DIRECTIVE 2002/88/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 9 December 2002

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

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 (1),

Having regard to the opinion of the Economic and Social Committee (2),

Following consultation of the Committee of the Regions,

Acting in accordance with the procedure laid down in Article 251 of the Treaty (3),

Whereas:

(1) The Auto oil II programme was aimed at identifying cost effective strategies to meet the air quality objectives of the Community. The Commission Communication Review on the Auto oil II programme concluded that there is a need for further 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 will thus be more predominant in the future.

(3) Directive 97/68/EC (4) 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 subsequent extension of its scope to include in particular 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 possible significantly to reduce the emissions.

(7) The absence of Community legislation means it is possible to place on the market 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 four to five years.

(11) To achieve the necessary flexibility for worldwide alignment, a possible derogation, to be made under the comitology procedure, is included.

---

(1) OJ C 180 E, 26.6.2001, p. 31.

(2) OJ C 260, 17.9.2001, p. 1.

(3) Opinion of the European Parliament of 2 October 2001 (OJ C 87 E, 11.4.2002, p. 18), Council Common Position of 25 March 2002 (OJ C 145 E, 18.6.2002, p. 17) and Decision of the European Parliament of 2 July 2002 (not yet published in the Official Journal).

(4) OJ L 59, 27.2.1998, p. 1. Directive as amended by Commission Directive 2001/63/EC (OJ L 227, 23.8.2001, p. 41).

(12) The measures necessary for the implementation of this Directive should be adopted in accordance with Council Decision 1999/468/EC of 28 June 1999 laying down the procedures for the exercise of implementing powers conferred on the Commission ([1]).

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

HAVE ADOPTED THIS DIRECTIVE:

Article 1

Directive 97/68/EC is hereby amended as follows:

1. In Article 2:

   (a) the eighth indent shall be replaced by the following:

   '— "placing on the market" shall mean the action of making an engine available for the first time on the market, for payment or free of charge, with a view to distribution and/or use in the Community,';

   (b) the following indents shall be 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,

   — "hand-held 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);

      (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-hand-held engine" shall mean an engine which does not fall under the definition of a hand-held engine,

   — "professional use multipositional hand-held engine" shall mean a hand-held engine which meets the requirements of both (a) and (b) of the hand-held engine definition and in relation to which the engine manufacturer has satisfied an approval authority that a Category 3 Emissions Durability Period (according to section 2.1 of Appendix 4 to Annex IV) would be applicable to the 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" shall mean a spark-ignition (SI) engine family with a total yearly production of fewer than 5 000 units,

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

2. Article 4 is hereby amended as follows:

   (a) paragraph 2 shall be amended as follows:

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

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

   (b) paragraph 4 shall be amended as follows:

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

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

   (c) in paragraph 5, 'Annex X' shall be replaced by 'Annex XI'.

3. Article 7(2) shall be replaced by the following:

   '2. Member States shall accept type-approvals and, where applicable, the pertaining approval marks listed in Annex XII as being in conformity with this Directive.'

4. Article 9 is hereby amended as follows:

   (a) the heading 'Timetable' shall be replaced by the heading 'Timetable-compression ignition engines';

---

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

(b) in paragraph 1, 'Annex VI' shall be replaced by 'Annex VII';

(c) paragraph 2 shall be amended as follows:

  (i) 'Annex VI' shall be replaced by 'Annex VII';

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

(d) paragraph 3 shall be amended as follows:

  (i) 'Annex VI' shall be replaced by 'Annex VII';

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

(e) in the first subparagraph of paragraph 4, the phrase 'placing on the market of new engines' shall be replaced by 'placing on the market of engines'.

5. The following Article shall be 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 hand-held machinery

N: engines for non-hand-held machinery

Class/category	Displacement (cubic cm)
Hand-held engines Class SH:1	< 20
Class SH:2	≥ 20 < 50
Class SH:3	≥ 50
Non-hand-held 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 11 August 2004, 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 1

Member States shall refuse to grant type-approval for an engine type or engine family and to issue the documents as described in Annex VII, and shall refuse to grant any other type-approval for non-road mobile machinery in which an engine is installed after 11 August 2004 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 VII, 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 2007 for engine classes SH:1, SH:2 and SN:3

after 1 August 2008 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 I.

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.

6. LABELLING OF EARLY COMPLIANCE WITH STAGE II

For engine types or engine families meeting the limit values set out in the table in section 4.2.2.2 of Annex I, before the dates laid down in point 4 of this Article, Member States shall allow special labelling and marking to show that the equipment concerned meets the required limit values before the dates laid down.

7. EXEMPTIONS

The following machinery shall be exempted from the implementation dates of stage II emission limit requirements for a period of three years after the entry into force of those emission limit requirements. For those three years, the stage I emission limit requirements shall continue to apply:

— hand-held chainsaw: a hand-held device designed to cut wood with a saw chain, designed to be supported with two hands and having an engine capacity in excess of 45 cm^3, according to EN ISO 11681-1,

— top handle machine (i.e., hand-held drills and tree service chainsaws): a hand-held device with the handle on top of the machine designed to drill holes or to cut wood with a saw chain (according to ISO 11681-2),

— hand-held brush cutter with an internal combustion engine: a hand-held device with a rotating blade made of metal or plastic intended to cut weeds, brush, small trees and similar vegetation. It must be designed according to EN ISO 11806 to operate multi-positionally, such as horizontally or upside down, and have an engine capacity in excess of 40 cm^3;

— hand-held hedge trimmer: a hand-held device designed for trimming hedges and bushes by means of one or more reciprocating cutter blades, according to EN 774,

— hand-held power cutter with an internal combustion engine: a hand-held device intended for cutting hard materials such as stone, asphalt, concrete or steel by means of a rotating metal blade with a displacement in excess of 50 cm^3, according to EN 1454, and

— non-hand-held, horizontal shaft class SN:3 engine: only those class SN:3 non-hand-held engines with a horizontal shaft that produce power equal to or less than 2,5 kW and are used mainly for select, industrial purposes, including tillers, reel cutters, lawn aerators and generators.

8. OPTIONAL IMPLEMENTATION DELAY

Nevertheless, for each category, Member States may postpone the dates in paragraphs 3, 4 and 5 for two years in respect of engines with a production date prior to those dates.'

6. Article 10 is hereby amended as follows:

(a) paragraph 1 shall be 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 shall be 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 shall be added:

'3. The requirements of Article 9a(4) and (5) shall be postponed by three years for small volume engine manufacturers.

4. The requirements of Article 9a(4) and (5) shall be replaced by the corresponding stage I requirements for a small volume engine family to a maximum of 25 000 units providing that the various engine families involved all have different cylinder displacements.'

7. Articles 14 and 15 shall be replaced by the following Articles:

'*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 14a

Procedure for derogations

The Commission shall study possible technical difficulties in complying with the stage II requirements for certain uses of the engines, in particular mobile machinery in which engines of classes SH:2 and SH:3 are installed. If the Commission studies conclude that for technical reasons certain mobile machinery, in particular, professional use, multi-positional, hand-held engines, cannot meet these deadlines, it shall submit, by 31 December 2003, a report accompanied by appropriate proposals for extensions of the period referred to in Article 9a(7) and/or further derogations, not exceeding five years, unless in exceptional circumstances, for such machinery, under the procedure laid down in Article 15(2).

Article 15

Committee

1. The Commission shall be assisted by the Committee on Adaptation to Technical Progress of the Directives on the Removal of Technical Barriers to Trade in the Motor Vehicle Sector (hereinafter referred to as “the Committee”).

2. Where reference is made to this paragraph, Articles 5 and 7 of Decision 1999/468/EC (*) shall apply, having regard to the provisions of Article 8 thereof.

The period laid down in Article 5(6) of Decision 1999/468/EC shall be set at three months.

3. The Committee shall adopt its Rules of Procedure.

(*) OJ L 184, 17.7.1999, p. 23.’

8. The following list of Annexes shall be added at the beginning of the Annexes:

‘List of Annexes

ANNEX I	Scope, definitions, symbols and abbreviations, engine markings, specifications and tests, specification of conformity of production assessments, parameters defining the engine family, choice of the parent engine
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 for CI 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 prescribed for approval tests and to verify conformity of production Non-road mobile machinery reference fuel for CI engines
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	Recognition of alternative type approvals’.

9. The Annexes shall be 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 11 August 2004. They shall forthwith inform the Commission thereof.

When Member States adopt these measures, they shall contain a reference to this Directive or shall be accompanied by such reference on the occasion of their official publication. The methods of making such reference shall be laid down by Member States.

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

Article 3

Not later than 11 August 2004, the Commission shall submit to the European Parliament and the Council a report and, if appropriate, a proposal regarding the potential costs, benefits and feasibility of:

(a) reducing particulate emissions from small spark ignition engines with special attention to two stroke engines. The report shall take into account:

  (i) estimates of the contribution of such engines to the emission of particles, and the way proposed emission reduction measures could contribute towards improving air quality and reduced health effects;

  (ii) tests, measurement procedures and equipment which could be used to assess particulate emissions from small spark ignition engines at type approval;

  (iii) work and conclusion within the particulate measurement programme;

  (iv) developments in test procedures, engine technology, exhaust purification as well as enhanced standards for fuel and engine oil; and

  (v) costs of reducing particulate emissions from small spark ignition engines and the cost effectiveness of any proposed measures;

(b) reducing emissions from those recreational vehicles, including snowmobiles and go-carts, currently not covered;

(c) reducing exhaust gas and particulate emissions from small compression ignition engines under 18 Kw;

(d) reducing exhaust gas and particulate emissions from locomotive compression ignition engines. A test cycle should be formulated in order to measure such emissions.

Article 4

This Directive shall enter into force on the day of its publication in the *Official Journal of the European Union*.

Article 5

This Directive is addressed to the Member States.

Done at Brussels, 9 December 2002.

For the European Parliamentt	*For the Council*
The President	*The President*
P. COX	H. C. SCHMIDT

ANNEX

1. Annex I is hereby 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) paragraphs 1 (A), (B), (C), (D) and (E) shall be amended as follows:

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

(i) a CI 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 . . . .

(remainder unchanged, down to

“— mobile cranes;”);

or

(ii) a CI engine having a net power in accordance with section 2.4 that is higher than 18 kW but not more than 560 kW and that is operated under constant speed. Limits only apply from 31 December 2006.

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,
- water pumps,
- turf care, chippers, snow removal equipment, sweepers;

or

(iii) a petrol fuelled SI 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, e.g.

- snow mobiles,
- off road motorcycles,
- all-terrain vehicles;’;

(c) section 2 shall be amended as follows:

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

'… except for cooling fans of air cooled engines directly fitted on the crankshaft (see Appendix 3 of Annex VII).',

— The following 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 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 (SI) 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;

2.16. mode length means 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.',

— section 2.9 shall become section 2.17 and current sections 2.9.1 to 2.9.3 shall become sections 2.17.1 to 2.17.3.

(d) section 3 shall be amended as follows:

— section 3.1 shall be replaced by the following:

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

— section 3.1.3 shall be amended as follows:

'Annex VII' shall be replaced by 'Annex VIII',

— the following section shall be inserted:

'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;',

— sections 3.2 to 3.6 shall become sections 3.3 to 3.7,

— section 3.7 shall be amended as follows: 'Annex VI' shall be replaced by 'Annex VII';

(e) section 4 shall be amended as follows:

— the following heading shall be inserted: '4.1 CI engines.',

— current section 4.1 shall become section 4.1.1 and the reference to section 4.2.1 and 4.2.3. shall be replaced by a reference to section 4.1.2.1 and 4.1.2.3,

— current section 4.2 shall become section 4.1.2 and shall be amended as follows: 'Annex V' shall be replaced throughout by 'Annex VI',

— current section 4.2.1 shall become section 4.1.2.1; current section 4.2.2 shall become 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 sections 4.1.2.3 and 4.1.2.4;

(f) the following 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	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	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 “hand-held engine” in Article 2 of this Directive two-stroke engines used to power snowthrowers only have to meet SH:1, SH:2 or SH:3 standards.

(*) See Annex 4, Appendix 4: deterioration factors included.’;

(g) sections 6.3 to 6.9 shall be replaced by the following sections:

‘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

- Oxidation catalyst
- Reduction catalyst
- Three way catalyst
- Thermal reactor
- Particulate trap'.

2. Annex II is hereby amended as follows:

(a) in Appendix 2 the text in the table shall be 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 shall be amended as follows:

- the heading of section 3 shall be replaced by 'FUEL FEED FOR DIESEL ENGINES'
- The following 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 shall become section 5 and the following points shall be added:

'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 sections shall be added:

'6. PORTING CONFIGURATION

6.1. Position, size and number'

‘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 shall be amended as follows:

(a) the heading shall be replaced by the following:

‘TEST PROCEDURE FOR C.I. ENGINES’;

(b) section 2.7 shall be amended as follows:

‘Annex VI’ shall be replaced by ‘Annex VII’ and ‘Annex IV’ shall be replaced by ‘Annex V’;

(c) section 3.6 shall be amended as follows:

— sections 3.6.1 and 3.6.1.1 shall be amended as follows:

‘3.6.1. Equipment specifications according to section 1(A) of Annex I:

3.6.1.1. Specification A: For engines covered by Section 1(A)(i) of Annex I, the following eight-mode cycle (*) shall be followed in dynamometer operation on the test engine: (table unchanged).

(*) Identical with C1 cycle of the draft ISO 8178-4 standard.’,

— the following section shall be added:

‘3.6.1.2. Specification B. For engines covered by Sections 1(A)(ii), the following five-mode cycle ([1]) shall be followed 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).

---

(1) Identical with D2 cycle of the ISO 8178-4: 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 shall be 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' (remainder unchanged);

(d) appendix 1, section 1 shall be amended as follows:

In section 1 and 1.4.3, 'Annex V' shall be replaced by 'Annex VI' throughout.

4. The following Annex shall be 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:

$$f_a = \left(\frac{99}{p_s}\right)^{1,2} \times \left(\frac{T_a}{298}\right)^{0,6}$$

2.1.1. *Test validity*

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

$$0,93 \leq f_a \leq 1,07$$

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 cm^3 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 cm^3 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 shall be 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 shall be 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:

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

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 1A(iii) 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):	engines with constant speed and intermittent load such as generating sets;
cycle G1:	non-hand-held intermediate speed applications;
cycle G2:	non-hand-held rated speed applications;
cycle G3:	hand-held applications.

---

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

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 (1) %	100	75	50	25	10						
Weighting factor	0,05	0,25	0,3	0,3	0,1						

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 (*)

(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. For a better illustration of the prime power definition, see figure 2 of ISO 8528-1: 1993(E) standard.

(*) For stage I, 0,90 and 0,10 may be used instead of 0,85 and 0,15 respectively.

3.5.1.2. 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 3.5.1.3. If the primary end use of an engine is uncertain then the appropriate test cycle should be chosen based upon the engine specification.

3.5.1.3. 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. Each mode sampling time shall be at least 180 s. The 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 ± 0,5 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 180 s 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 ppmC) or ± 2 % of each range used below 100 ppm (or ppmC).

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 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 electrochemical 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, a 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 after-treatment 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 minimise 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 % and 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,
- — 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 to 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 to 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:

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

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) If 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:

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

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.

Tabel 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:

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

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:

$$\text{conc (wet)} = k_w \times \text{conc (dry)}$$

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 α 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 as 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:

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

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:

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

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

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 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:

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

$$K_H = 1 \text{ (for 2 stroke engines)}$$

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):

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

where:

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

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

Table 1 — Molecular weights

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

(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).

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

— CO_{2AIR} 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 (2):

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

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:

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

with

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

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	0,000479	ppm
CO_2	15,19	%

Values of the u coefficient are based upon a molecular weight of the dilute exhaust gases equal to 29 [kg/kmol]; 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:

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

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).

---

(1) 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 SI. 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.

(2) 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).

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 four-stroke SI 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 four-stroke SI engine

Mode		1	2	3	4	5	6
Engine speed	min^{-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. *Dry/wet correction factor k_w*

The dry/wet correction factor kw 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:

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

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

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*

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

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

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*

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

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

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:

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

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

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

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

$$CO = \frac{2\,084{,}59 \times 0{,}090 + 997{,}64 \times 0{,}200 + 695{,}28 \times 0{,}290 + 591{,}18 \times 0{,}300 + 810{,}33 \times 0{,}070 + 227{,}92 \times 0{,}050}{9{,}96 \times 0{,}090 + 7{,}50 \times 0{,}200 + 4{,}88 \times 0{,}290 + 2{,}36 \times 0{,}300 + 0{,}940 \times 0{,}070 + 0 \times 0{,}050} = 181{,}93 \text{ g/kWh}$$

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

2.2. Raw exhaust gas data from a two-stroke SI 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 two-stroke SI engine

Mode		1	2
Engine speed	min^{-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_{H20}/kg_{air}	7,742	7,558
CO dry	ppm	37 086	16 150
NO_x wet	ppm	183	15
HC wet	ppmC1	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 O/C ratio β		0	0

2.2.1 *Dry/wet correction factor k_w*

The dry/wet correction factor kw 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
kw_2	—	0,012	0,012
kw	—	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
Weighting factors WF_i	—	0,85	0,15

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

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

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

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

2.3. Diluted exhaust gas data from a four-stroke SI 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 four-stroke SI engine

Mode		1	2	3	4	5	6
Engine speed	min^{-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 (1)	°C	25,3	25,1	24,5	23,7	23,5	22,6
Intake air relative humidity (1)	%	19,8	19,8	20,6	21,5	21,9	23,2
Intake air absolute humidity (1)	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

Mode		1	2	3	4	5	6
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 O/C ratio β		0	0	0	0	0	0

(1) Dilution air conditions equal to intake air conditions.

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:

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

where:

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

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

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

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

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

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

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

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.

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

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

$$CO_2\ [wet] = CO_2\ [dry] \times k_w = 0{,}042 \times 0{,}993 = 0{,}0421\ \%\ Vol$$

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
Kw	—	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:

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

$$K_H = 0{,}6272 + 44{,}030 \times 10^{-3} \times 4{,}8 - 0{,}862 \times 10^{-3} \times (4{,}08)^2 = 0{,}79$$

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

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

where:

u = 0,001587 from table 2

$conc_c$ = conc − $conc_d$ × (1−1/DF)

$conc_c$ = 85 − 0 × (1−1/9,465) = 85 ppm

NO_{xmass} = 0,001587 × 85 × 0,79 × 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 − $conc_d$ × (1−1/DF)

$conc_c$ = 3 622 − 3 × (1−1/9,465) = 3 620 ppm

CO_{mass} = 0,000966 × 3 620 × 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 — CO_2 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

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

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

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

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

Appendix 4

1. COMPLIANCE WITH EMISSION STANDARDS

This Appendix shall apply to SI engines stage 2 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 2 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 2 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 table 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: Hand-held engine HC+NO_x and CO assigned deterioration factors for small volume manufacturer

Engine class	Two-stroke engines		Four-stroke engines		Engines with after treatment
	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 section 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-hand-held 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 section 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 all classes of 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 DFs 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 ageing of the engine. The ageing 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 two hours) and one such test point shall be at one half of full EDP (plus or minus two 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 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 lubrication 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 manufacturer. 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 hand-held engines: manufacturers shall select an EDP category from table 1.

Table 1: EDP categories for hand-held 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-hand-held engines: manufacturers shall select an EDP category from table 2.

Table 2: EDP categories for non-hand-held 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 shall become Annex V and shall be 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 'Neutralisation' 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		
Oxidation stability (2)	min.	480	—	EN-ISO 7536	1996
Oxygen content	% m/m	—	2,3	EN 1601	1997

Parameter	Unit	Limits (1)		Test method	Publication
		Minimum	Maximum		
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

Note 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.

Note 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 shall become Annex VI.

7. Annex VI shall become Annex VII and shall be amended as follows:

(a) Appendix 1 shall be amended as follows:

— The heading 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):

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

(*) 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** (*)

Condition	Power setting (kW) at various engine speeds	
	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		

(*) 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)*

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

1.5.2. Emission results on the test cycle:';

(b) The following Appendix shall be added:

'Appendix 2

TEST RESULTS FOR SPARK IGNITION ENGINES

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

1.1. **Octane number**

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 two-stroke engines

1.1.3. Density of petrol for four-stroke engines and petrol/oil mixture for two-stroke engines

---

(*) In case of several parent engines, to be indicated for each of them.

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)

Equipment	Power P_{AE} (kW) absorbed at various engine speeds (*), taking into account Appendix 3 of this Annex	
	Equipment	Rated
Total		

(*) Must not be greater than 10 % of the power measured during the test.

1.4. **Engine performance**

1.4.1. Engine speeds:

Idle: min^{-1}

Intermediate: min^{-1}

Rated: min^{-1}

1.4.2. Engine power (*)

Condition	Power setting (kW) at various engine speeds	
	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		

(*) Uncorrected power measured in accordance with the provisions of section 2.4 of Annex I.

1.5. **Emission levels**

1.5.1. Dynamometer setting (kW)

Percent Load	Dynamometer setting (kW) at various engine speeds	
	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/kWh

HC: g/kWh

NO_x: g/kWh'

(c) The following Appendix 3 shall be added:

'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])
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

Number	Equipment and auxiliaries	Fitted for emission test
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
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

Number	Equipment and auxiliaries	Fitted for emission test
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 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 shall become Annexes VIII to XI.

9. The following Annex shall be added:

‘*ANNEX XII*

RECOGNITION OF ALTERNATIVE TYPE-APPROVALS

1. The following type-approvals and, where applicable, the pertaining approval marks are recognised as being equivalent to an approval to this Directive for engines of categories A, B and C as defined in Article 9(2):

1.1. Directive 2000/25/EC.

1.2. Type-approvals to Directive 88/77/EEC, complying with the requirements of stage A or B regarding Article 2 and Annex I, section 6.2.1 of Directive 88/77/EEC as amended by Directive 91/542/EEC, or UN-ECE Regulation 49.02 series of amendments corrigenda I/2.

1.3. Certificates of type approvals according to UN-ECE Regulation 96.

2. For engines categories D, E, F and G (stage II) as defined in Article 9(3), the following type-approvals and, where applicable, the pertaining approval marks are recognised as being equivalent to an approval to this Directive:

2.1. Directive 2000/25/EC, stage II approvals;

2.2. Type-approvals to Directive 88/77/EEC as amended by Directive 99/96/EC which are in compliance with stages A, B1, B2 or C provided for in Article 2 and section 6.2.1 of Annex I;

2.3. UN-ECE Regulation 49.03 series of amendments;

2.4. UN-ECE Regulation 96 stage B approvals according to paragraph 5.2.1 of the 01 series of amendments of Regulation 96.’.