NOx_{mass} = 0,001587 \times 85 \times 0,79 \times 625,722 = 67,168$ g/h

Table 23

NO_x emissions (g/h) according to test modes

Mode	1	2	3	4	5	6
NO_{xmass}	67,168	38,721	19,012	4,621	2,319	0,811

2.3.4. CO emissions

$CO_{mass} = u \times conc_c \times G_{TOTW}$

where:

u = 0,000966 from Table 2

$conc_c = conc - conc_d \times (1 - 1/DF)$

$conc_c = 3\ 622 - 3 \times (1 - 1/9,465) = 3\ 620$ ppm

$CO_{mass} = 0,000966 \times 3\ 620 \times 625,722 = 2\ 188,001$ g/h

Table 24

CO emissions (g/h) according to test modes

Mode	1	2	3	4	5	6
CO_{mass}	2 188,001	2 068,760	1 510,187	1 424,792	1 853,109	975,435

2.3.5 CO_2 emissions

$$CO_{2mass} = u \times conc_c \times G_{TOTW}$$

Where:

u = 15,19 from Table 2

$conc_c = conc - conc_d \times (1 - 1/DF)$

$conc_c = 1,0219 - 0,0421 \times (1 - 1/9,465) = 0,9842 \% \ Vol$

$CO_{2mass} = 15,19 \times 0,9842 \times 625,722 = 9\ 354,488 \ g/h$

Table 25

CO₂ emissions (g/h) according to different test modes

Mode	1	2	3	4	5	6
CO_{2mass}	9 354,488	7 295,794	5 717,531	3 973,503	2 756,113	1 430,229

2.3.6. Specific emissions

The specific emission (g/kWh) shall be calculated for all individual components:

$$\text{Individual gas} = \frac{\sum_{i=1}^{n}(Gas_{mass_i} \times WF_i)}{\sum_{i=1}^{n}(P_i \times WF_i)}$$

Table 26

Emissions (g/h) and weighting factors according to different test modes

Mode		1	2	3	4	5	6
HC_{mass}	G/h	25,666	25,993	21,607	21,850	34,074	48,963
NO_{xmass}	G/h	67,168	38,721	19,012	4,621	2,319	0,811
CO_{mass}	G/h	2 188,001	2 068,760	1 510,187	1 424,792	1 853,109	975,435
CO_{2mass}	G/h	9 354,488	7 295,794	5 717,531	3 973,503	2 756,113	1 430,229
Power P_i	KW	13,15	9,81	6,52	3,25	1,28	0
Weighting factors WF_I	—	0,090	0,200	0,290	0,300	0,070	0,050

$$HC = \frac{25,666\times0,090+25,993\times0,200+21,607\times0,290+21,850\times0,300+34,074\times0,070+48,963\times0,050}{13,15\times0,090+9,81\times0,200+6,52\times0,290+3,25\times0,300+1,28\times0,070+0\times0,050} = 4,12 \ g/kWh$$

$$NO_x = \frac{67,168\times0,090+38,721\times0,200+19,012\times0,290+4,621\times0,300+2,319\times0,070+0,811\times0,050}{13,15\times0,090+9,81\times0,200+6,52\times0,290+3,25\times0,300+1,28\times0,070+0\times0,050} = 3,42 \ g/kWh$$

$$CO = \frac{2\ 188,001\times0,09+2\ 068,760\times0,2+1\ 510,187\times0,29+1\ 424,792\times0,3+1\ 853,109\times0,07+975,435\times0,05}{13,15\times0,090+9,81\times0,200+6,52\times0,290+3,25\times0,300+1,28\times0,070+0\times0,050} = 271,15 \ g/kWh$$

$$CO_2 = \frac{9\ 354,488\times0,09+7\ 295,794\times0,2+5\ 717,531\times0,29+3\ 973,503\times0,3+2\ 756,113\times0,07+1\ 430,229\times0,05}{13,15\times0,090+9,81\times0,200+6,52\times0,290+3,25\times0,300+1,28\times0,070+0\times0,050} = 887,53 \ g/kWh$$

Appendix 4

1.   COMPLIANCE WITH EMISSION STANDARDS

This appendix shall apply to SI engines Stage II only.

1.1.   The exhaust emission standards for Stage 2 engines in Annex I 4.2 apply to the emissions of the engines for their emission durability period EDP as determined in accordance with this Appendix.

1.2.   For all Stage II engines, if, when properly tested according to the procedures in this Directive, all test engines representing an engine family have emissions which, when adjusted by multiplication by the deterioration factor (DF) laid down in this Appendix, are less than or equal to each Stage II emission standard (family emission limit (FEL), where applicable) for a given engine class, that family shall be considered to comply with the emission standards for that engine class. If any test engine representing an engine family has emissions which, when adjusted by multiplication by the deterioration factor laid down in this Appendix, are greater than any single emission standard (FEL, where applicable) for a given engine class, that family shall be considered not to comply with the emission standards for that engine class.

1.3.   Small volume engine manufacturers may, optionally, take deterioration factors for $HC + NO_x$ and CO from Tables 1 or 2 in this section, or they may calculate deterioration factors for $HC + NO_x$ and CO according to the process described in section 1.3.1. For technologies not covered by Tables 1 and 2 in this section, the manufacturer must use the process described in section 1.4 in this Appendix.

Table 1

Handheld Engine $HC + NO_x$ and CO Assigned Deterioration Factors for Small Volume Manufacturer

Engine class	Two-stroke engines		Four-stroke engines		Engines with aftertreatment
	$HC + NO_x$	CO	$HC + NO_x$	CO	
SH:1	1,1	1,1	1,5	1,1	DFs must be calculated using the formula in para 1.3.1
SH:2	1,1	1,1	1,5	1,1	
SH:3	1,1	1,1	1,5	1,1	

Table 2

Non-handheld Engine $HC + NO_x$ and CO Assigned Deterioration Factors for Small Volume Manufacturers

Engine Class	Side Valve Engines		Overhead Valve Engines		Engines with After treatment
	$HC + NO_x$	CO	$HC + NO_x$	CO	
SN:1	2,1	1,1	1,5	1,1	DFs must be calculated using the formula in para 1.3.1
SN:2	2,1	1,1	1,5	1,1	
SN:3	2,1	1,1	1,5	1,1	
SN:4	1,6	1,1	1,4	1,1	

1.3.1.   Formula for calculating deterioration factors for engines with after treatment:

$$DF = [(NE * EDF) - (CC * F)]/(NE - CC)$$

where:

DF   = deterioration factor

NE   = new engine emission levels prior to the catalyst (g/kWh)

EDF   = deterioration factor for engines without catalyst as shown in Table 1

CC   = amount converted at 0 hours in g/kWh

F   = 0,8 for HC and 0,0 for NO_x for Class SN3 and SN4 engines

F   = 0,8 for CO for all classes of engines

1.4.   Manufacturers shall obtain an assigned DF or calculate a DF, as appropriate, for each regulated pollutant for all Stage 2 engine families. Such DFs shall be used for type approval and production line testing.

1.4.1.   For engines not using assigned DF:s from Tables 1 or 2 of this section, DFs shall be determined as follows:

1.4.1.1.   On at least one test engine representing the configuration chosen to be the most likely to exceed HC + NO_x emission standards, (FELs where applicable), and constructed to be representative of production engines, conduct (full) test procedure emission testing as described in this Directive after the number of hours representing stabilised emissions.

1.4.1.2.   If more than one engine is tested, average the results and round to the same number of decimal places contained in the applicable standard, expressed to one additional significant figure;

1.4.1.3.   Conduct such emission testing again following aging of the engine. The aging procedure should be designed to allow the manufacturer to appropriately predict the in-use emission deterioration expected over the durability period of the engine, taking into account the type of wear and other deterioration mechanisms expected under typical consumer use which could affect emissions performance. If more than one engine is tested, average the results and round to the same number of decimal places contained in the applicable standard, expressed to one additional significant figure.

1.4.1.4.   Divide the emissions at the end of the durability period (average emissions, if applicable) for each regulated pollutant by the stabilised emissions (average emissions, if applicable) and round to two significant figures. The resulting number shall be the DF, unless it is less than 1,00, in which case the DF shall be 1,0.

1.4.1.5.   At the manufacturer's option additional emission test points can be scheduled between the stabilised emission test point and the Emission Durability Period. If intermediate tests are scheduled, the test points must be evenly spaced over the EDP (plus or minus 2 hours) and one such test point shall be at one-half of full EDP (plus or minus 2 hours).

For each pollutant HC + NO_x and CO, a straight line must be fitted to the data points treating the initial test as occurring at hour zero, and using the method of least-squares. The deterioration factor is the calculated emissions at the end of the durability period divided by the calculated emissions at zero hours.

1.4.1.6.   Calculated deterioration factors may cover families and production years in addition to the one on which they were generated if the manufacturer submits a justification acceptable to the national type approval authority in advance of type approval that the affected engine families can be reasonably expected to have similar emission deterioration characteristic based on the design and technology used.

A non-exclusive list of design and technology groupings is given below:

— Conventional two-stroke engines without after treatment system

— Conventional two-stroke engines with a ceramic catalyst of the same active material and loading, and the same number of cells per cm^2

— Conventional two-stroke engines with a metallic catalyst of the same active material and loading, same substrate and the same number of cells per cm^2

— Two-stroke engines provided with a stratified scavenging system

— Four-stroke engines with catalyst (defined as above) with same valve technology and identical lubri-cation system

— Four-stroke engines without catalyst with the same valve technology and identical lubrication system

2. EMISSION DURABILITY PERIODS FOR STAGE 2 ENGINES

2.1. Manufacturers shall declare the applicable EDP category for each engine family at the time of type approval. Such category shall be the category which most closely approximates the expected useful lives of the equipment into which the engines are expected to be installed as determined by the engine manu-facturer. Manufacturers shall retain data appropriate to support their choice of EDP category for each engine family. Such data shall be supplied to the approval authority upon request.

2.1.1. For handheld engines: Manufacturers shall select an EDP category from Table 1 of this paragraph.

Table 1

EDP categories for Handheld Engines (hours)

Category	1	2	3
Class SH:1	50	125	300
Class SH:2	50	125	300
Class SH:3	50	125	300

2.1.2. For non-handheld engines: Manufacturers shall select an EDP category from Table 2 of this paragraph.

Table 2

EDP categories for Non-handheld Engines (hours)

Category	1	2	3
Class SN:1	50	125	300
Class SN:2	125	250	500
Class SN:3	125	250	500
Class SN:4	250	500	1 000

2.1.3. The manufacturer must satisfy the approval authority that the declared useful life is appropriate. Data to support a manufacturer's choice of EDP category, for a given engine family, may include but are not limited to:

— Surveys of the life spans of the equipment in which the subject engines are installed;

— Engineering evaluations of field aged engines to ascertain when engine performance deteriorates to the point where usefulness and/or reliability is impacted to a degree sufficient to necessitate overhaul or replacement;

— Warranty statements and warranty periods;

— Marketing materials regarding engine life;

— Failure reports from engine customers; and

— Engineering evaluations of the durability, in hours, of specific engine technologies, engine materials or engine designs.'

5. Annex IV becomes a new Annex V and is amended as follows:

The current headings shall be replaced by the following:

'**TECHNICAL CHARACTERISTICS OF REFERENCE FUEL PRESCRIBED FOR APPROVAL TESTS AND TO VERIFY CONFORMITY OF PRODUCTION**

NON-ROAD MOBILE MACHINERY REFERENCE FUEL FOR CI ENGINES ([1])'.

In the table in the line on 'Neutralization' the word 'Minimum' in column 2 shall be replaced by the word 'Maximum'. The following new table and new footnotes shall be added:

'NON-ROAD MOBILE MACHINERY REFERENCE FUEL FOR SI ENGINES

Note: The fuel for two-stroke engines is a blend of lubricant oil and the petrol specified below. The fuel/oil mixture ratio must be the ratio which is recommended by the manufacturer as specified in Annex IV, section 2.7.

Parameter	Unit	Limits ([1])		Test Method	Publication
		Minimum	Maximum		
Research octane number, RON		95,0	—	EN 25164	1993
Motor octane number, MON		85,0	—	EN 25163	1993
Density at 15 °C	kg/m^3	748	762	ISO 3675	1995
Reid vapour pressure	kPa	56,0	60,0	EN 12	1993
Distillation					
— Initial boiling point	°C	24	40	EN-ISO 3405	1988
— Evaporated at 100 °C	% v/v	49,0	57,0	EN-ISO 3405	1988
— Evaporated at 150 °C	% v/v	81,0	87,0	EN-ISO 3405	1988
— Final boiling point	°C	190	215	EN-ISO 3405	1988
Residue	%	—	2	EN-ISO 3405	1988
Hydrocarbon analysis					
— Olefins	% v/v	—	10	ASTM D 1319	1995
— Aromatics	% v/v	28,0	40,0	ASTM D 1319	1995
— Benzene	% v/v	—	1,0	EN 12177	1998
— Saturates	% v/v	—	balance	ASTM D 1319	1995
Carbon/hydrogen ratio		report	report		
Oxidations tability ([2])	min	480	—	EN-ISO 7536	1996
Oxygen content	% m/m	—	2,4	EN 1601	1997
Existent gum	mg/ml	—	0,04	EN-ISO 6246	1997
Sulphur content	mg/kg	—	100	EN-ISO 14596	1998
Copper corrosion at 50 °C		—	1	EN-ISO 2160	1995
Lead content	g/l	—	0,005	EN 237	1996
Phosphorus content	g/l	—	0,0013	ASTM D 3231	1994

([1]) The values quoted in the specification 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 statistical 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 question as to whether a fuel meets the requirements of the specifications, the terms of ISO 4259 should be applied.

([2]) The fuel may contain oxidation inhibitors and metal deactivators normally used to stabilise refinery gasoline streams, but detergent/dispersive additives and solvent oils must not be added.'

6. Annex V becomes Annex VI.

7. Annex VI becomes Annex VII and is amended as follows:

(a) Appendix 1 is amended as follows:

— The header shall be replaced by the following:

'*Appendix 1*

TEST RESULTS FOR COMPRESSION IGNITION ENGINES'

— Section 1.3.2 shall be replaced by the following:

'1.3.2. Power absorbed at indicated engine speed (as specified by the manufacturer):

	Power P_{AE} (kW) absorbed at various engine speeds [1], taking into account Appendix 3 of this Annex	
Equipment	Intermediate (if applicable)	Rated
Total		

[1] Must not be greater than 10 % of the power measured during the test.'

— Section 1.4.2. shall be replaced by the following:

'1.4.2. Engine power [1]

	Power setting (kW) at various engine speeds	
Condition	Intermediate (if applicable)	Rated
Maximum power measured on test (P_M) (kW) (a)		
Total power absorbed by engine driven equipment as per section 1.3.2 of this Appendix, or section 2.8 of Annex III (P_{AE}) (kW) (b)		
Net engine power as specified in section 2.4 of Annex I (kW) (c)		
c = a + b		

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[1] Uncorrected power measured in accordance with the provisions of section 2.4 of Annex I.'

— Section 1.5 shall be amended as follows:

'1.5. Emission levels

1.5.1. Dynamometer setting (kW)

	Dynamometer setting (kW) at various engine speeds	
Percent Load	Intermediate (if applicable)	Rated
10 (if applicable)		
25 (if applicable)		
50		
75		
100		

1.5.2. Emission results on the test cycle:'

(b) A new Appendix 2 shall be added as follows:

'*Appendix 2*

TEST RESULTS FOR SPARK IGNITION ENGINES

1. INFORMATION CONCERNING THE CONDUCT OF THE TEST(S) [1]:

1.1. Reference fuel used for test

1.1.1. Octane number

1.1.2. State percentage of oil in mixture when lubricant and petrol are mixed as in the case of 2-stroke engines

1.1.3. Density of petrol for 4-stroke engines and petrol/oil mixture for 2-stroke engines . . .

1.2. Lubricant

1.2.1. Make(s)

1.2.2. Type(s)

1.3. Engine driven equipment (if applicable)

1.3.1. Enumeration and identifying details

1.3.2. Power absorbed at indicated engine speed (as specified by the manufacturer)

	Power PAE (kW) absorbed at various engine speeds [1], taking into account Appendix 3 of this Annex	
Equipment	Intermediate (if applicable)	Rated
Total		

[1] Must not be greater than 10 % of the power measured during the test.

1.4. Engine performance

1.4.1. Engine speeds:

Idle: m^{-1}

Intermediate: m^{-1}

Rated: m^{-1}

1.4.2. Engine power (^{2})

	Power setting (kW) at various engine speeds	
Condition	Intermediate (if applicable)	Rated
Maximum power measured on test (P_M) (kW) (a)		
Total power absorbed by engine driven equipment as per section 1.3.2 of this Appendix, or section 2.8 of Annex III (P_{AE}) (kW) (b)		
Net engine power as specified in section 2.4 of Annex I (kW) (c)		
c = a + b		

1.5. Emission levels

1.5.1. Dynamometer setting (kW)

	Dynamometer setting (kW) at various engine speeds	
Percent Load	Intermediate (if applicable)	Rated (if applicable)
10 (if applicable)		
25 (if applicable)		
50		
75		
100		

1.5.2. Emission results on the test cycle:

CO: g/kW

HC: g/kWh

NO_x: g/kWh

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(^{1}) In case of several parent engines, to be indicated for each of them.

(^{2}) Uncorrected power measured in accordance with the provisions of section 2.4 of Annex I.'

(c) A new appendix 3 shall be added as follows:

'*Appendix 3*

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, standard production equipment
	Crankcase emission control system	Yes, standard production equipment
	Control devices for dual induction inlet manifold system	Yes, standard production equipment
	Air flow meter	Yes, standard production equipment
	Air inlet duct work	Yes (a)
	Air filter	Yes (a)
	Inlet silencer	Yes (a)
	Speed-limiting device	Yes (a)

Number	Equipment and auxiliaries	Fitted for emission test
2	Induction-heating device of inlet manifold	Yes, standard production equipment. If possible to be set in the most favourable condition
3	Exhaust system	
	Exhaust purifier	Yes, standard production equipment
	Exhaust manifold	Yes, standard production equipment
	Connecting pipes	Yes (b)
	Silencer	Yes (b)
	Tail pipe	Yes (b)
	Exhaust brake	No (c)
	Pressure charging device	Yes, standard production equipment
4	Fuel supply pump	Yes, standard production equipment (d)
5	Carburation equipment	
	Carburettor	Yes, standard production equipment
	Electronic control system, air flow meter, etc.	Yes, standard production equipment
	Equipment for gas engines	
	Pressure reducer	Yes, standard production equipment
	Evaporator	Yes, standard production equipment
	Mixer	Yes, standard production equipment
6	Fuel injection equipment (petrol and diesel)	
	Prefilter	Yes, standard production or test bed equipment
	Filter	Yes, standard production or test bed equipment
	Pump	Yes, standard production equipment
	High-pressure pipe	Yes, standard production equipment
	Injector	Yes, standard production equipment
	Air inlet valve	Yes, standard production equipment (e)
	Electronic control system, air flow meter, etc.	Yes, standard production equipment
	Governor/control system	Yes, standard production equipment
	Automatic full-load stop for the control rack depending on atmospheric conditions	Yes, standard production equipment
7	Liquid-cooling equipment	
	Radiator	No
	Fan	No
	Fan cowl	No
	Water pump	Yes, standard production equipment (f)
	Thermostat	Yes, standard production equipment (g)
8	Air cooling	
	Cowl	No (h)
	Fan or Blower	No (h)
	Temperature-regulating device	No

Number	Equipment and auxiliaries	Fitted for emission test
9	Electrical equipment	
	Generator	Yes, standard production equipment (i)
	Spark distribution system	Yes, standard production equipment
	Coil or coils	Yes, standard production equipment
	Wiring	Yes, standard production equipment
	Spark plugs	Yes, standard production equipment
	Electronic control system including knock sensor/spark retard system	Yes, standard production equipment
10	Pressure charging equipment	
	Compressor driven either directly by the engine and/or by the exhaust gases	Yes, standard production equipment
	Charge air cooler	Yes, standard production or test bed equipment (j) (k)
	Coolant pump or fan (engine-driven)	No (h)
	Coolant flow control device	Yes, standard production equipment
11	Auxiliary test-bed fan	Yes, if necessary
12	Anti-pollution device	Yes, standard production equipment (l)
13	Starting equipment	Test bed equipment
14	Lubricating oil pump	Yes, standard production equipment

(a) The complete inlet system shall be fitted as provided for the intended application:
where there is a risk of an appreciable effect on the engine power;
in the case of naturally aspirated spark ignition engines;
when the manufacturer requests that this should be done.
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 complete exhaust system shall be fitted as provided for the intended application:
where there is a risk of an appreciable effect on the engine power;
in the case of naturally aspirated spark ignition engines;
when the manufacturer requests that this should be done.
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 air intake valve is the control valve for the pneumatic governor of the injection pump. The governor or the fuel injection equipment may contain other devices which may affect the amount of injected fuel.

(f) 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.

(g) The thermostat may be fixed in the fully open position.

(h) 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 (e.g. 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.

(i) Minimum power of the generator: the electrical power of the generator shall be limited to that necessary for operation of accessories which are indispensable for engine operation. If the connection of a battery is necessary, a fully charged battery in good condition shall be used.

(j) 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 specified by the manufacturer.

(k) These may include, for example, exhaust-gas recirculation (EGR)-system, catalytic converter, thermal reactor, secondary air-supply system and fuel evaporation protecting system.

(l) The power for electrical or other starting systems shall be provided from the test bed.'

8. Annexes VII to X become Annexes VIII to XI.

9. A new Annex XII is added as follows:

'ANNEX XII

PROCEDURE FOR VOLUNTARY AVERAGING AND BANKING ([1])

1. INTRODUCTION

1.1. Manufacturers may optionally use the averaging and banking procedures described in this Annex in lieu of type approving all engines to the limits in section 4.2.2.1 of Annex I.

1.2. The averaging and banking system described in this Annex may only be used to meet the requirements of stage II for spark ignition engines.

1.3. Engines complying with emission limits using the averaging and banking procedure are subject to all other requirements of this Directive including the CO emission limit values set out in section 4.2.2.1 of Annex I.

1.4. Manufacturers wishing to use the voluntary averaging and banking system must start using it from the following calendar years:

Class	starting year (calendar year)
SH:1	2005
SH:2	2005
SH:3	2007
SN:1	2004
SN:2	2004
SN:3	2007
SN:4	2005

1.5. Manufacturers may use the voluntary system in this Annex for one or more classes of engines.

2. DEFINITIONS

For the purpose of this Annex the following definitions shall apply:

Averaging: means the exchange of emission credits between engine families within a given manufacturer's product line.

Banking: means the retention of emission credits by the manufacturer generating the emission credits for use in future calendar year averaging as permitted in this Annex.

Family Emission Limit or FEL: means an emission level that is declared by the manufacturer to serve in lieu of an emission standard for the purpose of type approval or production in line testing.

Emission credits: represent the amount of emission reduction or exceedence, by an engine family, below or above the applicable $HC+NO_x$ emission standard. FELs below the standard create "positive credits" while FELs above the standard create "negative credits". In addition "type-approval credits" refer to emission credits based on the projected applicable production volume of the engine family. "Banking credits" are emission credits generated within a calendar year to be reported by 30 April of the subsequent calendar year. "Actual credits" refer to emission credits based on the applicable production volume as accumulated until the end of the calendar year.

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([1]) The Commission will review the provisions of this annex before it enters into force, with regard to its administrative consequences and the competition between large and small manufacturers, and propose appropriate changes.

3. GENERAL PROVISIONS

3.1. A manufacturer may include in its calculation of credits only engines that are intended to be placed on the EU market and which are manufactured in the applicable calendar year.

3.2. A manufacturer may type approve engine families at Family Emission Limits (FELs) above or below the applicable emission standard subject to the limitation of this Annex, provided that the summation of the manufacturer's projected balance of credits from all credit transactions for all engine classes that have been type approved under the provisions of this Annex in a given calendar year is greater than or equal to zero as determined in accordance with section 7 of this Annex.

3.3. A manufacturer of an engine family with an FEL exceeding the applicable emission standard must obtain emission credits sufficient to address the associated shortfall via averaging or banking.

3.4. An engine family with an FEL below the applicable emission standard may generate positive emission credits for averaging or banking or a combination thereof.

3.5. The limit values of stage I must always be met by all engine families.

4. APPLICABLE EMISSION STANDARDS

Manufacturers using the averaging and banking system for $HC + NO_x$ must meet the following standards (FEL) in g/kWh:

Class SH:1

Calendar year	2005	2006	2007	2008 and onwards
Limit value ($HC + NO_x$)	238	175	113	50

Class SH:2

Calendar year	2005	2006	2007	2008 and onwards
Limit value ($HC + NO_x$)	196	148	99	50

Class SH:3

Calendar year	2007	2008	2009	2010 and onwards
Limit value ($HC + NO_x$)	143	119	96	72

Class SN:1

Calendar year	2004	2005	2006	2007 and onwards
Limit value ($HC + NO_x$)	50	50	50	50

Class SN:2

Calendar year	2004	2005	2006	2007 and onwards
Limit value ($HC + NO_x$)	40	40	40	40

Class SN:3

Calendar year	2004	2005	2006	2007 and onwards
Limit value ($HC + NO_x$)	40	40	40	16,1

Class SN:4

Calendar year	2006	2007	2008	2009	2010 and onwards
Limit value NO_x	18,0	16,6	15,0	13,6	12,1

5. AVERAGING

5.1. Negative credits from engine families with FELs above the applicable emission standard must be offset by positive credits from engine families having FELs below the applicable emission standard, as allowed under this Annex. Averaging of credits in this manner is used to determine compliance with the limit values of section 4 of this Annex.

5.2. Cross-class averaging of credits is allowed across all classes of non-road spark ignition engines.

5.3. Credits used in averaging for a given calendar year may be obtained from credits generated in the same calendar year by another engine family or credits banked in previous calendar years.

6. BANKING

6.1. Starting on 1 January of the first year that a manufacturer receives type approval, in accordance with this Annex, for an engine family with an FEL below the applicable emission standard, the manufacturer may bank credits in the calendar year for use in averaging.

6.2. A manufacturer may bank actual credits only after the end of the calendar year and after the type-approval authority has reviewed the end of the year report from the manufacturer and confirmed that it is satisfactory.

7. CREDIT CALCULATION AND COMPLIANCE WITH EMISSION STANDARDS

7.1. For each engine family, $HC+NO_x$ type-approval emission credits (positive or negative) shall be calculated according to the following equation and rounded to the nearest gram. Consistent units shall be used throughout the equation.

Credit = Production × (Standard — FEL) × Power × EDP × load factor

Where:

Production = eligible production. Annual production projections are used to project credit available for initial type approval. Eligible production volume is used in determining actual credits for end-of-year compliance determination.

Standard = the current and applicable standard in grams per kilowatt hour as determined in section 4.

FEL = the family emission limit for the engine family in grams per kilowatt hour.

Power = the maximum modal power of the parent engine, in kilowatts, as calculated from the applicable test procedure as described in this Directive.

EDP = the emission durability period in hours corresponding to the EDP category for which the engine family was type approved.

Load factor = 47 % (i.e. 0,47) for Test Cycle (G1) and Test Cycle (G2). (85 % (i.e. 0,85) for test cycle G3).

8. TYPE-APPROVAL PROCEDURE

8.1. When using the voluntary system of averaging and banking as described in this Annex a manufacturer must:

8.1.1. Be bound for his whole product range for any given calendar year to one single national approval authority. The manufacturer is responsible for ensuring that his representatives in the Community take no separate action for selected engines.

8.1.2. Submit a statement that the engines for which the system is used will not, to the best of the manufacturer's belief, cause the manufacturer to be in non-compliance under section 7 of this Annex when all credits are calculated for the manufacturer's engine families.

8.1.3. Declare an FEL for each engine family for $HC+NO_x$. The FEL must have the same number of significant digits as the emission standard.

8.1.4. Submit copies of the type-approval certificates for each engine family in the averaging and banking scheme to the approval authority issuing the relevant averaging approval in order to demonstrate that the engines have been certified at an emission level below the declared FEL.

8.1.5. Indicate the projected number of credits generated/needed for this family, the projected applicable eligible annual sales volume, and the values required to calculate the emission credit as given in section 7 of this Annex.

8.1.6. Submit calculations in accordance with section 7 of this Annex of projected emission credits (positive or negative) based on annual production projections for each engine family to be included in the averaging and banking scheme.

8.1.7. If the engine family is projected to have negative emission credits, state specifically the source (from averaging and banking) of the credits necessary to offset the credit deficit according to projected annual production.

8.1.8. If the engine family is projected to generate credits, state specifically (from averaging and banking) where the projected credits will be applied.

8.2. All type approvals issued in accordance with this Annex shall be conditional upon manufacturer compliance with the provisions of this Annex both during and after the calendar year. They are valid until 30 April of the following calendar year. A new type approval can be issued only if the manufacturer has presented an end-of-year report showing that the provisions of this Annex are met.

8.3. The manufacturer bears the burden of establishing to the satisfaction of the National Approval Authority that the conditions upon which the type approval was issued were satisfied or waived.

9. MAINTENANCE OF RECORDS

9.1. A manufacturer using the option of averaging and banking in accordance with this Annex must establish, maintain and retain the following adequately organised and indexed records for each engine family:

— the engine family identification code,

— Family Emission Limit (FEL) or FELs where FEL changes have been implemented during the calendar year,

— maximum modal power for the parent engine,

— projected production volume for the calendar year,

— records appropriate to establish the quantities of engines that constitute eligible production as defined in section 2 of this Annex for each FEL.

9.2. A manufacturer using the option of averaging and banking in accordance with this Annex must retain all records required to be maintained under this section for a period of 8 years from the due date for the end of the year report. Records may be retained as hard copy or reduced to microfilm, ADP diskettes, and so forth, depending on the manufacturer's record retention procedure, providing that in every case all information used for the approval is retained.

9.3. Pursuant to a request made by the type-approval authority, the manufacturer must submit to it the information that the manufacturer is required to retain.

9.4. The type-approval authority may withdraw the type-approval certificate(s) for an engine family for which the manufacturer fails to retain the records required in this section or to provide such information to the type-approval authority.

10.   END-OF-YEAR REPORTS

10.1. End-of-year reports must indicate the engine family, the engine class, the actual volume of engines placed on the market, the values required to calculate credits as indicated in section 7 of this Annex and the number of credits generated/required. Manufacturers must also submit how and where credit surpluses were dispersed (or are to be banked) and/or how and through what means credit deficits were met. The report must include a calculation of credit balances to show that the credit summation for all engines actually produced is equal to or greater than zero. The report must include a calculation of the production average HC+NO$_x$ FEL to show compliance with the provisions of section 4 of Annex XII.

10.2. The calculation of eligible production for end-of-year reports must be based on engines placed on the market in the EU.

10.3. End-of-year reports must be submitted to the type-approval authority before 1 April of the year after the issue of the type approval.

       On the basis of the end-of-year report the type-approval authority shall issue a new type-approval certificate.

10.4. Failure by a manufacturer to submit an end-of-year report in the specified time for any engines subject to regulation under this Annex will automatically lead to the withdrawal of the type-approval certificates for all engine families subject to this Annex.

10.5. If the end-of-year report shows the total actual credit to be negative the negative credit will be banked and carried across to the next year. If a negative credit is achieved for two or more years running the approval authority may withdraw the manufacturer's averaging and banking approval. If a negative credit is achieved for four years running the approval authority must suspend the manufacturer's averaging and banking approval.'