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Session document

C5-0028/1999

19/07/1999

*****II**

COMMON POSITION

Subject : COMMON POSITION (EC) No /99
ADOPTED BY THE COUNCIL ON 22 APRIL 1999
WITH A VIEW TO THE ADOPTION OF
DIRECTIVE 99/ /EC
OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
ON THE APPROXIMATION OF THE LAWS OF THE MEMBER STATES
RELATING TO MEASURES TO BE TAKEN AGAINST THE EMISSION OF
GASEOUS AND PARTICULATE POLLUTANTS FROM COMPRESSION
IGNITION ENGINES FOR USE IN VEHICLES, AND THE EMISSION OF
GASEOUS POLLUTANTS FROM POSITIVE IGNITION ENGINES FUELLED
WITH NATURAL GAS OR LIQUEFIED PETROLEUM GAS FOR USE IN
VEHICLES
AND AMENDING COUNCIL DIRECTIVE 88/77/EEC
(COD 1997/0350)

**COUNCIL
OF THE
EUROPEAN UNION**

Brussels, **19 -07- 1999**

COMMON POSITION

C5-0028/99

97/0350 (COD)

EN

Mr José Maria GIL-ROBLES
President of the European Parliament
c/o Mr H. RØMER
Deputy Secretary-General
Case Postale 1601
LUXEMBOURG

Sir,

In accordance with the Treaty, I am sending you the common position adopted by the Council on 22 April 1999 with a view to adopting a Directive of the European Parliament and of the Council amending Directive 88/77/EEC on the approximation of the laws of the Member States relating to the measures to be taken against the emission of gaseous and particulate pollutants from diesel engines for use in vehicles, [97/0350(COD)], together with the statement of the Council's reasons.

Allow me to clarify the conditions under which the Council adopted this Decision: the Danish, Luxembourg, United Kingdom and Swedish delegations explained their votes. The statement of explanation is attached.

Enclosures : 5734/1/99 + ADD 1
Statements
SEC(99)0423
EN

EN

Rue de la Loi, 175
1048 BRUSSELS

Furthermore, when it adopted this common position, the Council did not enter statements in its minutes other than unilateral statements made by members of the Council.

All the documents to be forwarded are enclosed.

Yours faithfully,
For the Secretary-General

A. BOIXAREU
Director-General

Enclosures: 5734/1/99 REV 1 + REV 1 ADD 1
Explanation of vote

**Statement explaining the votes of the Danish, Luxembourg,
United Kingdom and Swedish delegations**

"The Danish, Luxembourg, United Kingdom and Swedish delegations have cast a positive vote for this Directive in the interests of environmental gains and can, as part of the overall compromise, accept the inclusion of the provisions on tax incentives. However, they regard their vote as without prejudice to the question of the inclusion of such tax provisions in future legislation under Article 100a of the Treaty, which they consider to be an inappropriate legal basis for such provisions."

**Interinstitutional File:
97/0350 (COD)**

**5734/1/99
REV 1**

LIMITE

**ENT 21
ENV 23
CODEC 52**

**COMMON POSITION (EC) No /99
ADOPTED BY THE COUNCIL ON 22 APRIL 1999
WITH A VIEW TO THE ADOPTION OF
DIRECTIVE 99/ /EC
OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
ON THE APPROXIMATION OF THE LAWS OF THE MEMBER STATES
RELATING TO MEASURES TO BE TAKEN AGAINST THE EMISSION OF GASEOUS
AND PARTICULATE POLLUTANTS FROM COMPRESSION IGNITION ENGINES FOR
USE IN VEHICLES, AND THE EMISSION OF GASEOUS POLLUTANTS FROM
POSITIVE IGNITION ENGINES FUELLED WITH NATURAL GAS OR LIQUEFIED
PETROLEUM GAS FOR USE IN VEHICLES
AND AMENDING COUNCIL DIRECTIVE 88/77/EEC**

DIRECTIVE 98/ /EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of

on the approximation of the laws of the Member States
relating to measures to be taken against the emission of gaseous
and particulate pollutants from compression ignition engines for
use in vehicles, and the emission of gaseous pollutants from
positive ignition engines fuelled with natural gas or liquefied
petroleum gas for use in vehicles
and amending Council Directive 88/77/EEC

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 proposals from the Commission ¹,

Having regard to the Opinion of the Economic and Social Committee ²,

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

(1) Whereas measures should be adopted within the framework of the internal market;

¹ OJ C 173, 8. 6.1998, p. 1 and OJ C 43, 17.2.1999, p. 25.

² OJ C 407, 28.12.1998, p. 27.

³ Opinion of the European Parliament of 21 October 1998 (OJ C 341, 9.11.1998, p. 74),
Council Common Position of _____ and Decision of the European Parliament
of _____

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- (2) Whereas the first programme of action of the European Community on protection of the environment ¹, approved by the Council on 22 November 1973, called for account to be taken of the latest scientific advances in combating atmospheric pollution caused by gases emitted from motor vehicles and for Directives adopted previously to be amended accordingly; whereas the fifth programme of action, which in its general approach was approved by the Council in its Resolution of 1 February 1993 ², provides for additional efforts to be made for a considerable reduction in the present level of emissions of pollutants from motor vehicles;
- (3) Whereas it is recognised that the development of transport in the Community has entailed significant constraints for the environment; whereas a number of official estimates of the increase in traffic density have proved to be lower than the actual figures; whereas for that reason stringent emission standards should be laid down for all motor vehicles;

¹ OJ C 112, 20.12.1973, p. 1.

² OJ C 138, 17. 5.1993, p. 1.

- (4) Whereas Directive 88/77/EEC¹ laid down the limit values for the emissions of carbon monoxide, unburnt hydrocarbons and nitrogen oxides from diesel engines for use in motor vehicles on the basis of a test procedure for European driving conditions for the vehicles concerned; whereas this Directive was first amended by Directive 91/542/EEC² in two stages, the first stage (1992/3) coinciding with the implementation dates of the new European emission standards for passenger cars; whereas the second stage (1995/6) established a longer-term orientation for the European motor industry by fixing limit values based on the expected performance of technologies still under development, whilst granting to industry a lead time to perfect such technologies; whereas Directive 96/1/EC³ required that for small diesel engines with a cylinder swept volume lower than 0,7 dm³ and a rated power speed higher than 3,000 min⁻¹, the limit value for particulate emissions set in Directive 91/542/EEC be introduced instead from 1999; whereas, however, it is reasonable on a technical basis to maintain a differential on particulate emissions for small high speed diesel engines that have a cylinder swept volume lower than 0,75 dm³ and a rated power speed higher than 3,000 min⁻¹, but to end this differential in 2005;
- (5) Whereas, under Article 5(3) of Directive 91/542/EEC, the Commission was to report to the Council before the end of 1996 on progress made regarding the revision of the limit values for polluting emissions combined, if necessary, with a revision of the test procedure; whereas such revised limits are not to apply before 1 October 1999 as regards new type approvals;

¹ OJ L 36, 9. 2.1988, p. 33.

² OJ L 295, 25.10.1991, p. 1.

³ OJ L 40, 17. 2.1996, p. 1.

- (6) Whereas the Commission has implemented a European programme on air quality, road traffic emissions, fuels and engine technologies, (the Auto-Oil Programme), with a view to fulfilling the requirements of Article 4 of Directive 94/12/EC¹; whereas a cost/effectiveness study within the Auto-Oil Programme has shown that a further improvement of diesel engine technology for heavy duty vehicles was necessary with a view to achieving air quality in the year 2010 as described in the Communication by the Commission on the Auto-Oil Programme;
- (7) Whereas improvement of requirements for new diesel engines in Directive 88/77/EEC constitute a part of a global Community strategy which will also include a revision of standards for light commercial vehicles and passenger cars from the year 2000, an improvement in motor fuels and more accurate assessment of in-service vehicle emission performances;
- (8) Whereas Directive 88/77/EEC is one of the separate directives under the type-approval procedure laid down by Council Directive 70/156/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to type approval of motor vehicle and their trailers²; whereas the objective of reducing the level of pollutant emissions from motor vehicles cannot be sufficiently achieved by individual Member States and can therefore be better achieved by the approximation of the laws of the Member States relating to measures to be taken against air pollution by motor vehicles;

¹ OJ L 100, 19.4.1994, p. 42.

² OJ L 42, 23.2.1970, p. 1. Directive as last amended by Directive 98/91/EC of the European Parliament and of the Council (OJ L 11, 16.1.1999, p. 25).

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- (9) Whereas reductions in emission limits applicable from the year 2000 corresponding to abatements of 30% in emissions of carbon monoxide, total hydrocarbons, NO_x and particulate matter have been identified by the Auto-Oil Programme as key measures to achieving satisfactory medium-term air quality; whereas a reduction of 30% in exhaust smoke opacity over that measured on current engine types and complementing Council Directive 72/306/EEC¹ will contribute to the reduction of particulate matter; whereas additional reductions in emission limits applicable from 2005 of 30% carbon monoxide, total hydrocarbons and NO_x and 80% in particulates will greatly contribute to medium-term air quality benefits; whereas these reductions will take into account the effect on emissions of new test cycles that better represent the driving patterns experienced by in-service vehicles; whereas the additional NO_x limit applicable from 2008 will result in a further 43% reduction in the emission limit for this pollutant; whereas, no later than the end of 2002, the Commission is to consider the available technology with a view to confirming the mandatory NO_x standard for 2008 in a report to the European Parliament and the Council, accompanied, if necessary, by appropriate proposals;
- (10) Whereas permissive emission limit values are introduced which are applicable to vehicles defined as "Enhanced Environmentally Friendly Vehicles" (EEVs);
- (11) Whereas on-board diagnostics (OBD) are not fully developed for heavy duty vehicles but are to be introduced from 2005 with a view to permitting rapid detection of failure of emission critical components and systems on vehicles and thus allowing a significant upgrading of the maintenance of initial emission performances on in-service vehicles through improved inspection and maintenance; whereas specific requirements for the durability of new heavy duty engines and for the conformity testing of in-service heavy duty vehicles should be introduced from 2005;

¹ OJ L 190, 20.4.1972, p. 1. Directive as last amended by Directive 97/20/EC (OJ L 125, 16.5.1997, p. 21).

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- (12) Whereas new type approval test cycles for gaseous and particulate emissions and smoke opacity are introduced that will allow a more representative evaluation of the emissions performance of diesel engines over test conditions that more closely resemble those encountered by vehicles in-service; whereas a new combined (two cycle) test procedure is introduced for conventional diesel engines and those diesel engines fitted with oxydation catalysts; whereas a new combined (two cycle) test procedure is introduced for gas-fuelled engines and, additionally, for diesel engines fitted with advanced emission control systems; whereas from 2005, all diesel engines are to be tested on both applicable test cycles; whereas the Commission will monitor progress in negotiations towards a worldwide harmonised test procedure;
- (13) Whereas Member States should be allowed, by means of tax incentives, to expedite the placing on the market of vehicles which satisfy the requirements adopted at Community level, such incentives having to comply with the provisions of the Treaty and satisfy certain conditions intended to avoid distortions of the internal market; whereas this Directive does not affect the Member States' right to include emissions of pollutants and other substances in the basis for calculating road traffic taxes on motor vehicles;
- (14) Whereas, in the development of Community legislation concerning emissions from motor vehicles, results of ongoing research into the characteristics of particulates should be taken into account;

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(15) Whereas the Commission will report before 31 December 2000 on the evolution of emission control equipment for heavy duty diesel vehicles and the relationship with fuel quality, the need to improve the accuracy and reproducibility of particulate measurement and sampling procedures and the development of a worldwide harmonised test cycle;

(16) Whereas Directive 88/77/EEC should be amended accordingly,

HAVE ADOPTED THIS DIRECTIVE:

Article 1

Directive 88/77/EEC is hereby amended as follows:

(1) the title shall be replaced by the following:

"Council Directive 88/77/EEC of 3 December 1987 on the approximation of the laws of the Member States relating to the measures to be taken against the emission of gaseous and particulate pollutants from compression ignition engines for use in vehicles, and the emission of gaseous pollutants from positive ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles";

(2) Article 1 shall be replaced by the following: __

"Article 1

For the purposes of this Directive:

- "vehicle" means any vehicle as defined in Annex II Section A to Directive 70/156/EEC propelled by a compression ignition or gas engine, with the exception of vehicles of category M₁ with a technically permissible maximum laden mass less than or equal to 3,5 tonnes.
- "compression ignition or gas engine" means the motive propulsion source of a vehicle for which type approval, as a separate technical unit as defined in Article 2 of Directive 70/156/EEC, can be granted.
- "EEV" means Enhanced Environmentally Friendly Vehicle which is a vehicle propelled by an engine which complies with the permissive emission limit values given in row C of the Tables given in section 6.2.1 of Annex I.";

(3) Annexes I to VIII shall be replaced by Annexes I to VII appearing in the Annex to this Directive.

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Article 2

1. With effect from 1 October 1999, no Member State may, on grounds relating to the gaseous and particulate pollutants and opacity of smoke emissions from an engine:

- refuse to grant EC type-approval, or to issue the document provided for in the last indent of Article 10(1) of Directive 70/156/EEC, or to grant national type-approval for a type of vehicle propelled by a compression ignition or gas engine, or
- prohibit the registration, sale, entry into service or use of such new vehicles, or
- refuse to grant EC type-approval for a type of compression ignition or gas engine, or
- prohibit the sale or use of new compression ignition or gas engines,

if the appropriate requirements of the Annexes to Directive 88/77/EEC, as amended by this Directive, are satisfied in particular where the emissions of gaseous and particulate pollutants and opacity of smoke from the engine comply with the limit values set out in either row A or row B1 or B2 or the limit values set out in row C of the Tables in section 6.2.1 of Annex I to Directive 88/77/EEC, as amended by this Directive.

2. With effect from 1 October 2000, Member States:

- may no longer grant EC type-approval or issue the document provided for in the last indent of Article 10(1) of Directive 70/156/EEC, and
- shall refuse national type-approval,

for types of compression ignition or gas engines and types of vehicle propelled by compression ignition or gas engine where the emissions of gaseous and particulate pollutants and opacity of smoke from the engine do not comply with the limit values set out in row A of the Tables in section 6.2.1. of Annex I to Directive 88/77/EEC, as amended by this Directive.

3. With effect from 1 October 2001 and except for vehicles and engines intended for export to third countries and except for replacement engines for in-service vehicles, Member States shall:

- consider certificates of conformity which accompany new vehicles or new engines pursuant to Directive 70/156/EEC as no longer valid for the purpose of Article 7(1) of that Directive, and
- prohibit the registration, sale, entry into service or use of new vehicles propelled by a compression ignition or gas engine and the sale and use of new compression ignition or gas engines:

where the emissions of gaseous and particulate pollutants and opacity of smoke from the engine do not comply with the limit values set out in row A of the Tables in section 6.2.1. of Annex I to Directive 88/77/EEC, as amended by this Directive.

4. With effect from 1 October 2005, Member States:

- may no longer grant EC type-approval or issue the document provided for in the last indent of Article 10(1) of Directive 70/156/EEC, and
- shall refuse national type-approval,

for types of compression ignition or gas engines and types of vehicle propelled by a compression ignition or gas engine where the emissions of gaseous and particulate pollutants and opacity of smoke from the engine do not comply with the limit values set out in row B1 of the Tables in section 6.2.1. of Annex I to Directive 88/77/EEC, as amended by this Directive.

5. With effect from 1 October 2006 and except for vehicles and engines intended for export to third countries and except for replacement engines for in-service vehicles, Member States shall:

- consider certificates of conformity which accompany new vehicles or new engines pursuant to Directive 70/156/EEC as no longer valid for the purpose of Article 7(1) of that Directive, and
- prohibit the registration, sale, entry into service or use of new vehicles propelled by a compression ignition or gas engine and the sale and use of new compression ignition or gas engines:

where the emissions of gaseous and particulate pollutants and opacity of smoke from the engine do not comply with the limit values set out in row B1 of the Tables in section 6.2.1. of Annex I to Directive 88/77/EEC, as amended by this Directive.

6. With effect from 1 October 2008, Member States:

- may no longer grant EC type-approval or issue the document provided for in the last indent of Article 10(1) of Directive 70/156/EEC, and
- shall refuse national type-approval,

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for types of compression ignition or gas engines and types of vehicle propelled by a compression ignition or gas engine where the emissions of gaseous and particulate pollutants and opacity of smoke from the engine do not comply with the limit values set out in row B2 of the Tables in section 6.2.1. of Annex I to Directive 88/77/EEC, as amended by this Directive.

7. With effect from 1 October 2009 and except for vehicles and engines intended for export to third countries and except for replacement engines for in-service vehicles, Member States shall:

- consider certificates of conformity which accompany new vehicles or new engines pursuant to Directive 70/156/EEC as no longer valid for the purpose of Article 7(1) of that Directive, and
- prohibit the registration, sale, entry into service or use of new vehicles propelled by a compression ignition or gas engine and the sale and use of new compression ignition or gas engines:

where the emissions of gaseous and particulate pollutants and opacity of smoke from the engine do not comply with the limit values set out in row B2 of the Tables in section 6.2.1. of Annex I to Directive 88/77/EEC, as amended by this Directive.

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8. In accordance with paragraph 1, an engine that satisfies the appropriate requirements of the Annexes to Directive 88/77/EEC, as amended by this Directive, and meets the limit values set out in row C of the Tables in section 6.2.1 of Annex I to Directive 88/77/EEC, as amended by this Directive, shall be considered as complying with the requirements of paragraphs 2 to 7.

Article 3

1. Member States may make provision for tax incentives only in respect of motor vehicles which comply with Directive 88/77/EEC, as amended by this Directive. Such incentives shall comply with the provisions of the Treaty as well as the conditions as set out in (a) or (b) below:

- (a) they shall apply to all new vehicles offered for sale on the market of a Member State which comply in advance with the limit values set out in row A of the Tables in section 6.2.1 of Annex I to Directive 88/77/EEC, as amended by this Directive, and thereafter as from 1 October 2000 with the limit values set out in row B1 or B2 of the said Tables;

they shall be terminated with effect from the mandatory application of the emission limit values referred to in Article 2(3) for new vehicles, or by the dates of mandatory application of the emission limit values set out in row B1 or B2 of the Tables in section 6.2.1 of Annex I to Directive 88/77/EEC as amended by this Directive;

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(b) they shall apply to all new vehicles offered for sale on the market of a Member State which comply with the permissive limit values set out in row C of the Tables in section 6.2.1 of Annex I to Directive 88/77/EEC, as amended by this Directive.

2. For each type of vehicle, the incentives shall not exceed the additional cost of the technical solutions introduced to ensure compliance with the limit values set out in either row A or row B1 or B2 or the limit values set out in row C of the Tables in section 6.2.1 of Annex I to Directive 88/77/EEC, as amended by this Directive, and of their installation on the vehicle.

3. The Commission shall be informed in sufficient time of plans to institute or change the tax incentives referred to in this Article, so that it can submit its observations.

Article 4

From 1 October 2005, new types of vehicles, and from 1 October 2006, all types of vehicles, shall be equipped with an on-board diagnostic system (OBD) or an on-board measurement system (OBM) to monitor in-service exhaust emissions.

The Commission shall propose provisions to this effect to the European Parliament and the Council. They shall include:

- unrestricted and standardised access to the OBD system for inspection, diagnosis, servicing and repairs;
- the standardisation of fault codes;
- the compatibility of spare parts to facilitate repair, replacement, and servicing of OBD-equipped vehicles.

Article 5

From 1 October 2005, for new types, and from 1 October 2006, for all types, type-approvals granted to vehicles and engines shall also confirm the correct operation of the emission control devices during the normal life of the vehicle or engine.

The Commission shall examine differences in normal life of various categories of heavy duty vehicles and consider proposing appropriate durability requirements specific to each category.

Article 6

From 1 October 2005, for new types, and from 1 October 2006, for all types, type-approvals granted to vehicles shall also require confirmation of the correct operation of the emission control devices during the normal life of the vehicle under normal conditions of use (conformity of in-service vehicles properly maintained and used).

This provision must be confirmed and complemented by the Commission in accordance with Article 7.

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Article 7

The Commission shall submit a proposal to the European Parliament and the Council confirming or complementing this Directive no later than twelve months after the date of entry into force of this Directive or 31 December 2000, whichever is the earlier.

The proposal shall take account of:

- the review process set out in Article 3 of Directive 98/69/EC ¹ and Article 9 of Directive 98/70/EC ²;
- the development of compression ignition engine and gas engine emission control technology including the after treatment technology, taking into account the interdependence of such technology with fuel quality;
- the need to improve the accuracy and repeatability of the current measurement and sampling procedures for very low levels of particulates from engines;
- the development of a worldwide harmonised test cycle for type approval testing;

¹ OJ L 350, 28.12.1998, p. 1.

² OJ L 350, 28.12.1998, p. 58.

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and the proposal shall include:

- rules laying down the introduction of an OBD system for heavy-duty vehicles from 1 October 2005 pursuant to Article 4 of this Directive and, *mutatis mutandis*, to Directive 98/69/EC on the reduction of exhaust emissions from passenger cars and light commercial vehicles;
- provisions on the durability of emission control devices with effect from 1 October 2005 pursuant to Article 5 of this Directive;
- provisions to ensure the conformity of in-service vehicles in the type-approval procedure for vehicles with effect from 1 October 2005 pursuant to Article 6 of this Directive taking into account the specificity of the tests carried out on the engines of these vehicles and the specific information obtained from the OBD systems in a cost-effectiveness approach;
- appropriate limits for pollutants currently non-regulated as a consequence of the widespread introduction of new alternative fuels.

By 31 December 2001 the Commission shall report on progress in negotiations for a worldwide harmonised test cycle.

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By 30 June 2002 the Commission shall submit a report to the European Parliament and the Council on requirements for the operation of an OBM system. On the basis of the report the Commission will submit a proposal for measures to enter into force no later than 1 January 2005 to include the technical specifications and corresponding annexes in order to provide for the type-approval of OBM systems which ensure at least equivalent levels of monitoring to OBD systems and which shall be compatible therewith.

The Commission shall, not later than 31 December 2002, consider the available technology with a view to confirming the mandatory NO_x standard for 2008 in a report to the European Parliament and to the Council, accompanied, if necessary, by appropriate proposals.

Article 8

1. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive before [.....]. 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 a reference shall be laid down by Member States.

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

Article 9

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

Article 10

This Directive is addressed to the Member States.

Done at Brussels,

For the European Parliament
The President

For the Council
The President

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**SCOPE, DEFINITIONS AND ABBREVIATIONS, APPLICATION FOR EC-TYPE-APPROVAL,
SPECIFICATIONS AND TESTS AND CONFORMITY OF PRODUCTION**

1. SCOPE

This Directive applies to the gaseous and particulate pollutants from all motor vehicles equipped with compression-ignition engines and to the gaseous pollutants from all motor vehicles equipped with positive ignition engines fuelled with natural gas or LPG, and to compression-ignition and positive ignition engines as specified in Article 1 with the exception of those vehicles of category N₁, N₂ and M₂ for which type-approval has been granted under Council Directive 70/220/EEC¹, as last amended by Commission Directive 98/77/EC².

2. DEFINITIONS AND ABBREVIATIONS

For the purposes of this Directive:

- 2.1. "*test cycle*" means a sequence of test points each with a defined speed and torque to be followed by the engine under steady state (ESC test) or transient operating conditions (ETC, ELR test);
- 2.2. "*approval of an engine (engine family)*" means the approval of an engine type (engine family) with regard to the level of the emission of gaseous and particulate pollutants;
- 2.3. "*diesel engine*" means an engine which works on the compression-ignition principle;
"*gas engine*" means an engine which is fuelled with natural gas (NG) or liquid petroleum gas (LPG);
- 2.4. "*engine type*" means a category of engines which do not differ in such essential respects as engine characteristics as defined in Annex II to this Directive;
- 2.5. "*engine family*" means a manufacturers grouping of engines which, through their design as defined in Annex II, Appendix 2 to this Directive, have similar exhaust emission characteristics; all members of the family must comply with the applicable emission limit values;
- 2.6. "*parent engine*" means an engine selected from an engine family in such a way that its emissions characteristics will be representative for that engine family;
- 2.7. "*gaseous pollutants*" means carbon monoxide, hydrocarbons (assuming a ratio of CH_{1,85} for diesel, CH_{2,525} for LPG and CH_{2,93} for NG (NMHC)), methane (assuming a ratio of CH₄ for NG) and oxides of nitrogen, the last-named being expressed in nitrogen dioxide (NO₂) equivalent;
"*particulate pollutants*" means any material collected on a specified filter medium after diluting the exhaust with clean filtered air so that the temperature does not exceed 325 K (52°C);
- 2.8. "*smoke*" means particles suspended in the exhaust stream of a diesel engine which absorb, reflect, or refract light;
- 2.9. "*net power*" means the power in EC kW obtained on the test bench at the end of the crankshaft, or its equivalent, measured in accordance with the EC method of measuring power as set out in Commission Directive 80/1269/EEC³, as last amended by Directive 97/21/EC⁴;
- 2.10. "*declared maximum power (P_{max})*" means the maximum power in EC kW (net power) as declared by the manufacturer in his application for type-approval;

¹ OJ L 76, 6. 4.1970, p. 1.

² OJ L 286, 23.10.1998, p. 1.

³ OJ L 375, 31.12.1980, p. 46.

⁴ OJ L 125, 16. 5.1997, p. 31.

- 2.11. "per cent load" means the fraction of the maximum available torque at an engine speed;
- 2.12. "ESC test" means a test cycle consisting of 13 steady state modes to be applied in accordance with section 6.2 of this Annex;
- 2.13. "ELR test" means a test cycle consisting of a sequence of load steps at constant engine speeds to be applied in accordance with section 6.2 of this Annex;
- 2.14. "ETC test" means a test cycle consisting of 1800 second-by-second transient modes to be applied in accordance with section 6.2 of this Annex;
- 2.15. "engine operating speed range" means the engine speed range, most frequently used during engine field operation, which lies between the low and high speeds, as set out in Annex III to this Directive;
- 2.16. "low speed (n_{low})" means the lowest engine speed where 50% of the declared maximum power occurs;
- 2.17. "high speed (n_{hd})" means the highest engine speed where 70% of the declared maximum power occurs;
- 2.18. "engine speeds A, B and C" means the test speeds within the engine operating speed range to be used for the ESC test and the ELR test, as set out in Annex III, Appendix 1 to this Directive;
- 2.19. "control area" means the area between the engine speeds A and C and between 25 to 100 per cent load;
- 2.20. "reference speed (n_{ref})" means the 100 per cent speed value to be used for denormalizing the relative speed values of the ETC test, as set out in Annex III, Appendix 2 to this Directive;
- 2.21. "opacimeter" means an instrument designed to measure the opacity of smoke particles by means of the light extinction principle;
- 2.22. "NG gas range" means one of the H or L range as defined in European Standard EN 437, dated November 1993;
- 2.23. "self adaptability" means any engine device allowing the air/fuel ratio to be kept constant;
- 2.24. "recalibration" means a fine tuning of an NG engine in order to provide the same performance (power, fuel consumption) in a different range of natural gas;
- 2.25. "Wobbe Index (lower Wl ; or upper Wu)" means the ratio of the corresponding calorific value of a gas per unit volume and the square root of its relative density under the same reference conditions:

$$W = H_{gas} X \sqrt{\rho_{air} / \rho_{gas}}$$

- 2.26. " λ -shift factor (S_λ)" means an expression that describes the required flexibility of the engine management system regarding a change of the excess-air ratio λ if the engine is fuelled with a gas composition different from pure methane (see Annex VII for the calculation of S_λ).
- 2.27. "EEV" means Enhanced Environmentally Friendly Vehicle which is a type of vehicle propelled by an engine complying with the permissive emission limit values given in row C of the Tables in section 6.2.1 of this Annex;
- 2.28. "Defeat Device" means any element of engine or vehicle design which measures or senses vehicle speed, engine speed, gear used, temperature, intake pressure or any other parameter, with a view to activating, modulating delaying or deactivating the operation of any component of the emission control system so that the effectiveness of the emission control system is reduced under conditions encountered in normal vehicle use.

Such a device will not be regarded as a defeat device if:

- the need for the device is justified temporarily to protect the engine against intermittent operating conditions that could lead to damage or failure and no other measures are applicable for the same purpose which do not reduce the effectiveness of the emission control system;
- the device operates only when needed during engine starting and/or warming-up and no other measures are applicable for the same purpose which do not reduce the effectiveness of the emission control system.

2.29. Symbols and Abbreviations

2.29.1. Symbols for Test Parameters

| Symbol | Unit | Term |
|--------|-------|---|
| A_P | m^2 | Cross sectional area of the isokinetic sampling probe |
| A_T | m^2 | Cross sectional area of the exhaust pipe |
| CE_E | - | Ethane efficiency |
| CE_M | - | Methane efficiency |
| CI | - | Carbon 1 equivalent hydrocarbon |

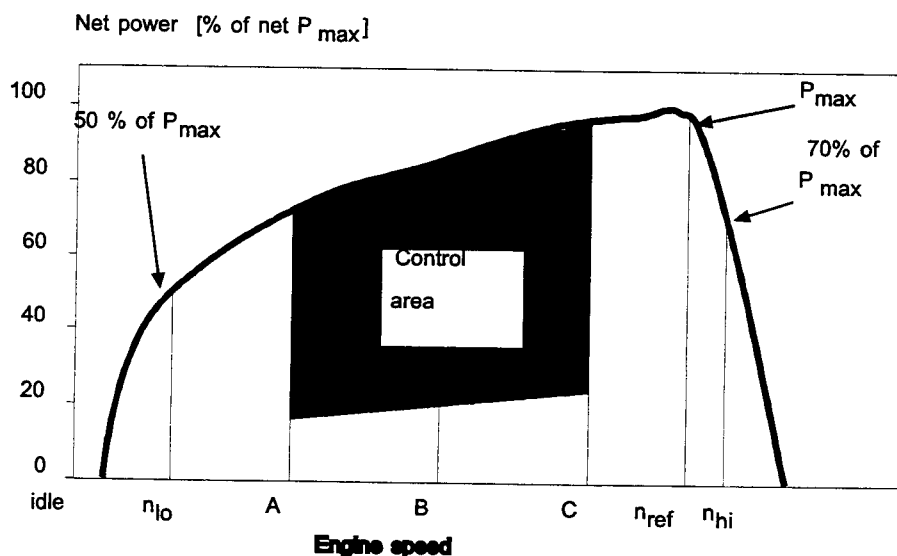


Figure 1 Specific definitions of the test cycles

| Symbol | Unit | Term |
|------------|------------|---|
| conc | ppm / vol% | Subscript denoting concentration |
| D_0 | m^3/s | Intercept of PDP calibration function |
| DF | - | Dilution factor |
| D | - | Bessel function constant |
| E | - | Bessel function constant |
| E_Z | g/kWh | Interpolated NO_x emission of the control point |
| f_a | - | Laboratory atmospheric factor |
| f_c | s^{-1} | Bessel filter cut-off frequency |
| F_{FH} | - | Fuel specific factor for the calculation of wet concentration for dry concentration |
| F_S | - | Stoichiometric factor |
| G_{AIRW} | kg/h | Intake air mass flow rate on wet basis |
| G_{AIRD} | kg/h | Intake air mass flow rate on dry basis |

| | | |
|--------------|-------------------|--|
| G_{DILW} | kg/h | Dilution air mass flow rate on wet basis |
| G_{EDFW} | kg/h | Equivalent diluted exhaust gas mass flow rate on wet basis |
| G_{EXHW} | kg/h | Exhaust gas mass flow rate on wet basis |
| G_{FUEL} | kg/h | Fuel mass flow rate |
| G_{TOTW} | kg/h | Diluted exhaust gas mass flow rate on wet basis |
| H | MJ/m ³ | Calorific value |
| H_{REF} | g/kg | Reference value of absolute humidity (10,71g/kg) |
| H_a | g/kg | Absolute humidity of the intake air |
| H_d | g/kg | Absolute humidity of the dilution air |
| HTCRAT | mol/mol | Hydrogen-to-Carbon ratio |
| i | - | Subscript denoting an individual mode |
| K | - | Bessel constant |
| k | m ⁻¹ | Light absorption coefficient |
| $K_{H,D}$ | - | Humidity correction factor for NO _x for diesel engines |
| $K_{H,G}$ | - | Humidity correction factor for NO _x for gas engines |
| K_V | - | CFV calibration function |
| $K_{W,a}$ | - | Dry to wet correction factor for the intake air |
| $K_{W,d}$ | - | Dry to wet correction factor for the dilution air |
| $K_{W,e}$ | - | Dry to wet correction factor for the diluted exhaust gas |
| $K_{W,r}$ | - | Dry to wet correction factor for the raw exhaust gas |
| L | % | Percent torque related to the maximum torque for the test engine |
| L_a | m | Effective optical path length |
| m | - | Slope of PDP calibration function |
| mass | g/h or g | Subscript denoting emissions mass flow (rate) |
| M_{DIL} | kg | Mass of the dilution air sample passed through the particulate sampling filters |
| M_d | mg | Particulate sample mass of the dilution air collected |
| M_f | mg | Particulate sample mass collected |
| $M_{f,p}$ | mg | Particulate sample mass collected on primary filter |
| $M_{f,b}$ | mg | Particulate sample mass collected on back-up filter |
| M_{SAM} | kg | Mass of the diluted exhaust sample passed through the particulate sampling filters |
| M_{SEC} | kg | Mass of secondary dilution air |
| M_{TOTW} | kg | Total CVS mass over the cycle on wet basis |
| $M_{TOTW,i}$ | kg | Instantaneous CVS mass on wet basis |
| N | % | Opacity |
| N_P | - | Total revolutions of PDP over the cycle |
| $N_{P,i}$ | - | Revolutions of PDP during a time interval |
| n | min ⁻¹ | Engine speed |
| n_P | s ⁻¹ | PDP speed |
| n_{hi} | min ⁻¹ | High engine speed |
| n_{lo} | min ⁻¹ | Low engine speed |
| n_{ref} | min ⁻¹ | Reference engine speed for ETC test |
| P_a | kPa | Saturation vapour pressure of the engine intake air |
| P_A | kPa | Absolute pressure |
| P_B | kPa | Total atmospheric pressure |
| P_d | kPa | Saturation vapour pressure of the dilution air |
| P_s | kPa | Dry atmospheric pressure |

| | | |
|--------------|---------------------|---|
| P_1 | kPa | Pressure depression at pump inlet |
| $P(a)$ | kW | Power absorbed by auxiliaries to be fitted for test |
| $P(b)$ | kW | Power absorbed by auxiliaries to be removed for test |
| $P(n)$ | kW | Net power non-corrected |
| $P(m)$ | kW | Power measured on test bed |
| Ω | - | Bessel constant |
| Q_s | m ³ /s | CVS volume flow rate |
| q | - | Dilution ratio |
| r | - | Ratio of cross sectional areas of isokinetic probe and exhaust pipe |
| R_a | % | Relative humidity of the intake air |
| R_d | % | Relative humidity of the dilution air |
| R_f | - | FID response factor |
| ρ | kg/m ³ | density |
| S | kW | Dynamometer setting |
| S_i | m ⁻¹ | Instantaneous smoke value |
| S_λ | - | λ -shift factor |
| T | K | Absolute temperature |
| T_a | K | Absolute temperature of the intake air |
| t | s | Measuring time |
| t_e | s | Electrical response time |
| t_f | s | Filter response time for Bessel function |
| t_p | s | Physical response time |
| Δt | s | Time interval between successive smoke data (= 1/sampling rate) |
| Δt_i | s | Time interval for instantaneous CFV flow |
| τ | % | Smoke transmittance |
| V_0 | m ³ /rev | PDP volume flow rate at actual conditions |
| W | - | Wobbe index |
| W_{act} | kWh | Actual cycle work of ETC |
| W_{ref} | kWh | Reference cycle work of ETC |
| WF | - | Weighting factor |
| WF_E | - | Effective weighting factor |
| X_0 | m ³ /rev | Calibration function of PDP volume flow rate |
| Y_i | m ⁻¹ | 1 s Bessel averaged smoke value |

2.29.2. *Symbols for the Chemical Components*

| | |
|-------------------------------|--------------------------|
| CH ₄ | Methane |
| C ₂ H ₆ | Ethane |
| C ₃ H ₈ | Propane |
| CO | Carbon monoxide |
| DOP | Di-octylphthalate |
| CO ₂ | Carbon dioxide |
| HC | Hydrocarbons |
| NMHC | Non-methane hydrocarbons |
| NO _x | Oxides of nitrogen |
| NO | Nitric oxide |
| NO ₂ | Nitrogen dioxide |
| PT | Particulates |

2.29.3. *Abbreviations*

| | |
|------|----------------------------------|
| CFV | Critical flow venturi |
| CLD | Chemiluminescent detector |
| ELR | European Load Response Test |
| ESC | European Steady State Cycle |
| ETC | European Transient Cycle |
| FID | Flame Ionisation Detector |
| GC | Gas Chromatograph |
| HCLD | Heated Chemiluminescent Detector |
| HFID | Heated Flame Ionisation Detector |
| LPG | Liquefied Petroleum Gas |
| NDIR | Non-Dispersive Infrared Analyser |
| NG | Natural Gas |
| NMC | Non-Methane Cutter |

3. **APPLICATION FOR EC TYPE-APPROVAL**

3.1. **Application for EC Type-Approval for a Type of Engine or Engine Family as a Separate Technical Unit**

3.1.1. The application for approval of an engine type or engine family with regard to the level of the emission of gaseous and particulate pollutants for diesel engines and with regard to the level of the emission of gaseous pollutants for gas engines shall be submitted by the engine manufacturer or by a duly accredited representative.

3.1.2. It shall be accompanied by the undermentioned documents in triplicate and the following particulars:

3.1.2.1. a description of the engine type or engine family, if applicable, comprising the particulars referred to in Annex II to this Directive which conform to the requirements of Articles 3 and 4 of Directive 70/156/EEC.

3.1.3. An engine conforming to the "engine type" or "parent engine" characteristics described in Annex II shall be submitted to the technical service responsible for conducting the approval tests defined in section 6.

3.2. **Application for EC Type-Approval for a Vehicle Type in Respect of its Engine**

3.2.1. The application for approval of a vehicle with regard to emission of gaseous and particulate pollutants by its diesel engine or engine family and with regard to the level of the emission of gaseous pollutants by its gas engine or engine family shall be submitted by the vehicle manufacturer or a duly accredited representative.

- 3.2.2. It shall be accompanied by the undermentioned documents in triplicate and the following particulars:
- 3.2.2.1. a description of the vehicle type, of the engine-related vehicle parts and of the engine type or engine family, if applicable, comprising the particulars referred to in Annex II, along with the documentation required in application of Article 3 of Directive 70/156/EEC,

3.3. Application for EC Type-Approval for a Vehicle Type with an Approved Engine

- 3.3.1. The application for approval of a vehicle with regard to emission of gaseous and particulate pollutants by its approved diesel engine or engine family and with regard to the level of the emission of gaseous pollutants by its approved gas engine or engine family shall be submitted by the vehicle manufacturer or a duly accredited representative.
- 3.3.2. It shall be accompanied by the undermentioned documents in triplicate and the following particulars:
- 3.3.2.1. a description of the vehicle type and of engine-related vehicle parts comprising the particulars referred to in Annex II, as applicable, and a copy of the EC Type-Approval Certificate (Annex VI) for the engine or engine family, if applicable, as a separate technical unit which is installed in the vehicle type, along with the documentation required in application of Article 3 of Directive 70/156/EEC.

4. EC TYPE-APPROVAL

4.1. Granting of a universal fuel EC type-approval

A universal fuel EC type-approval is granted subject to the following requirements:

- 4.1.1. In the case of diesel fuel the parent engine meets the requirements of this Directive on the reference fuel specified in Annex IV.
- 4.1.2. In the case of natural gas the parent engine should demonstrate its capability to adapt to any fuel composition that may occur across the market. In the case of natural gas there are generally two types of fuel, high calorific fuel (H-gas) and low calorific fuel (L-gas), but with a significant spread within both ranges; they differ significantly in their energy content expressed by the Wobbe Index and in their λ -shift factor (S_λ). The formulae for the calculation of the Wobbe index and S_λ are given in sections 2.25 and 2.26. The composition of the reference fuels reflects the variations of those parameters.
- The parent engine shall meet the requirements of this Directive on the reference fuels G20 and G25, as specified in Annex IV, without any readjustment to the fuelling between the two tests. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing, the parent engine shall be run-in using the procedure given in paragraph 3 of Appendix 2 to Annex III.
- 4.1.3. In the case of an engine fuelled with natural gas which is self-adaptive for the range of H-gases on the one hand and the range of L-gases on the other hand, and which switches between the H-range and the L-range by means of a switch, the parent engine shall be tested on the two relevant reference fuels as specified in Annex IV for each range, at each position of the switch. The fuels are G20 (fuel 1) and G23 (fuel 2) for the H-range of gases, G23 (fuel 1) and G25 (fuel 2) for the L-range of gases. The parent engine shall meet the requirements of this Directive at both positions of the switch without any readjustment to the fuelling between the two tests at each position of the switch. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing the parent engine shall be run-in using the procedure given in paragraph 3 of Appendix 2 to Annex III.
- 4.1.3.1. On the manufacturer's request the engine may be tested on a third fuel (fuel 3) if the λ -shift factor (S_λ) lies between those of the fuels G20 and G25, e.g. when fuel 3 is a market fuel. The results of this test may be used as a basis for the evaluation of the conformity of the production.

4.1.3.2. The ratio of emission results "r" shall be determined for each pollutant as follows:

$$r = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 1}}$$

or,

$$ra = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 3}}$$

and,

$$rb = \frac{\text{emission result on reference fuel 1}}{\text{emission result on reference fuel 3}}$$

4.1.4. In the case of LPG the parent engine should demonstrate its capability to adapt to any fuel composition that may occur across the market. In the case of LPG there are variations in C₃/C₄ composition. These variations are reflected in the reference fuels. The parent engine should meet the emission requirements on the reference fuels A and B as specified in Annex IV without any readjustment to the fuelling between the two tests. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing the parent engine shall be run-in using the procedure defined in paragraph 3 of Appendix 2 to Annex III.

4.1.4.1. The ratio of emission results "r" shall be determined for each pollutant as follows:

$$r = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 1}}$$

4.2. Granting of a fuel range restricted EC type-approval

At the present state of technology it is not yet possible to make leanburn natural gas engines self-adaptive. Yet these engines offer an advantage in efficiency and CO₂ emission. If a user has the guarantee of a supply of fuel of uniform composition, he may opt for a leanburn engine. Such an engine could be given a fuel restricted approval. In the interest of international harmonisation it is regarded desirable that a specimen of such an engine is granted international approval. Fuel restricted variants would then need to be identical except for the contents of the database of the ECU of the fuelling system, and such parts of the fuelling system (such as injector nozzles) that need to be adapted to the different fuel flow.

Fuel range restricted EC type-approval is granted subject to the following requirements:

4.2.1. *Exhaust emissions approval of an engine running on natural gas and laid out for operation on either the range of H-gases or on the range of L-gases*

The parent engine shall be tested on the two relevant reference fuels as specified in Annex IV for the relevant range. The fuels are G20 (fuel 1) and G23 (fuel 2) for the H-range of gases, G23 (fuel 1) and G25 (fuel 2) for the L-range of gases. The parent engine shall meet the emission requirements without any readjustment to the fuelling between the two tests. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing the parent engine shall be run-in using the procedure defined in paragraph 3 of Appendix 2 to Annex III.

4.2.1.1. On the manufacturer's request it may be tested on a third fuel (fuel 3) if the λ-shift factor (S_λ) lies between those of the fuels G20 and G23, or G23 and G25 respectively, e.g. when fuel 3 is a market fuel. The results of this test may be used as a basis for the evaluation of the conformity of the production.

4.2.1.2. The ratio of emission results "r" shall be determined for each pollutant as follows:

$$r = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 1}}$$

or,

$$ra = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 3}}$$

and,

$$rb = \frac{\text{emission result on reference fuel 1}}{\text{emission result on reference fuel 3}}$$

4.2.1.3. Upon delivery to the customer the engine shall bear a label (see paragraph 5.1.5) stating for which range of gases the engine is approved.

4.2.2. *Exhaust emissions approval of an engine running on natural gas or LPG and laid out for operation on one specific fuel composition*

4.2.2.1. The parent engine shall meet the emission requirements on the reference fuels G20 and G25 in the case of natural gas, or the reference fuels A and B in the case of LPG, as specified in Annex IV. Between the tests fine-tuning of the fuelling system is allowed. This fine-tuning will consist of a recalibration of the fuelling database, without any alteration to either the basic control strategy or the basic structure of the database. If necessary the exchange of parts that are directly related to the amount of fuel flow (such as injector nozzles) is allowed.

4.2.2.2. If the manufacturer so desires the engine may be tested on the reference fuels G20 and G23, or G23 and G25, in which case the type approval is only valid for the H-range or the L-range of gases respectively.

4.2.2.3. Upon delivery to the customer the engine shall bear a label (see paragraph 5.1.5) stating for which fuel composition the engine has been calibrated.

4.3. **Exhaust emissions approval of a member of a family**

4.3.1. With the exception of the case mentioned in paragraph 4.3.2, the approval of a parent engine shall be extended to all family members without further testing, for any fuel composition within the range for which the parent engine has been approved (in the case of engines described in paragraph 4.2.2) or the same range of fuels (in the case of engines described in either paragraphs 4.1 or 4.2) for which the parent engine has been approved.

4.3.2. Secondary test engine

In case of an application for type approval of an engine, or a vehicle in respect of its engine, that engine belonging to an engine family, if the approval authority determines that, with regard to the selected parent engine the submitted application does not fully represent the engine family defined in Annex I, Appendix 1, an alternative and if necessary an additional reference test engine may be selected by the approval authority and tested.

4.4. **Type-approval certificate**

A certificate conforming to the model specified in Annex VI shall be issued for approval referred to under sections 3.1, 3.2 and 3.3.

5. ENGINE MARKINGS

5.1. The engine approved as a technical unit must bear:

5.1.1. the trademark or trade name of the manufacturer of the engine;

5.1.2. the manufacturer's commercial description;

5.1.3. the EC type-approval number preceded by the distinctive letter(s) or number(s) of the country granting EC type-approval⁵;

5.1.4. in case of an NG engine one of the following markings to be placed after the EC type approval number:

- H in case of the engine being approved and calibrated for the H-range of gases;
- L in case of the engine being approved and calibrated for the L-range of gases;
- HL in case of the engine being approved and calibrated for both the H-range and L-range of gases;
- H_i in case of the engine being approved and calibrated for a specific gas composition in the H-range of gases and transformable to another specific gas in the H-range of gases by fine tuning of the engine fuelling;
- L_i in case of the engine being approved and calibrated for a specific gas composition in the L-range of gases and transformable to another specific gas in the L-range of gases after fine tuning of the engine fuelling;
- HL_i in the case of the engine being approved and calibrated for a specific gas composition in either the H-range or the L-range of gases and transformable to another specific gas in either the H-range or the L-range of gases by fine tuning of the engine fuelling.

5.1.5. Labels

In the case of NG and LPG fuelled engines with a fuel range restricted type approval, the following labels are applicable:

5.1.5.1. Content

The following information must be given:

In the case of paragraph 4.2.1.3, the label shall state "ONLY FOR USE WITH NATURAL GAS RANGE H". If applicable, "H" is replaced by "L".

In the case of paragraph 4.2.2.3, the label shall state "ONLY FOR USE WITH NATURAL GAS SPECIFICATION" or "ONLY FOR USE WITH LIQUEFIED PETROLEUM GAS SPECIFICATION", as applicable. All the information in the appropriate table(s) in Annex IV shall be given with the individual constituents and limits specified by the engine manufacturer.

The letters and figures must be at least 4 mm in height.

Note:

If lack of space prevents such labelling, a simplified code may be used. In this event, explanatory notes containing all the above information must be easily accessible to any person filling the fuel tank or performing maintenance or repair on the engine and its accessories, as well as to the authorities concerned. The site and content of these explanatory notes will be determined by agreement between the manufacturer and the approval authority.

⁵ 1 = Germany, 2 = France, 3 = Italy, 4 = Netherlands, 5 = Sweden, 6 = Belgium, 9 = Spain, 11 = United Kingdom, 12 = Austria, 13 = Luxembourg, 16 = Norway, 17 = Finland, 18 = Denmark, 21 = Portugal, 23 = Greece, FL = Liechtenstein, IS = Iceland, IRL = Ireland

5.1.5.2. Properties

Labels must be durable for the useful life of the engine. Labels must be clearly legible and their letters and figures must be indelible. Additionally, labels must be attached in such a manner that their fixing is durable for the useful life of the engine, and the labels cannot be removed without destroying or defacing them.

5.1.5.3. Placing

Labels must be secured to an engine part necessary for normal engine operation and not normally requiring replacement during engine life. Additionally, these labels must be located so as to be readily visible to the average person after the engine has been completed with all the auxiliaries necessary for engine operation.

5.2. In case of an application for EC type-approval for a vehicle type in respect of its engine, the marking specified in section 5.1.5 shall also be placed close to fuel filling aperture.

5.3. In case of an application for EC type-approval for a vehicle type with an approved engine, the marking specified in section 5.1.5 shall also be placed close to the fuel filling aperture.

6. SPECIFICATIONS AND TESTS

6.1. General

The components liable to affect the emission of gaseous and particulate pollutants from diesel engines and the emission of gaseous pollutants from gas engines shall be so designed, constructed and assembled as to enable the engine, in normal use, to comply with the provisions of this Directive.

6.1.1. The use of a defeat device and/or irrational emissions control strategy is forbidden. If the type-approval authority suspects that a vehicle type utilises defeat device(s) and/or any irrational emission control strategy under certain operating conditions, upon request the manufacturer has to provide information on the operation and effect on emissions of the use of such devices and/or control strategy. Such information shall include a description of all emission control components, fuel control system logic including timing strategies and switch points during all modes of operation. This information should remain strictly confidential and not be attached to the documentation required in Annex I, section 3.

6.2. Specifications Concerning the Emission of Gaseous and Particulate Pollutants and Smoke

For type approval to row A of the tables in section 6.2.1, the emissions shall be determined on the ESC and ELR tests with conventional diesel engines including those fitted with electronic fuel injection equipment, exhaust gas recirculation (EGR), and/or oxidation catalysts. Diesel engines fitted with advanced exhaust aftertreatment systems including deNOx catalysts and/or particulate traps, shall additionally be tested on the ETC test.

For type approval testing to either row B1 or B2 or row C of the tables in section 6.2.1 the emissions shall be determined on the ESC, ELR and ETC tests.

For gas engines, the gaseous emissions shall be determined on the ETC test.

The ESC and ELR test procedures are described in Annex III, Appendix 1, the ETC test procedure in Annex III, Appendices 2 and 3.

The emissions of gaseous pollutants and particulate pollutants, if applicable, and smoke, if applicable, by the engine submitted for testing shall be measured by the methods described in Annex III, Appendix 4. Annex V describes the recommended analytical systems for the gaseous pollutants, the recommended particulate sampling systems, and the recommended smoke measurement system.

Other systems or analysers may be approved by the Technical Service if it is found that they yield equivalent results on the respective test cycle. The determination of system equivalency shall be based upon a 7 sample pair (or larger) correlation study between the system under consideration and one of the reference systems of this Directive. For particulate emissions only the full flow dilution system is recognised as the reference system. "Results" refer to the specific cycle emissions value. The correlation testing shall be performed at the same laboratory, test cell, and on the same engine, and is preferred to be run concurrently. The equivalency criterion is defined as a $\pm 5\%$ agreement of the sample pair averages. For introduction of a new system into the Directive the determination of equivalency shall be based upon the calculation of repeatability and reproducibility, as described in ISO 5725.

6.2.1. *Limit Values*

The specific mass of the carbon monoxide, of the total hydrocarbons, of the oxides of nitrogen and of the particulates, as determined on the ESC test, and of the smoke opacity, as determined on the ELR test, shall not exceed the amounts shown in Table 1.

Table 1 Limit values – ESC and ELR tests

| Row | Mass of carbon monoxide (CO) g/kWh | Mass of hydrocarbons (HC) g/kWh | Mass of nitrogen oxides (NOx) g/kWh | Mass of particulates (PT) g/kWh | Smoke m ⁻¹ |
|------------|------------------------------------|---------------------------------|-------------------------------------|---------------------------------|-----------------------|
| A (2000) | 2,1 | 0,66 | 5,0 | 0,10 0,13 ^(a) | 0,8 |
| B 1 (2005) | 1,5 | 0,46 | 3,5 | 0,02 | 0,5 |
| B 2 (2008) | 1,5 | 0,46 | 2,0 | 0,02 | 0,5 |
| C (EEV) | 1,5 | 0,25 | 2,0 | 0,02 | 0,15 |

^(a) For engines having a swept volume of less than 0,75 dm³ per cylinder and a rated power speed of more than 3000 min⁻¹.

For diesel engines that are additionally tested on the ETC test, and specifically for gas engines, the specific masses of the carbon monoxide, of the non-methane hydrocarbons, of the methane (where applicable), of the oxides of nitrogen and of the particulates (where applicable) shall not exceed the amounts shown in Table 2.

Table 2 Limit values – ETC tests ^(b)

| Row | Mass of carbon monoxide (CO) g/kWh | Mass of non-methane hydrocarbons (NMHC) g/kWh | Mass of methane (CH ₄) ^(c) g/kWh | Mass of nitrogen oxides ((NO _x) g/kWh | Mass of particulates (PT) ^(d) g/kWh |
|-----------|------------------------------------|---|---|---|--|
| A (2000) | 5,45 | 0,78 | 1,6 | 5,0 | 0,16 0,21 ^(a) |
| B1 (2005) | 4,0 | 0,55 | 1,1 | 3,5 | 0,03 |
| B2 (2008) | 4,0 | 0,55 | 1,1 | 2,0 | 0,03 |
| C (EEV) | 3,0 | 0,40 | 0,65 | 2,0 | 0,02 |

- (a) For engines having a swept volume of less than 0,75 dm³ per cylinder and a rated power speed of more than 3000 min⁻¹.
- (b) The conditions for verifying the acceptability of the ETC tests (see Annex III, Appendix 2, section 3.9) when measuring the emissions of gas fuelled engines against the limit values applicable in row A shall be re-examined and, where necessary, modified in accordance with the procedure laid down in Article 13 of Directive 70/156/EEC.
- (c) For NG engines only.
- (d) Not applicable for gas fuelled engines at stage A and stages B1 and B2 .

6.2.2. *Hydrocarbon measurement for diesel and gas fuelled engines*

6.2.2.1. A manufacturer may choose to measure the mass of total hydrocarbons (THC) on the ETC test instead of measuring the mass of non-methane hydrocarbons. In this case, the limit for the mass of total hydrocarbons is the same as shown in table 2 for the mass of non-methane hydrocarbons.

6.2.3. *Specific requirements for diesel engines*

6.2.3.1. The specific mass of the oxides of nitrogen measured at the random check points within the control area of the ESC test must not exceed by more than 10 per cent the values interpolated from the adjacent test modes (reference Annex III, Appendix 1 sections 4.6.2 and 4.6.3).

6.2.3.2. The smoke value on the random test speed of the ELR must not exceed the highest smoke value of the two adjacent test speeds by more than 20 per cent, or by more than 5 per cent of the limit value, whichever is greater.

7. INSTALLATION ON THE VEHICLE

7.1. The engine installation on the vehicle shall comply with the following characteristics in respect to the type-approval of the engine:

7.1.1. intake depression shall not exceed that specified for the type-approved engine in Annex VI;

7.1.2. exhaust back pressure shall not exceed that specified for the type-approved engine in Annex VI;

7.1.3. exhaust system volume shall not differ by more than 40 % of that specified for the type-approved engine in Annex VI;

7.1.4. power absorbed by the auxiliaries needed for operating the engine shall not exceed that specified for the type-approved engine in Annex VI.

8. ENGINE FAMILY

8.1. Parameters Defining the Engine Family

The engine family, as determined by the engine manufacturer, may be defined by basic characteristics which must be common to engines within the family. In some cases there may be interaction of parameters. These effects must also be taken into consideration to ensure that only engines with similar exhaust emission characteristics are included within an engine family.

In order that engines may be considered to belong to the same engine family, the following list of basic parameters must be common:

8.1.1. Combustion cycle:

- 2 cycle
- 4 cycle

8.1.2. Cooling medium:

- air
- water
- oil

8.1.3. For gas engines and engines with aftertreatment --

- Number of cylinders

(other diesel engines with fewer cylinders than the parent engine may be considered to belong to the same engine family provided the fuelling system meters fuel for each individual cylinder).

8.1.4. Individual cylinder displacement:

- engines to be within a total spread of 15%

8.1.5. Method of air aspiration:

- naturally aspirated
- pressure charged
- pressure charged with charge air cooler

8.1.6. Combustion chamber type/design:

- pre-chamber
- swirl chamber
- open chamber

8.1.7. Valve and porting - configuration, size and number:

- cylinder head
- cylinder wall
- crankcase

8.1.8. Fuel injection system (diesel engines):

- pump-line-injector
- in-line pump
- distributor pump
- single element
- unit injector

8.1.9. Fuelling system (gas engines):

- mixing unit
- gas induction/injection (single point, multi point)
- liquid injection (single point, multi point)

8.1.10. Ignition system (gas engines)

8.1.11. Miscellaneous features:

- exhaust gas recirculation
- water injection/emulsion
- secondary air injection
- charge cooling system

8.1.12. Exhaust aftertreatment:

- 3-way-catalyst
- oxidation catalyst
- reduction catalyst
- thermal reactor
- particulate trap

8.2. Choice of the Parent Engine

--

8.2.1. Diesel Engines

The parent engine of the family shall be selected using the primary criteria of the highest fuel delivery per stroke at the declared maximum torque speed. In the event that two or more engines share this primary criteria, the parent engine shall be selected using the secondary criteria of highest fuel delivery per stroke at rated speed. Under certain circumstances, the approval authority may conclude that the worst case emission rate of the family can best be characterised by testing a second engine. Thus, the approval authority may select an additional engine for test based upon features which indicate that it may have the highest emission level of the engines within that family.

If engines within the family incorporate other variable features which could be considered to affect exhaust emissions, these features shall also be identified and taken into account in the selection of the parent engine.

8.2.2. Gas Engines

The parent engine of the family shall be selected using the primary criteria of the largest displacement. In the event that two or more engines share this primary criteria, the parent engine shall be selected using the secondary criteria in the following order:

- the highest fuel delivery per stroke at the speed of declared rated power;
- the most advanced spark timing;
- the lowest EGR rate;
- no air pump or lowest actual air flow pump.

Under certain circumstances, the approval authority may conclude that the worst case emission rate of the family can best be characterised by testing a second engine. Thus, the approval authority may select an additional engine for test based upon features which indicate that it may have the highest emission level of the engines within that family.

9. PRODUCTION CONFORMITY

- 9.1. Measures to ensure production conformity must be taken in accordance with the provisions of Article 10 of Directive 70/156/EEC. Production conformity is checked on the basis of the description in the type-approval certificates set out in Annex VI to this Directive.

Sections 2.4.2 and 2.4.3 of Annex X to Directive 70/156/EEC are applicable where the competent authorities are not satisfied with the auditing procedure of the manufacturer.

- 9.1.1. If emissions of pollutants are to be measured and an engine type-approval has had one or several extensions, the tests will be carried out on the engine(s) described in the information package relating to the relevant extension.

- 9.1.1.1. Conformity of the engine subjected to a pollutant test:

After submission of the engine to the authorities, the manufacturer shall not carry out any adjustment to the engines selected.

- 9.1.1.1.1. Three engines are randomly taken in the series. Engines that are subject to testing only on the ESC and ELR tests or only on the ETC test for type approval to row A of the tables in section 6.2.1 are subject to those applicable tests for the checking of production conformity. With the agreement of the authority, all other engines type approved to row A, B1 or B2, or C of the tables in section 6.2.1 are subjected to testing either on the ESC and ELR cycles or on the ETC cycle for the checking of the production conformity. The limit values are given in Section 6.2.1 of this Annex.

9.1.1.1.2. The tests are carried out according to Appendix 1 to this Annex, where the competent authority is satisfied with the production standard deviation given by the manufacturer, in accordance with Annex X to Directive 70/156/EEC, which applies to motor vehicles and their trailers.

The tests are carried out according to Appendix 2 to this Annex, where the competent authority is not satisfied with the production standard deviation given by the manufacturer, in accordance with Annex X to Directive 70/156/EEC, which applies to motor vehicles and their trailers.

At the manufacturer's request, the tests may be carried out in accordance with Appendix 3 to this Annex.

9.1.1.1.3. On the basis of a test of the engine by sampling, the production of a series is regarded as conforming where a pass decision is reached for all the pollutants and non conforming where a fail decision is reached for one pollutant, in accordance with the test criteria applied in the appropriate Appendix.

When a pass decision has been reached for one pollutant, this decision may not be changed by any additional tests made in order to reach a decision for the other pollutants.

If no pass decision is reached for all the pollutants and if no fail decision is reached for one pollutant, a test is carried out on another engine (see figure 2).

If no decision is reached, the manufacturer may at any time decide to stop testing. In that case a fail decision is recorded.

9.1.1.2. The tests will be carried out on newly manufactured engines. Gas fuelled engines shall be run-in using the procedure defined in paragraph 3 of Appendix 2 to Annex III.

9.1.1.2.1. However, at the request of the manufacturer, the tests may be carried out on diesel or gas engines which have been run-in more than the period referred to in section 9.1.1.2, up to a maximum of 100 hours. In this case, the running-in procedure will be conducted by the manufacturer who shall undertake not to make any adjustments to those engines.

9.1.1.2.2. When the manufacturer asks to conduct a running-in procedure in accordance with section 9.1.1.2.1, it may be carried out on:

– all the engines that are tested,

or,

– the first engine tested, with the determination of an evolution coefficient as follows:

– the pollutant emissions will be measured at zero and at "x" hours on the first engine tested,
– the evolution coefficient of the emissions between zero and "x" hours will be calculated for each pollutant:

$$\frac{\text{Emissions "x" hours}}{\text{Emissions zero hours}}$$

It may be less than one.

The subsequent test engines will not be subjected to the running-in procedure, but their zero hour emissions will be modified by the evolution coefficient.

In this case, the values to be taken will be:

– the values at "x" hours for the first engine,
– the values at zero hour multiplied by the evolution coefficient for the other engines.

9.1.1.2.3. For diesel and LPG fuelled engines, all these tests may be conducted with commercial fuel. However, at the manufacturer's request, the reference fuels described in Annex IV may be used. This implies tests, as described in section 4 of this Annex, with at least two of the reference fuels for each gas engine.

9.1.1.2.4. For NG fuelled engines, all these tests may be conducted with commercial fuel in the following way:

- for H marked engines with a commercial fuel within the H range;
- for L marked engines with a commercial fuel within the L range;
- for HL marked engines with a commercial fuel within the H or the L range.

However, at the manufacturer's request, the reference fuels described in Annex IV may be used. This implies tests, as described in section 4 of this Annex, with at least two of the reference fuels for each gas engine.

9.1.1.2.5. In the case of dispute caused by the non-compliance of gas fuelled engines when using a commercial fuel, the tests shall be performed with a reference fuel on which the parent engine has been tested, or with the possible additional fuel 3 as referred to in paragraphs 4.1.3.1 and 4.2.1.1 on which the parent engine may have been tested. Then, the result has to be converted by a calculation applying the relevant factor(s) " r ", " r_a " or " r_b " as described in paragraphs 4.1.3.2, 4.1.4.1 and 4.2.1.2. If r , r_a or r_b are less than one no correction shall take place. The measured results and the calculated results must demonstrate that the engine meets the limit values with all relevant fuels (fuels 1, 2 and, if applicable, fuel 3).

9.1.1.2.6. Tests for conformity of production of a gas fuelled engine laid out for operation on one specific fuel composition shall be performed on the fuel for which the engine has been calibrated.

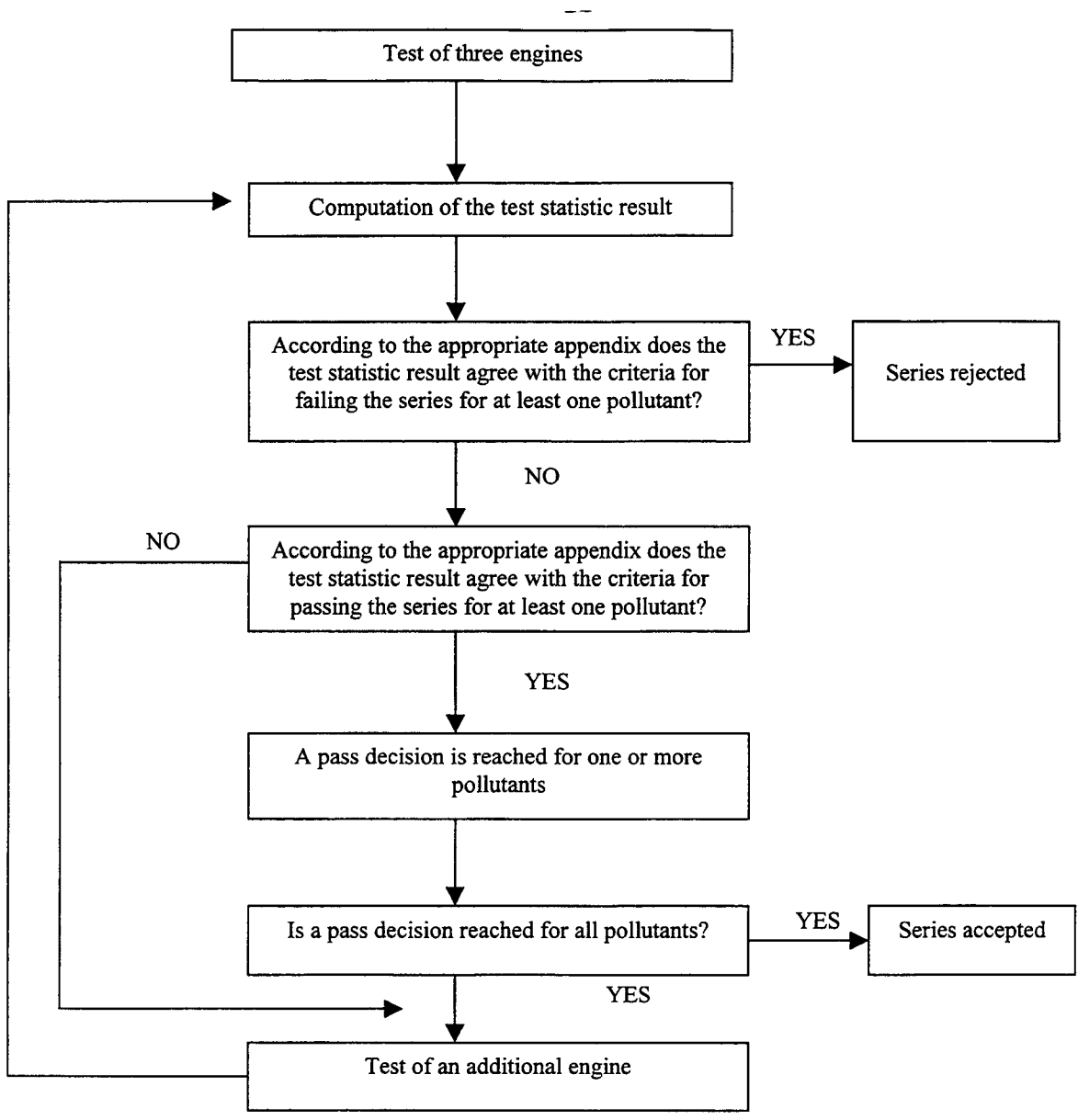


Figure 2 Schematic of production conformity testing

ANNEX I - APPENDIX 1

PROCEDURE FOR PRODUCTION CONFORMITY TESTING WHEN STANDARD DEVIATION IS SATISFACTORY

1. This Appendix describes the procedure to be used to verify production conformity for the emissions of pollutants when the manufacturer's production standard deviation is satisfactory.
2. With a minimum sample size of three engines the sampling procedure is set so that the probability of a lot passing a test with 40% of the engines defective is 0,95 (producer's risk = 5%) while the probability of a lot being accepted with 65% of the engines defective is 0,10 (consumer's risk = 10%).
3. The following procedure is used for each of the pollutants given in Section 6.2.1. of Annex I (see Figure 2):

Let:

- L = the natural logarithm of the limit value for the pollutant;
x_i = the natural logarithm of the measurement for the i-th engine of the sample;
s = an estimate of the production standard deviation (after taking the natural logarithm of the measurements);
n = the current sample number.

4. For each sample the sum of the standardised deviations to the limit is calculated using the following formula:

$$\frac{1}{s} \sum_{i=1}^n (L - x_i)$$

5. Then:
 - if the test statistic result is greater than the pass decision number for the sample size given in table 3, a pass decision is reached for the pollutant;
 - if the test statistic result is less than the fail decision number for the sample size given in table 3, a fail decision is reached for the pollutant;
 - otherwise, an additional engine is tested according to Section 9.1.1.1 of Annex I and the calculation procedure is applied to the sample increased by one more unit.

Table 3 Pass and Fail Decision Numbers of Appendix 1 Sampling Plan
 Minimum sample size:3

| Cumulative number of engines tested (sample size) | Pass decision number A_n | Fail decision number B_n |
|---|----------------------------|----------------------------|
| 3 | 3,327 | -4,724 |
| 4 | 3,261 | -4,790 |
| 5 | 3,195 | -4,856 |
| 6 | 3,129 | -4,922 |
| 7 | 3,063 | -4,988 |
| 8 | 2,997 | -5,054 |
| 9 | 2,931 | -5,120 |
| 10 | 2,865 | -5,185 |
| 11 | 2,799 | -5,251 |
| 12 | 2,733 | -5,317 |
| 13 | 2,667 | -5,383 |
| 14 | 2,601 | -5,449 |
| 15 | 2,535 | -5,515 |
| 16 | 2,469 | -5,581 |
| 17 | 2,403 | -5,647 |
| 18 | 2,337 | -5,713 |
| 19 | 2,271 | -5,779 |
| 20 | 2,205 | -5,845 |
| 21 | 2,139 | -5,911 |
| 22 | 2,073 | -5,977 |
| 23 | 2,007 | -6,043 |
| 24 | 1,941 | -6,109 |
| 25 | 1,875 | -6,175 |
| 26 | 1,809 | -6,241 |
| 27 | 1,743 | -6,307 |
| 28 | 1,677 | -6,373 |
| 29 | 1,611 | -6,439 |
| 30 | 1,545 | -6,505 |
| 31 | 1,479 | -6,571 |
| 32 | -2,112 | -2,112 |

ANNEX I – APPENDIX 2

PROCEDURE FOR PRODUCTION CONFORMITY TESTING WHEN STANDARD DEVIATION IS UNSATISFACTORY OR UNAVAILABLE

1. This Appendix describes the procedure to be used to verify production conformity for the emissions of pollutants when the manufacturer's production standard deviation is either unsatisfactory or unavailable.
2. With a minimum sample size of three engines the sampling procedure is set so that the probability of a lot passing a test with 40% of the engines defective is 0,95 (producer's risk = 5%) while the probability of a lot being accepted with 65% of the engines defective is 0,10 (consumer's risk = 10%).
3. The values of the pollutants given in Section 6.2.1 of Annex I are considered to be log normally distributed and should be transformed by taking their natural logarithms. Let m_0 and m denote the minimum and maximum sample size respectively ($m_0 = 3$ and $m = 32$) and let n denote the current sample number.
4. If the natural logarithms of the values measured in the series are x_1, x_2, \dots, x_i and L is the natural logarithm of the limit value for the pollutant, then, define

$$d_i = x_i - L$$

and,

$$\bar{d}_n = \frac{1}{n} \sum_{i=1}^n d_i$$

$$V_n^2 = \frac{1}{n} \sum_{i=1}^n (d_i - \bar{d}_n)^2$$

5. Table 4 shows values of the pass (A_n) and fail (B_n) decision numbers against current sample number. The test statistic result is the ratio \bar{d}_n / V_n , and shall be used to determine whether the series has passed or failed as follows:

For $m_0 \leq n \leq m$:

- pass the series if $\bar{d}_n / V_n \leq A_n$
- fail the series if $\bar{d}_n / V_n \geq B_n$
- take another measurement if $A_n \leq \bar{d}_n / V_n \leq B_n$

6. Remarks

The following recursive formulae are useful for calculating successive values of the test statistic:

$$\bar{d}_n = \left(1 - \frac{1}{n}\right) \bar{d}_{n-1} + \frac{1}{n} d_n$$

$$V_n^2 = \left(1 - \frac{1}{n}\right) V_{n-1}^2 + \frac{(\bar{d}_n - d_n)^2}{n-1}$$

$$(n = 2, 3, \dots; \bar{d}_1 = d_1; V_1 = 0)$$

Table 4 Pass and Fail Decision Numbers of Appendix 2 Sampling Plan

Minimum sample size:3

| Cumulative number of engines tested (sample size) | Pass decision number A_n | Fail decision number B_n |
|---|----------------------------|----------------------------|
| 3 | -0,80381 | 16,64743 |
| 4 | -0,76339 | 7,68627 |
| 5 | -0,72982 | 4,67136 |
| 6 | -0,69962 | 3,25573 |
| 7 | -0,67129 | 2,45431 |
| 8 | -0,64406 | 1,94369 |
| 9 | -0,61750 | 1,59105 |
| 10 | -0,59135 | 1,33295 |
| 11 | -0,56542 | 1,13566 |
| 12 | -0,53960 | 0,97970 |
| 13 | -0,51379 | 0,85307 |
| 14 | -0,48791 | 0,74801 |
| 15 | -0,46191 | 0,65928 |
| 16 | -0,43573 | 0,58321 |
| 17 | -0,40933 | 0,51718 |
| 18 | -0,38266 | 0,45922 |
| 19 | -0,35570 | 0,40788 |
| 20 | -0,32840 | 0,36203 |
| 21 | -0,30072 | 0,32078 |
| 22 | -0,27263 | 0,28343 |
| 23 | -0,24410 | 0,24943 |
| 24 | -0,21509 | 0,21831 |
| 25 | -0,18557 | 0,18970 |
| 26 | -0,15550 | 0,16328 |
| 27 | -0,12483 | 0,13880 |
| 28 | -0,09354 | 0,11603 |
| 29 | -0,06159 | 0,09480 |
| 30 | -0,02892 | 0,07493 |
| 31 | -0,00449 | 0,05629 |
| 32 | 0,03876 | 0,03876 |

PROCEDURE FOR PRODUCTION CONFORMITY TESTING
AT MANUFACTURER'S REQUEST

1. This Appendix describes the procedure to be used to verify, at the manufacturer's request, production conformity for the emissions of pollutants.
2. With a minimum sample size of three engines the sampling procedure is set so that the probability of a lot passing a test with 30% of the engines defective is 0,90 (producer's risk = 10%) while the probability of a lot being accepted with 65% of the engines defective is 0,10 (consumer's risk = 10%).
3. The following procedure is used for each of the pollutants given in Section 6.2.1 of Annex I (see figure 2):
Let:
L = the limit value for the pollutant,
 x_i = the value of the measurement for the i-th engine of the sample,
n = the current sample number.
4. Calculate for the sample the test statistic quantifying the number of non-conforming engines, i.e. $x_i \geq L$:
5. Then:
 - if the test statistic is less than or equal to the pass decision number for the sample size given in table 5, a pass decision is reached for the pollutant;
 - if the test statistic is greater than or equal to the fail decision number for the sample size given in table 5, a fail decision is reached for the pollutant;
 - otherwise, an additional engine is tested according to Section 9.1.1.1 of Annex I and the calculation procedure is applied to the sample increased by one more unit.

In table 5 the pass and fail decision numbers are calculated by means of the International Standard ISO 8422/1991.

Table 5 Pass and Fail Decision Numbers of Appendix 3 Sāmping Plan

Minimum sample size:3

| Cumulative number of engines tested (sample size) | Pass decision number | Fail decision number |
|---|----------------------|----------------------|
| 3 | - | 3 |
| 4 | 0 | 4 |
| 5 | 0 | 4 |
| 6 | 1 | 5 |
| 7 | 1 | 5 |
| 8 | 2 | 6 |
| 9 | 2 | 6 |
| 10 | 3 | 7 |
| 11 | 3 | 7 |
| 12 | 4 | 8 |
| 13 | 4 | 8 |
| 14 | 5 | 9 |
| 15 | 5 | 9 |
| 16 | 6 | 10 |
| 17 | 6 | 10 |
| 18 | 7 | 11 |
| 19 | 8 | 9 |

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INFORMATION DOCUMENT No...
IN ACCORDANCE WITH ANNEX I OF COUNCIL
DIRECTIVE 70/156/EEC RELATING TO EC TYPE APPROVAL
and referring to

MEASURES TO BE TAKEN AGAINST THE EMISSION OF GASEOUS AND PARTICULATE
POLLUTANTS FROM COMPRESSION IGNITION ENGINES FOR USE IN VEHICLES, AND THE
EMISSION OF GASEOUS POLLUTANTS FROM POSITIVE IGNITION ENGINES FUELLED WITH
NATURAL GAS OR LIQUEFIED PETROLEUM GAS FOR USE IN VEHICLES
(DIRECTIVE 88/77/EEC as last amended by Directive.../.../EC)

- Vehicle type / parent engine / engine type ⁽¹⁾:
- 0 GENERAL
- 0.1 Make (name of undertaking):
- 0.2 Type and commercial description (mention any variants):
-
- 0.3 Means and location of identification of type, if marked on the vehicle:
- 0.4 Category of vehicle (if applicable):
- 0.5 Category of engine: diesel / NG fuelled / LPG fuelled ⁽¹⁾:
- 0.6 Name and address of manufacturer:
- 0.7 Location of statutory plates and inscriptions and method of affixing:
- 0.8 In the case of components and separate technical units, location and method of affixing of the EC approval mark:
.....
- 0.9 Address(es) of assembly plant(s):

ATTACHMENTS

- 1.1 Essential characteristics of the (parent) engine and information concerning the conduct of test.
- 1.2 Essential characteristics of the engine family
- 1.3 Essential characteristics of the engine types within the family
2. Characteristics of the engine-related vehicle parts (if applicable).
3. Photographs and/or drawings of the parent engine / engine type and, if applicable, of the engine compartment.
4. List further attachments if any.

Date, File

⁽¹⁾ Delete as appropriate

ANNEX II - APPENDIX 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TEST ⁽¹⁾

1 DESCRIPTION OF ENGINE

- 1.1 Manufacturer:
- 1.2 Manufacturer's engine code:
- 1.3 Cycle: four stroke / two stroke ⁽²⁾
- 1.4 Number and arrangement of cylinders:.....
- 1.4.1 Bore: mm
- 1.4.2 Stroke: mm
- 1.4.3 Firing order:
- 1.5 Engine capacity: cm³
- 1.6 Volumetric compression ratio ⁽³⁾ :.....
- 1.7 Drawing(s) of combustion chamber and piston crown:
- 1.8 Minimum cross-sectional area of inlet and outlet ports: cm²
- 1.9 Idling speed: min⁻¹
- 1.10 Maximum net power:kW at min⁻¹
- 1.11 Maximum permitted engine speed:..... min⁻¹
- 1.12 Maximum net torque:Nm at min⁻¹
- 1.13 *Combustion system*: compression ignition/positive ignition ⁽²⁾
- 1.14 *Fuel*: Diesel/LPG/NG-H/NG-L/NG-HL ⁽²⁾
- 1.15 *Cooling system*
- 1.15.1 Liquid
- 1.15.1.1 Nature of liquid:
- 1.15.1.2 Circulating pump(s): yes/no ⁽²⁾
- 1.15.1.3 Characteristics or make(s) and type(s) (if applicable):
- 1.15.1.4 Drive ratio(s) (if applicable):
- 1.15.2 Air
- 1.15.2.1 Blower: yes/no ⁽²⁾
- 1.15.2.2 Characteristics or make(s) and type(s) (if applicable):
- 1.15.2.3 Drive ratio(s) (if applicable):
- 1.16 *Temperature permitted by the manufacturer*
- 1.16.1 Liquid cooling: Maximum temperature at outlet: K
- 1.16.2 Air cooling:Reference point:.....
- Maximum temperature at reference point: K

- 1.16.3 Maximum temperature of the air at the outlet of the intake intercooler (if applicable) K
- 1.16.4 Maximum exhaust temperature at the point in the exhaust pipe(s) adjacent to the outer flange(s) of the exhaust manifold(s) or turbocharger(s):..... K
- 1.16.5 Fuel temperature: min.K, max. K
for diesel engines at injection pump inlet, for gas fuelled engines at pressure regulator final stage
- 1.16.6 Fuel pressure: min.kPa, max. kPa
at pressure regulator final stage, NG fuelled gas engines only
- 1.16.7 Lubricant temperature: min.K, max. K
- 1.17 *Pressure charger: yes/no* ⁽²⁾
- 1.17.1 Make:.....
- 1.17.2 Type:.....
- 1.17.3 Description of the system (e.g. max. charge pressure, wastegate, if applicable):.....
- 1.17.4 Intercooler: yes/no ⁽²⁾
- 1.18 *Intake system*
Maximum allowable intake depression at rated engine speed and at 100 % load as specified in and under the operating conditions of Directive 80/1269/EEC ⁽⁴⁾, as last amended by Directive 89/491/EEC ⁽⁵⁾ kPa
- 1.19 *Exhaust system*
Maximum allowable exhaust back pressure at rated engine speed and at 100 % load as specified in and under the operating conditions of Directive 80/1269/EEC ⁽⁴⁾, as last amended by Directive 89/491/EEC ⁽⁵⁾:..... kPa
Exhaust system volume: dm³

2 MEASURES TAKEN AGAINST AIR POLLUTION

- 2.1 Device for recycling crankcase gases (description and drawings):.....
- 2.2 Additional anti-pollution devices (if any, and if not covered by another heading)
- 2.2.1 Catalytic converter: yes/no ⁽²⁾
- 2.2.1.1 Make(s):.....
- 2.2.1.2 Type(s):.....
- 2.2.1.3 Number of catalytic converters and elements.
- 2.2.1.4 Dimensions, shape and volume of the catalytic converter(s):.....
- 2.2.1.5 Type of catalytic action:
- 2.2.1.6 Total charge of precious metals:
- 2.2.1.7 Relative concentration:
- 2.2.1.8 Substrate (structure and material):
- 2.2.1.9 Cell density:
- 2.2.1.10 Type of casing for the catalytic converter(s):
- 2.2.1.11 Location of the catalytic converter(s) (place and reference distance in the exhaust line):

- 2.2.2 Oxygen sensor: yes/no ⁽²⁾ -----
- 2.2.2.1 Make(s):.....
- 2.2.2.2 Type:.....
- 2.2.2.3 Location:.....
- 2.2.3 Air injection: yes/no ⁽²⁾
- 2.2.3.1 Type (pulse air, air pump, etc.):
- 2.2.4 EGR: yes/no ⁽²⁾
- 2.2.4.1 Characteristics (flow rate, etc.):
- 2.2.5 Particulate trap: yes/no ⁽²⁾
- 2.2.5.1 Dimensions, shape and capacity of the particulate trap:
- 2.2.5.2 Type and design of the particulate trap:.....
- 2.2.5.3 Location (reference distance in the exhaust line):.....
- 2.2.5.4 Method or system of regeneration, description and/or drawing:
- 2.2.6 Other systems: yes/no ⁽²⁾
- 2.2.6.1 Description and operation:.....

3 FUEL FEED

3.1 Diesel engines

3.1.1 Feed pump

Pressure ⁽³⁾ :kPa or characteristic diagram ⁽²⁾.

3.1.2 Injection system

3.1.2.1 Pump

3.1.2.1.1 Make(s):.....

3.1.2.1.2 Type(s):.....

3.1.2.1.3 Delivery:mm³ ⁽³⁾ per stroke at engine speed ofrpm at full injection, or characteristic diagram ⁽²⁾⁽³⁾.

Mention the method used: On engine/on pump bench ⁽²⁾

If boost control is supplied, state the characteristic fuel delivery and boost pressure versus engine speed.

3.1.2.1.4 Injection advance

3.1.2.1.4.1 Injection advance curve⁽³⁾:

3.1.2.1.4.2 Static injection timing⁽³⁾:.....

3.1.2.2 Injection piping

3.1.2.2.1 Length:..... mm

3.1.2.2.2 Internal diameter:..... mm

- 3.1.2.3 Injector(s)
- 3.1.2.3.1 Make(s):
- 3.1.2.3.2 Type(s):
- 3.1.2.3.3 "Opening pressure": kPa⁽³⁾
or characteristic diagram ⁽²⁾⁽³⁾
- 3.1.2.4 Governor
- 3.1.2.4.1 Make(s):
- 3.1.2.4.2 Type(s):
- 3.1.2.4.3 Speed at which cut-off starts under full load: rpm
- 3.1.2.4.4 Maximum no-load speed: rpm
- 3.1.2.4.5 Idling speed: rpm
- 3.1.3 Cold start system
- 3.1.3.1 Make(s):
- 3.1.3.2 Type(s):
- 3.1.3.3 Description:
- 3.1.3.4 Auxiliary starting aid:
- 3.1.3.4.1 Make:
- 3.1.3.4.2 Type:
- 3.2. Gas fuelled engines⁽⁶⁾
- 3.2.1. Fuel: Natural gas/LPG ⁽²⁾
- 3.2.2 Pressure regulator(s) or vaporiser/pressure regulator(s) ⁽³⁾
- 3.2.2.1. Make(s):
- 3.2.2.2. Type(s):
- 3.2.2.3 Number of pressure reduction stages:
- 3.2.2.4 Pressure in final stage: min. kPa, max. kPa
- 3.2.2.5 Number of main adjustment points:
- 3.2.2.6 Number of idle adjustment points:
- 3.2.2.7 Certification number according to **/**/EC:
- 3.2.3 Fuelling system: mixing unit / gas injection / liquid injection / direct injection ⁽²⁾
- 3.2.3.1 Mixture strength regulation:
- 3.2.3.2 System description and/or diagram and drawings:
- 3.2.3.3 Certification number according to **/**/EC:

3.2.4 Mixing unit

- 3.2.4.1 Number:
- 3.2.4.2 Make(s):.....
- 3.2.4.3 Type(s):
- 3.2.4.4 Location:.....
- 3.2.4.5 Adjustment possibilities:
- 3.2.4.6 Certification number according to **/***/EC:.....

3.2.5 Inlet manifold injection

- 3.2.5.1 Injection: single point / multipoint ⁽²⁾
- 3.2.5.2 Injection : continuous / simultaneously timed / sequentially timed ⁽²⁾
- 3.2.5.3 Injection equipment
 - 3.2.5.3.1 Make(s):
 - 3.2.5.3.2 Type(s):
 - 3.2.5.3.3 Adjustment possibilities:.....
 - 3.2.5.3.4 Certification number according to **/***/EC:
- 3.2.5.4 Supply pump (if applicable):
- 3.2.5.4.1 Make(s):
- 3.2.5.4.2 Type(s):
- 3.2.5.4.3 Certification number according to **/***/EC:
- 3.2.5.5 Injector(s):
- 3.2.5.5.1 Make(s):
- 3.2.5.5.2 Type(s):.....
- 3.2.5.5.3 Certification number according to **/***/EC:.....

3.2.6 Direct injection

- 3.2.6.1 Injection pump / pressure regulator ⁽²⁾
 - 3.2.6.1.1 Make(s):.....
 - 3.2.6.1.2 Type(s):.....
 - 3.2.6.1.3 Injection timing:
 - 3.2.6.1.4 Certification number according to **/***/EC:
- 3.2.6.2 Injector(s)
 - 3.2.6.2.1 Make(s):
 - 3.2.6.2.2 Type(s):
 - 3.2.6.2.3 Opening pressure or characteristic diagram ⁽³⁾:
 - 3.2.6.2.4 Certification number according to **/***/EC:

3.2.7 Electronic control unit (ECU)

3.2.7.1 Make(s):

3.2.7.2 Type(s):

3.2.7.3 Adjustment possibilities:

3.2.8 NG fuel-specific equipment

3.2.8.1 Variant 1 (only in the case of approvals of engines for several specific fuel compositions)

3.2.8.1.1 Fuel composition:

| | | | | | | |
|---|--------------|-------|-----------|-------|-----------|-------|
| methane (CH ₄): | basis: | %mole | min | %mole | max | %mole |
| ethane (C ₂ H ₆): | basis: | %mole | min | %mole | max | %mole |
| propane (C ₃ H ₈): | basis: | %mole | min | %mole | max | %mole |
| butane (C ₄ H ₁₀): | basis: | %mole | min | %mole | max | %mole |
| C5/C5+: | basis: | %mole | min | %mole | max | %mole |
| oxygen (O ₂): | basis: | %mole | min | %mole | max | %mole |
| inert (N ₂ , He etc): | basis: | %mole | min | %mole | max | %mole |

3.2.8.1.2 Injector(s)

3.2.8.1.2.1 Make(s):

3.2.8.1.2.2 Type(s):

3.2.8.1.3 Others (if applicable)

3.2.8.2 Variant 2 (only in the case of approvals for several specific fuel compositions)

4 VALVE TIMING

4.1 Maximum lift of valves and angles of opening and closing in relation to dead centres or equivalent data:.....

.....

4.2 Reference and/or setting ranges ⁽²⁾:

5 IGNITION SYSTEM (SPARK IGNITION ENGINES ONLY)

5.1 Ignition system type: common coil and plugs / individual coil and plugs / coil on plug / other (specify) ⁽²⁾

5.2 Ignition control unit

5.2.1 Make(s):

5.2.2 Type(s):

5.3 Ignition advance curve / advance map ⁽²⁾⁽³⁾:

5.4 Ignition timing ⁽³⁾:degrees before TDC at a speed of rpm and a MAP of kPa

- 5.5 *Spark plugs*
- 5.5.1. Make(s):
- 5.5.2. Type(s):.....
- 5.5.3. Gap setting:mm
- 5.6 *Ignition coil(s)*
- 5.6.1 Make(s):
- 5.6.2 Type(s):.....

6 ENGINE-DRIVEN EQUIPMENT

The engine shall be submitted for testing with the auxiliaries needed for operating the engine (e.g. fan, water pump, etc.), as specified in and under the operating conditions of Directive 80/1269/EEC ⁽⁴⁾, as last amended by Directive 97/211/EC ⁽⁵⁾, Annex I, section 5.1.1.

6.1 *Auxiliaries to be fitted for the test*

If it is impossible or inappropriate to install the auxiliaries on the test bench, the power absorbed by them shall be determined and subtracted from the measured engine power over the whole operating area of the test cycle(s).

6.2 *Auxiliaries to be removed for the test*

Auxiliaries needed only for the operation of the vehicle (e.g. air compressor, air-conditioning system etc.) shall be removed for the test. Where the auxiliaries cannot be removed, the power absorbed by them may be determined and added to the measured engine power over the whole operating area of the test cycle(s).

7 ADDITIONAL INFORMATION ON TEST CONDITIONS

7.1 *Lubricant used*

- 7.1.1 Make:.....
- 7.1.2 Type:
- (State percentage of oil in mixture if lubricant and fuel are mixed):

7.2 *Engine-driven equipment (if applicable)*

The power absorbed by the auxiliaries needs only be determined,
 – if auxiliaries needed for operating the engine, are not fitted to the engine and/or
 – if auxiliaries not needed for operating the engine, are fitted to the engine.

7.2.1 Enumeration and identifying details:

7.2.2 Power absorbed at various indicated engine speeds:

| Equipment | Power absorbed (kW) at various engine speeds | | | | | | |
|---|--|-----------|------------|------------------------|------------------------|------------------------|---------------------------|
| | Idle | Low Speed | High Speed | Speed A ⁽⁷⁾ | Speed B ⁽⁷⁾ | Speed C ⁽⁷⁾ | Ref. Speed ⁽⁸⁾ |
| P(a) Auxiliaries needed for operating the engine (to be subtracted from measured engine power) see section 6.1 | | | | | | | |
| P(b) Auxiliaries not needed for operating the engine (to be added to measured engine power) see section 6.2 | | | | | | | |

8 ENGINE PERFORMANCE

8.1 Engine speeds ⁽⁹⁾

Low speed (n_{lo}).....rpm
 High speed (n_{hi}):rpm

for ESC and ELR Cycles

Idle:rpm
 Speed A:rpm
 Speed B:rpm
 Speed C:rpm

for ETC cycle
 Reference speed:rpm

8.2 Engine power (measured in accordance with the provisions of Directive 80/1269/EEC ⁽⁴⁾, as last amended by Directive 97/11/EC ⁽⁵⁾ in kW

| | Engine speed | | | | |
|--|--------------|------------------------|------------------------|------------------------|---------------------------|
| | Idle | Speed A ⁽⁷⁾ | Speed B ⁽⁷⁾ | Speed C ⁽⁷⁾ | Ref. Speed ⁽⁸⁾ |
| P(m) Power measured on test bed | | | | | |
| P(a) Power absorbed by auxiliaries to be fitted for test (section 6.1) - if fitted - if not fitted | 0 | 0 | 0 | 0 | 0 |
| P(b) Power absorbed by auxiliaries to be removed for test (section 6.2) - if fitted - if not fitted | 0 | 0 | 0 | 0 | 0 |
| P(n) Net engine power = P(m) - P(a) + P(b) | | | | | |

8.3 Dynamometer settings (kW)

The dynamometer settings for the ESC and ELR tests and for the reference cycle of the ETC test shall be based upon the net engine power P(n) of section 8.2. It is recommended to install the engine on the test bed in the net condition. In this case, P(m) and P(n) are identical. If it is impossible or inappropriate to operate the engine under net conditions, the dynamometer settings shall be corrected to net conditions using the above formula.

8.3.1 ESC and ELR Tests

The dynamometer settings shall be calculated according to the formula in Annex III, Appendix 1, section 1.2.

| Percent load | Engine speed | | | |
|--------------|--------------|---------|---------|---------|
| | Idle | Speed A | Speed B | Speed C |
| 10 | ----- | | | |
| 25 | ----- | | | |
| 50 | ----- | | | |
| 75 | ----- | | | |
| 100 | | | | |

8.3.2 ETC Test

If the engine is not tested under net conditions, the correction formula for converting the measured power or measured cycle work, as determined according to Annex III, Appendix 2, section 2, to net power or net cycle work shall be submitted by the engine manufacturer for the whole operating area of the cycle, and approved by the Technical Service.

Footnotes:

--

- (1) In the case of non-conventional engines and systems, particulars equivalent to those referred to here shall be supplied by the manufacturer.
- (2) Strike out what does not apply.
- (3) Specify the tolerance.
- (4) OJ L 375, 31.12.1980, p. 46.
- (5) OJ L 125, 16. 5.1997, p. 31.
- (6) In the case of systems laid out in a different manner, supply equivalent information (for paragraph 3.2).
- (7) ESC test
- (8) ETC test only.
- (9) Specify the tolerance; to be within $\pm 3\%$ of the values declared by the manufacturer.

ANNEX II - APPENDIX 2

ESSENTIAL CHARACTERISTICS OF THE ENGINE FAMILY

1 COMMON PARAMETERS

- 1.1 Combustion cycle:
 - 1.2 Cooling medium:
 - 1.3 Number of cylinders ⁽¹⁾
 - 1.4 Individual cylinder displacement:
 - 1.5 Method of air aspiration:
 - 1.6 Combustion chamber type/design:
 - 1.7 Valve and porting - configuration, size and number:
 - 1.8 Fuel system:
 - 1.9 Ignition system (gas engines):
 - 1.10 Miscellaneous features:
 - charge cooling system ⁽¹⁾:
 - exhaust gas recirculation ⁽¹⁾:
 - water injection/emulsion ⁽¹⁾:
 - air injection ⁽¹⁾
 - 1.11 Exhaust aftertreatment ⁽¹⁾:
- Proof of identical (or lowest for the parent engine) ratio: system capacity / fuel delivery per stroke, pursuant to diagram number(s):

2 ENGINE FAMILY LISTING

2.1 Name of diesel engine family:

2.1.1 Specification of engines within this family:

| | | | | | Parent Engine |
|---|--|--|--|--|---------------|
| Engine Type | | | | | |
| No. of cylinders | | | | | |
| Rated speed (rpm) | | | | | |
| Fuel delivery per stroke (mm ³) | | | | | |
| Rated net power (kW) | | | | | |
| Maximum torque speed (rpm) | | | | | |
| Fuel delivery per stroke (mm ³) | | | | | |
| Maximum torque (Nm) | | | | | |
| Low idle speed (rpm) | | | | | |
| Cylinder displacement (in % of parent engine) | | | | | 100 |

2.2 Name of gas engine family:

2.2.1 Specification of engines within this family:

| | | | | | Parent Engine |
|---|--|--|--|--|---------------|
| Engine Type | | | | | |
| No. of cylinders | | | | | |
| Rated speed (rpm) | | | | | |
| Fuel delivery per stroke (mg) | | | | | |
| Rated net power (kW) | | | | | |
| Maximum torque speed (rpm) | | | | | |
| Fuel delivery per stroke (mm ³) | | | | | |
| Maximum torque (Nm) | | | | | |
| Low idle speed (rpm) | | | | | |
| Cylinder displacement (in % of parent engine) | | | | | 100 |
| Spark timing | | | | | |
| EGR flow | | | | | |
| Air pump yes / no | | | | | |
| Air pump actual flow | | | | | |

⁽¹⁾ If not applicable, mark n.a.

ANNEX II - APPENDIX 3

ESSENTIAL CHARACTERISTICS OF THE ENGINE TYPE
WITHIN THE FAMILY ⁽¹⁾

1 DESCRIPTION OF ENGINE

- 1.1 Manufacturer:.....
- 1.2 Manufacturer's engine code:
- 1.3 Cycle: four stroke / two stroke ⁽²⁾
- 1.4 Number and arrangement of cylinders:
- 1.4.1 Bore:mm
- 1.4.2 Stroke:mm
- 1.4.3 Firing order:
- 1.5 Engine capacity:cm³
- 1.6 Volumetric compression ratio ⁽³⁾:
- 1.7 Drawing(s) of combustion chamber and piston crown:
- 1.8 Minimum cross-sectional area of inlet and outlet ports:cm²
- 1.9 Idling speed:min⁻¹
- 1.10 Maximum net power:kW atmin⁻¹
- 1.11 Maximum permitted engine speed:min⁻¹
- 1.12 Maximum net torque:Nm atmin⁻¹
- 1.13 *Combustion system*: compression ignition/positive ignition ⁽²⁾
- 1.14 *Fuel*: Diesel/LPG/NG-H/NG-L/NG-HL ⁽²⁾
- 1.15 *Cooling system*
 - 1.15.1 Liquid
 - 1.15.1.1 Nature of liquid:
 - 1.15.1.2 Circulating pump(s): yes/no ⁽²⁾
 - 1.15.1.3 Characteristics or make(s) and type(s) (if applicable):
 - 1.15.1.4 Drive ratio(s) (if applicable):
 - 1.15.2 Air
 - 1.15.2.1 Blower: yes/no ⁽²⁾
 - 1.15.2.2 Characteristics or make(s) and type(s) (if applicable):
 - 1.15.2.3 Drive ratio(s) (if applicable):

- 1.16 *Temperature permitted by the manufacturer* --
- 1.16.1 Liquid cooling: Maximum temperature at outlet:K
- 1.16.2 Air cooling: Reference point:
Maximum temperature at reference point:K
- 1.16.3 Maximum temperature of the air at the outlet of the intake intercooler (if applicable):K
- 1.16.4 Maximum exhaust temperature at the point in the exhaust pipe(s) adjacent to the outer flange(s) of the exhaust manifold(s) or turbocharger(s):K
- 1.16.5 Fuel temperature: min.K, max.K
for diesel engines at injection pump inlet, for NG fuelled gas engines at pressure regulator final stage
- 1.16.6 Fuel pressure: min.kPa, max.kPa
at pressure regulator final stage, NG fuelled gas engines only
- 1.16.7 Lubricant temperature: min.K, max.K
- 1.17 *Pressure charger: yes/no* ⁽²⁾
- 1.17.1 Make:
- 1.17.2 Type:
- 1.17.3 Description of the system (e.g. max. charge pressure, wastegate, if applicable):
- 1.17.4 Intercooler: yes/no ⁽²⁾
- 1.18 *Intake system*
Maximum allowable intake depression at rated engine speed and at 100 % load as specified in and under the operating conditions of Directive 80/1269/EEC ⁽⁴⁾, as last amended by Directive 97/21/EC ⁽⁵⁾kPa
- 1.19 *Exhaust system*
Maximum allowable exhaust back pressure at rated engine speed and at 100 % load as specified in and under the operating conditions of Directive 80/1269/EEC ⁽⁴⁾, as last amended by Directive 97/21/EC ⁽⁵⁾:kPa
- Exhaust system volume:cm³

- 2.1 Device for recycling crankcase gases (description and drawings):
- 2.2 Additional anti-pollution devices (if any, and if not covered by another heading)
- 2.2.1 Catalytic converter: yes/no ⁽²⁾
- 2.2.1.1 Number of catalytic converters and elements.
- 2.2.1.2 Dimensions, shape and volume of the catalytic converter(s):.....
- 2.2.1.3 Type of catalytic action:
- 2.2.1.4 Total charge of precious metals:
- 2.2.1.5 Relative concentration:
- 2.2.1.6 Substrate (structure and material):
- 2.2.1.7 Cell density:
- 2.2.1.8 Type of casing for the catalytic converter(s):
- 2.2.1.9 Location of the catalytic converter(s) (place and reference distance in the exhaust line):
-
- 2.2.2 Oxygen sensor: yes/no ⁽²⁾
- 2.2.2.1 Type:
- 2.2.3 Air injection: yes/no ⁽²⁾
- 2.2.3.1 Type (pulse air, air pump, etc.):
- 2.2.4 EGR: yes/no ⁽²⁾
- 2.2.4.1 Characteristics (flow rate etc.):
- 2.2.5 Particulate trap: yes/no ⁽²⁾:
- 2.2.5.1 Dimensions, shape and capacity of the particulate trap:
- 2.2.5.2 Type and design of the particulate trap:
- 2.2.5.3 Location (reference distance in the exhaust line):
- 2.2.5.4 Method or system of regeneration, description and/or drawing:
- 2.2.6 Other systems: yes/no ⁽²⁾
- 2.2.6.1 Description and operation:

3 FUEL FEED

3.1 Diesel engines

3.1.1 Feed pump

Pressure ⁽³⁾ :kPa or characteristic diagram ⁽²⁾

3.1.2 Injection system

3.1.2.1 Pump

3.1.2.1.1 Make(s):

3.1.2.1.2 Type(s):

3.1.2.1.3 Delivery:mm³ ⁽³⁾ per stroke at engine speed ofrpm at full injection, or characteristic diagram ⁽²⁾ ⁽³⁾:

Mention the method used: On engine/on pump bench ⁽²⁾

If boost control is supplied, state the characteristic fuel delivery and boost pressure versus engine speed.

3.1.2.1.4 Injection advance

3.1.2.1.4.1 Injection advance curve ⁽³⁾:

3.1.2.1.4.2 Static injection timing ⁽³⁾:

3.1.2.2 Injection piping

3.1.2.2.1 Length:mm

3.1.2.2.2 Internal diameter:mm

3.1.2.3 Injector(s)

3.1.2.3.1 Make(s):

3.1.2.3.2 Type(s):

3.1.2.3.3 "Opening pressure":kPa⁽³⁾
or characteristic diagram ⁽²⁾ ⁽³⁾:

3.1.2.4 Governor

3.1.2.4.1 Make(s):

3.1.2.4.2 Type(s):

3.1.2.4.3 Speed at which cut-off starts under full load:rpm

3.1.2.4.4 Maximum no-load speed:rpm

3.1.2.4.5 Idling speed:rpm

-
- 3.1.3 Cold start system
 - 3.1.3.1 Make(s):
 - 3.1.3.2 Type(s):
 - 3.1.3.3 Description:
 - 3.1.3.4 Auxiliary starting aid:
 - 3.1.3.4.1 Make:
 - 3.1.3.4.2 Type:
 - 3.2. *Gas fuelled engines* ⁽⁶⁾
 - 3.2.1. Fuel: Natural gas/LPG ⁽²⁾
 - 3.2.2 Pressure regulator(s) or vaporiser/pressure regulator(s)⁽²⁾
 - 3.2.2.1. Make(s):
 - 3.2.2.2. Type(s):
 - 3.2.2.3 Number of pressure reduction stages:
 - 3.2.2.4 Pressure in final stage: min.kPa, max.kPa
 - 3.2.2.5 Number of main adjustment points:
 - 3.2.2.6 Number of idle adjustment points:
 - 3.2.2.7 Certification number according to **/***/EC:
 - 3.2.3 Fuelling system: mixing unit / gas injection / liquid injection / direct injection ⁽²⁾
 - 3.2.3.1 Mixture strength regulation:
 - 3.2.3.2 System description and/or diagram and drawings:
 - 3.2.3.3 Certification number according to **/***/EC:
 - 3.2.4 Mixing unit
 - 3.2.4.1 Number:
 - 3.2.4.2 Make(s):
 - 3.2.4.3 Type(s):
 - 3.2.4.4 Location:
 - 3.2.4.5 Adjustment possibilities:
 - 3.2.4.6 Certification number according to **/***/EC:

-
- 3.2.5 Inlet manifold injection
 - 3.2.5.1 Injection: single point / multipoint ⁽²⁾
 - 3.2.5.2 Injection : continuous / simultaneously timed / sequentially timed ⁽²⁾
 - 3.2.5.3 Injection equipment
 - 3.2.5.3.1 Make(s):
 - 3.2.5.3.2 Type(s):
 - 3.2.5.3.3 Adjustment possibilities:
 - 3.2.5.3.4 Certification number according to **/***/EC:
 - 3.2.5.4 Supply pump (if applicable):
 - 3.2.5.4.1 Make(s):
 - 3.2.5.4.2 Type(s):
 - 3.2.5.4.3 Certification number according to **/***/EC:
 - 3.2.5.5 Injector(s):
 - 3.2.5.5.1 Make(s):
 - 3.2.5.5.2 Type(s):
 - 3.2.5.5.3 Certification number according to **/***/EC:
 - 3.2.6 Direct injection
 - 3.2.6.1 Injection pump / pressure regulator ⁽²⁾
 - 3.2.6.1.1 Make(s):
 - 3.2.6.1.2 Type(s):
 - 3.2.6.1.3 Injection timing:
 - 3.2.6.1.4 Certification number according to **/***/EC:
 - 3.2.6.2 Injector(s)
 - 3.2.6.2.1 Make(s):
 - 3.2.6.2.2 Type(s):
 - 3.2.6.2.3 Opening pressure or characteristic diagram ⁽³⁾ :
 - 3.2.6.2.4 Certification number according to **/***/EC:
 - 3.2.7 Electronic control unit (ECU)
 - 3.2.7.1 Make(s):
 - 3.2.7.2 Type(s):
 - 3.2.7.3 Adjustment possibilities:

3.2.8 NG fuel-specific equipment

3.2.8.1 Variant 1 (only in the case of approvals of engines for several specific fuel compositions)

3.2.8.1.1 Fuel composition:

| | | | |
|---|--------------------|-----------------|-----------------|
| methane (CH ₄): | basis: %mole | min. %mole | max. %mole |
| ethane (C ₂ H ₆): | basis: %mole | min. %mole | max. %mole |
| propane (C ₃ H ₈): | basis: %mole | min. %mole | max. %mole |
| butane (C ₄ H ₁₀): | basis: %mole | min. %mole | max. %mole |
| C5/C5+: | basis: %mole | min. %mole | max. %mole |
| oxygen (O ₂): | basis: %mole | min. %mole | max. %mole |
| inert (N ₂ , He etc): | basis: %mole | min. %mole | max. %mole |

3.2.8.1.2 Injector(s)

3.2.8.1.2.1 Make(s):

3.2.8.1.2.2 Type(s):

3.2.8.1.3 Others (if applicable)

3.2.8.2 Variant 2 (only in the case of approvals for several specific fuel compositions)

4 VALVE TIMING

4.1 Maximum lift of valves and angles of opening and closing in relation to dead centres of equivalent data:.....

.....

4.2 Reference and/or setting ranges ⁽²⁾ :

5 IGNITION SYSTEM (SPARK IGNITION ENGINES ONLY)

5.1. Ignition system type: common coil and plugs / individual coil and plugs / coil on plug / other (specify) ⁽²⁾

5.2 Ignition control unit

5.2.1 Make(s):

5.2.2 Type(s):

5.3 Ignition advance curve / advance map ⁽²⁾⁽³⁾:

- 5.4 Ignition timing⁽³⁾:degrees before TDC
 at a speed of rpm and a MAP of kPa
- 5.5 *Spark plugs*
- 5.5.1. Make(s):
- 5.5.2. Type(s):.....
- 5.5.3. Gap setting:mm
- 5.6 *Ignition coil(s)*
- 5.6.1 Make(s):
- 5.6.2 Type(s):.....

Footnotes

- (1) To be submitted for each engine of the family.
- (2) Strike out what does not apply.
- (3) Specify the tolerance.
- (4) OJ L 375, 31.12.1980, p. 46.
- (5) OJ L 125, 16. 5.1997, p. 31.
- (6) In the case of systems laid out in a different manner, supply equivalent information (for paragraph 3.2).

ANNEX II - APPENDIX 4

CHARACTERISTICS OF THE ENGINE-RELATED VEHICLE PARTS

Intake system depression at rated engine speed and at 100% load:.....kPa

Exhaust system back pressure at rated engine speed and at 100% load:kPa

Volume of exhaust system:cm³

Power absorbed by the auxiliaries needed for operating the engine as specified in and under the operation conditions of Directive 80/1269/EEC ⁽¹⁾, as last amended by Directive 97/21/EC ⁽²⁾, Annex I, section 5.1.1.

| Equipment | Power absorbed (kW) at various engine speeds | | | | | | |
|---|--|-----------|------------|------------------------|------------------------|------------------------|---------------------------|
| | Idle | Low Speed | High Speed | Speed A ⁽³⁾ | Speed B ⁽³⁾ | Speed C ⁽³⁾ | Ref. Speed ⁽⁴⁾ |
| P(a) Auxiliaries needed for operating the engine (to be subtracted from measured engine power) see section 5.1 | | | | | | | |

⁽¹⁾ OJ L 375, 31.12.1980, p. 46.

⁽²⁾ OJ L 125, 16. 5.1997, p. 31.

⁽³⁾ ESC test

⁽⁴⁾ ETC test only.

--
TEST PROCEDURE

1. INTRODUCTION

1.1. This Annex describes the methods of determining emissions of gaseous components, particulates and smoke from the engines to be tested. Three test cycles are described that shall be applied according to the provisions of Annex I, section 6.2:

- the ESC which consists of a steady state 13-mode cycle,
- the ELR which consists of transient load steps at different speeds, which are integral parts of one test procedure, and are run concurrently;
- the ETC which consists of a second-by-second sequence of transient modes.

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

1.3. Measurement principle

The emissions to be measured from the exhaust of the engine include the gaseous components (carbon monoxide, total hydrocarbons for diesel engines on the ESC test only; non-methane hydrocarbons for diesel and gas engines on the ETC test only; methane for gas engines on the ETC test only and oxides of nitrogen), the particulates (diesel engines only) and smoke (diesel engines on the ELR test only). Additionally, carbon dioxide is often used as a tracer gas for determining the dilution ratio of partial and full flow dilution systems. Good engineering practice recommends the general measurement of carbon dioxide as an excellent tool for the detection of measurement problems during the test run.

1.3.1. *ESC Test*

During a prescribed sequence of warmed-up engine operating conditions the amounts of the above exhaust emissions shall be examined continuously by taking a sample from the raw exhaust gas. The test cycle consists of a number of speed and power modes which cover the typical operating range of diesel engines. During each mode the concentration of each gaseous pollutant, exhaust flow and power output shall be determined, and the measured values weighted. The particulate sample shall be diluted with conditioned ambient air. One sample over the complete test procedure shall be taken, and collected on suitable filters. The grams of each pollutant emitted per kilowatt hour shall be calculated as described in Appendix 1 to this Annex. Additionally, NO_x shall be measured at three test points within the control area selected by the Technical Service ¹ and the measured values compared to the values calculated from those modes of the test cycle enveloping the selected test points. The NO_x control check ensures the effectiveness of the emission control of the engine within the typical engine operating range.

1.3.2. *ELR Test*

During a prescribed load response test, the smoke of a warmed-up engine shall be determined by means of an opacimeter. The test consists of loading the engine at constant speed from 10 % to 100% load at three different engine speeds. Additionally, a fourth load step selected by the Technical Service ¹ shall be run, and the value compared to the values of the previous load steps. The smoke peak shall be determined using an averaging algorithm, as described in Appendix 1 to this Annex.

¹ The test points shall be selected using approved statistical methods of randomisation.

1.3.3. *ETC Test*

During a prescribed transient cycle of warmed-up engine operating conditions, which is based closely on road-type-specific driving patterns of heavy-duty engines installed in trucks and buses, the above pollutants shall be examined after diluting the total exhaust gas with conditioned ambient air. Using the engine torque and speed feedback signals of the engine dynamometer, the power shall be integrated with respect to time of the cycle resulting in the work produced by the engine over the cycle. The concentration of NO_x and HC shall be determined over the cycle by integration of the analyser signal. The concentration of CO, CO₂, and NMHC may be determined by integration of the analyser signal or by bag sampling. For particulates, a proportional sample shall be collected on suitable filters. The diluted exhaust gas flow rate shall be determined over the cycle to calculate the mass emission values of the pollutants. The mass emission values shall be related to the engine work to get the grams of each pollutant emitted per kilowatt hour, as described in Appendix 2 to this Annex.

2. TEST CONDITIONS

2.1. Engine Test Conditions

2.1.1. 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 shall be determined according to the following provisions:

(a) for diesel engines:

Naturally aspirated and mechanically supercharged engines:

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

Turbocharged engines with or without cooling of the intake air:

$$F = \left(\frac{99}{p_s} \right)^{0,7} * \left(\frac{T_a}{298} \right)^{1,5}$$

(b) for gas engines:

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

2.1.2. *Test Validity*

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

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

2.2. Engines with Charge Air Cooling

The charge air temperature shall be recorded and shall be, at the speed of the declared maximum power and full load, within ± 5 K of the maximum charge air temperature specified in Annex II, Appendix 1, section 1.16.3. The temperature of the cooling medium shall be at least 293 K (20°C).

If a test shop system or external blower is used, the charge air temperature shall be within ± 5 K of the maximum charge air temperature specified in Annex II, Appendix 1, section 1.16.3 at the speed of the declared maximum power and full load. The setting of the charge air cooler for meeting the above conditions shall be used for the whole test cycle.

2.3. Engine Air Intake System

An engine air intake system shall be used presenting an air intake restriction within ± 100 Pa of the upper limit of the engine operating at the speed at the declared maximum power and full load.

2.4. Engine Exhaust System

An exhaust system shall be used presenting an exhaust back pressure within ± 1000 Pa of the upper limit of the engine operating at the speed of declared maximum power and full load and a volume within $\pm 40\%$ of that specified by the manufacturer. A test shop system may be used, provided it represents actual engine operating conditions. The exhaust system shall conform to the requirements for exhaust gas sampling, as set out in Annex III, Appendix 4, section 3.4 and in Annex V, section 2.2.1, EP and section 2.3.1, EP.

If the engine is equipped with an exhaust aftertreatment device, the exhaust pipe must have the same diameter as found in-use for at least 4 pipe diameters upstream to the inlet of the beginning of the expansion section containing the aftertreatment device. The distance from the exhaust manifold flange or turbocharger outlet to the exhaust aftertreatment device shall be the same as in the vehicle configuration or within the distance specifications of the manufacturer. The exhaust backpressure or restriction shall follow the same criteria as above, and may be set with a valve. The aftertreatment container may be removed during dummy tests and during engine mapping, and replaced with an equivalent container having an inactive catalyst support.

2.5. Cooling System

An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures prescribed by the manufacturer shall be used.

2.6. Lubricating Oil

Specifications of the lubricating oil used for the test shall be recorded and presented with the results of the test, as specified in Annex II, Appendix 1, section 7.1.

2.7. Fuel

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

The fuel temperature and measuring point shall be specified by the manufacturer within the limits given in Annex II, Appendix 1, section 1.16.5. The fuel temperature shall not be lower than 306 K (33°C). If not specified, it shall be $311 \text{ K} \pm 5 \text{ K}$ ($38^\circ\text{C} \pm 5^\circ\text{C}$) at the inlet to the fuel supply.

For NG and LPG fuelled engines, the fuel temperature and measuring point shall be within the limits given in Annex II, Appendix 1, section 1.16.5 or in Annex II, Appendix 3, section 1.16.5 in cases where the engine is not a parent engine.

2.8. Testing of Exhaust Aftertreatment Systems ---

If the engine is equipped with an exhaust aftertreatment system, the emissions measured on the test cycle(s) shall be representative of the emissions in the field. If this cannot be achieved with one single test cycle (e.g. for particulate filters with periodic regeneration), several test cycles shall be conducted and the test results averaged and/or weighted. The exact procedure shall be agreed by the engine manufacturer and the Technical Service based upon good engineering judgement.

ANNEX III - APPENDIX 1

ESC AND ELR TEST CYCLES

1 ENGINE AND DYNAMOMETER SETTINGS

1.1. Determination of Engine Speeds A, B and C

The engine speeds A, B and C shall be declared by the manufacturer in accordance with the following provisions:

The high speed n_{hi} shall be determined by calculating 70 % of the declared maximum net power $P(n)$, as determined in Annex II, Appendix 1, section 8.2. The highest engine speed where this power value occurs on the power curve is defined as n_{hi} .

The low speed n_{lo} shall be determined by calculating 50 % of the declared maximum net power $P(n)$, as determined in Annex II, Appendix 1, section 8.2.. The lowest engine speed where this power value occurs on the power curve is defined as n_{lo} .

The engine speeds A, B and C shall be calculated as follows:

$$\begin{aligned}\text{Speed A} &= n_{lo} + 25 \% (n_{hi} - n_{lo}) \\ \text{Speed B} &= n_{lo} + 50 \% (n_{hi} - n_{lo}) \\ \text{Speed C} &= n_{lo} + 75 \% (n_{hi} - n_{lo})\end{aligned}$$

The engine speeds A, B and C may be verified by either of the following methods:

- (a) Additional test points shall be measured during engine power approval according to Directive 80/1269/EEC for an accurate determination of n_{hi} and n_{lo} . The maximum power, n_{hi} and n_{lo} shall be determined from the power curve, and engine speeds A, B and C shall be calculated according to the above provisions.
- (b) The engine shall be mapped along the full load curve, from maximum no load speed to idle speed, using at least 5 measurement points per 1000 rpm intervals and measurement points within ± 50 rpm of the speed at declared maximum power. The maximum power, n_{hi} and n_{lo} shall be determined from this mapping curve, and engine speeds A, B and C shall be calculated according to the above provisions.

If the measured engine speeds A, B and C are within ± 3 % of the engine speeds as declared by the manufacturer, the declared engine speeds shall be used for the emissions test. If the tolerance is exceeded for any of the engine speeds, the measured engine speeds shall be used for the emissions test.

1.2. Determination of Dynamometer Settings

The torque curve at full load shall be determined by experimentation to calculate the torque values for the specified test modes under net conditions, as specified in Annex II, Appendix 1, section 8.2. The power absorbed by engine-driven equipment, if applicable, shall be taken into account. The dynamometer setting

for each test mode shall be calculated using the formula: $s = P(n) * \frac{L}{100}$

if tested under net conditions

$$s = P(n) * \frac{L}{100} + (P(a) - P(b))$$

if not tested under net conditions

where,

s = dynamometer setting, kW

P(n) = net engine power as indicated in Annex II, Appendix 1, section 8.2, kW

L = per cent load as indicated in section 2.7.1, %

- P(a) = power absorbed by auxiliaries to be fitted as indicated in Annex II, Appendix 1, section 6.1
P(b) = power absorbed by auxiliaries to be removed as indicated in Annex II, Appendix 1, section 6.2

2. ESC TEST RUN

At the manufacturers request, a dummy test may be run for conditioning of the engine and exhaust system before the measurement cycle.

2.1. Preparation of the Sampling Filters

At least one hour before the test, each filter (pair) shall be placed in a closed, but unsealed petri dish and placed in a weighing chamber for stabilisation. At the end of the stabilisation period, each filter (pair) shall be weighed and the tare weight shall be recorded. The filter (pair) shall then be stored in a closed petri dish or sealed filter holder until needed for testing. If the filter (pair) is not used within eight hours of its removal from the weighing chamber, it must be conditioned and reweighed before use.

2.2. Installation of the Measuring Equipment

The instrumentation and sample 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.

2.3. Starting the Dilution System and the Engine

The dilution system and the engine shall be started and warmed up until all temperatures and pressures have stabilised at maximum power according to the recommendation of the manufacturer and good engineering practice.

2.4. Starting the Particulate Sampling System

The particulate sampling system shall be started and running on by-pass. The particulate background level of the dilution air may be determined by passing dilution air through the particulate filters. If filtered dilution air is used, one measurement may be done prior to or after the test. If the dilution air is not filtered, measurements at the beginning and at the end of the cycle, may be done, and the values averaged.

2.5. Adjustment of the Dilution Ratio

--

The dilution air shall be set such that the temperature of the diluted exhaust gas measured immediately prior to the primary filter shall not exceed 325 K (52°C) at any mode. The dilution ratio (q) shall not be less than 4.

For systems that use CO₂ or NO_x concentration measurement for dilution ratio control, the CO₂ 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 CO₂ or NO_x concentration measurements of the dilution air must be within 100 ppm or 5 ppm of each other, respectively.

2.6. Checking the Analysers

The emission analysers shall be set at zero and spanned.

2.7. Test Cycle

2.7.1. The following 13-mode cycle shall be followed in dynamometer operation on the test engine:

| Mode Number | Engine Speed | Percent Load | Weighting Factor | Mode Length |
|-------------|--------------|--------------|------------------|-------------|
| 1 | idle | - | 0,15 | 4 minutes |
| 2 | A | 100 | 0,08 | 2 minutes |
| 3 | B | 50 | 0,10 | 2 minutes |
| 4 | B | 75 | 0,10 | 2 minutes |
| 5 | A | 50 | 0,05 | 2 minutes |
| 6 | A | 75 | 0,05 | 2 minutes |
| 7 | A | 25 | 0,05 | 2 minutes |
| 8 | B | 100 | 0,09 | 2 minutes |
| 9 | B | 25 | 0,10 | 2 minutes |
| 10 | C | 100 | 0,08 | 2 minutes |
| 11 | C | 25 | 0,05 | 2 minutes |
| 12 | C | 75 | 0,05 | 2 minutes |
| 13 | C | 50 | 0,05 | 2 minutes |

2.7.2. Test Sequence

The test sequence shall be started. The test shall be performed in the order of the mode numbers as set out in section 2.7.1.

The engine must be operated for the prescribed time in each mode, completing engine speed and load changes in the first 20 seconds. The specified speed shall be held to within ± 50 rpm and the specified torque shall be held to within $\pm 2\%$ of the maximum torque at the test speed.

At the manufacturers request, the test sequence may be repeated a sufficient number of times for sampling more particulate mass on the filter. The manufacturer shall supply a detailed description of the data evaluation and calculation procedures. The gaseous emissions shall only be determined on the first cycle.

2.7.3. 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 throughout the test cycle.

2.7.4. *Particulate Sampling*

One pair of filters (primary and back-up filters, see Annex III, Appendix 4) shall be used for the complete test procedure. The modal weighting factors specified in the test cycle procedure shall be taken into account by taking a sample proportional to the exhaust mass flow during each individual mode of the cycle. This can be achieved by adjusting sample flow rate, sampling time, and/or dilution ratio, accordingly, so that the criterion for the effective weighting factors in section 5.6 is met.

The sampling time per mode must be at least 4 seconds per 0,01 weighting factor. Sampling must be conducted as late as possible within each mode. Particulate sampling shall be completed no earlier than 5 seconds before the end of each mode.

2.7.5. *Engine Conditions*

The engine speed and load, intake air temperature and depression, exhaust temperature and backpressure, fuel flow and air or exhaust flow, charge air temperature, fuel temperature and humidity shall be recorded during each mode, with the speed and load requirements (see section 2.7.2) being met during the time of particulate sampling, but in any case during the last minute of each mode.

Any additional data required for calculation shall be recorded (see sections 4 and 5).

2.7.6. *NO_x Check within the Control Area*

The NO_x check within the control area shall be performed immediately upon completion of mode 13. The engine shall be conditioned at mode 13 for a period of three minutes before the start of the measurements. Three measurements shall be made at different locations within the control area, selected by the Technical Service¹. The time for each measurement shall be 2 minutes.

The measurement procedure is identical to the NO_x measurement on the 13-mode cycle, and shall be carried out in accordance with sections 2.7.3, 2.7.5, and 4.1 of this Appendix, and Annex III, Appendix 4, section 3.

The calculation shall be carried out in accordance with section 4.

2.7.7. *Rechecking the Analysers*

After the emission test a zero gas and the same span gas shall be used for rechecking. The test will be considered acceptable if the difference between the pre-test and post-test results is less than 2 % of the span gas value.

3. **ELR TEST RUN**

3.1. **Installation of the Measuring Equipment**

The opacimeter and sample probes, if applicable, shall be installed after the exhaust silencer or any aftertreatment device, if fitted, according to the general installation procedures specified by the instrument manufacturer. Additionally, the requirements of section 10 of ISO IDS 11614 shall be observed, where appropriate.

Prior to any zero and full scale checks, the opacimeter shall be warmed up and stabilised according to the instrument manufacturer's recommendations. If the opacimeter is equipped with a purge air system to prevent sooting of the meter optics, this system shall also be activated and adjusted according to the manufacturer's recommendations.

¹ The test points shall be selected using approved statistical methods of randomisation.

3.2. Checking of the Opacimeter

The zero and full scale checks shall be made in the opacity readout mode, since the opacity scale offers two truly definable calibration points, namely 0 % opacity and 100 % opacity. The light absorption coefficient is then correctly calculated based upon the measured opacity and the L_A , as submitted by the opacimeter manufacturer, when the instrument is returned to the k readout mode for testing.

With no blockage of the opacimeter light beam, the readout shall be adjusted to $0,0 \% \pm 1,0 \%$ opacity. With the light being prevented from reaching the receiver, the readout shall be adjusted to $100,0 \% \pm 1,0 \%$ opacity.

3.3. Test Cycle

3.3.1. Conditioning of the Engine

Warming up of the engine and the system shall be at maximum power in order to stabilise the engine parameters according to the recommendation of the manufacturer. The preconditioning phase should also protect the actual measurement against the influence of deposits in the exhaust system from a former test.

When the engine is stabilised, the cycle shall be started within 20 ± 2 s after the preconditioning phase. At the manufacturers request, a dummy test may be run for additional conditioning before the measurement cycle.

3.3.2. Test Sequence

The test consists of a sequence of three load steps at each of the three engine speeds A (cycle 1), B (cycle 2) and C (cycle 3) determined in accordance with Annex III, section 1.1, followed by cycle 4 at a speed within the control area and a load between 10% and 100%, selected by the Technical Service¹. The following sequence shall be followed in dynamometer operation on the test engine, as shown in Figure 3.

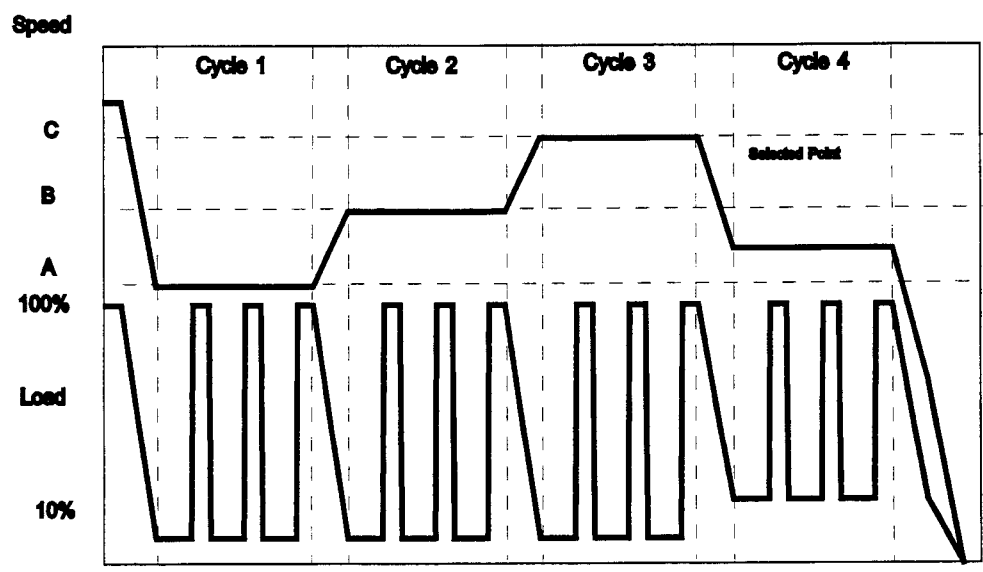


Figure 3 Sequence of ELR Test

- (a) The engine shall be operated at engine speed A and 10 per cent load for 20 ± 2 s. The specified speed shall be held to within ± 20 rpm and the specified torque shall be held to within $\pm 2\%$ of the maximum torque at the test speed.

¹ The test points shall be selected using approved statistical methods of randomisation.

- (b) At the end of the previous segment, the speed control lever shall be moved rapidly to, and held in, the wide open position for 10 ± 1 s. The necessary dynamometer load shall be applied to keep the engine speed within ± 150 rpm during the first 3 s, and within ± 20 rpm during the rest of the segment.
- (c) The sequence described in (a) and (b) shall be repeated two times.
- (d) Upon completion of the third load step, the engine shall be adjusted to engine speed B and 10 per cent load within 20 ± 2 s.
- (e) The sequence (a) to (c) shall be run with the engine operating at engine speed B.
- (f) Upon completion of the third load step, the engine shall be adjusted to engine speed C and 10 per cent load within 20 ± 2 s.
- (g) The sequence (a) to (c) shall be run with the engine operating at engine speed C.
- (h) Upon completion of the third load step, the engine shall be adjusted to the selected engine speed and any load above 10 per cent within 20 ± 2 s.
- (i) The sequence (a) to (c) shall be run with the engine operating at the selected engine speed.

3.4. Cycle Validation

The relative standard deviations of the mean smoke values at each test speed (SV_A , SV_B , SV_C , as calculated in accordance with section 6.3.3 of this Appendix from the three successive load steps at each test speed) shall be lower than 15 % of the mean value, or 10 % of the limit value shown in Table 1 of Annex I, whichever is greater. If the difference is greater, the sequence shall be repeated until 3 successive load steps meet the validation criteria.

3.5. Rechecking of the Opacimeter

The post-test opacimeter zero drift value shall not exceed $\pm 5,0$ % of the limit value shown in Table 1 of Annex I.

4. CALCULATION OF THE GASEOUS EMISSIONS

4.1. Data Evaluation

For the evaluation of the gaseous emissions, the chart reading of the last 30 seconds of each mode shall be averaged, and the average concentrations (conc) of HC, CO and NO_x 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.

For the NO_x check within the control area, the above requirements apply for NO_x , only.

The exhaust gas flow G_{EXHW} or the diluted exhaust gas flow G_{TOTW} , if used optionally, shall be determined in accordance with Annex III, Appendix 4, section 2.3.

4.2. Dry / Wet Correction

The measured concentration shall be converted to a wet basis according to the following formulae, if not already measured on a wet basis.

$$\text{conc(wet)} = K_w * \text{conc(dry)}$$

For the raw exhaust gas:

$$K_{w,r} = \left(1 - F_{FH} * \frac{G_{FUEL}}{G_{AIRD}} \right) - K_{w2}$$

and

$$F_{FH} = \frac{1,969}{\left(1 + \frac{G_{FUEL}}{G_{AIRW}} \right)}$$

For the diluted exhaust gas:

$$K_{w,e,1} = \left(1 - \frac{HTCRAT * CO_2 \% (kosteaa)}{200} \right) - K_{w1}$$

or

$$K_{w,e,2} = \left(\frac{(1 - K_{w1})}{1 + \frac{HTCRAT * CO_2 \% (kuiva)}{200}} \right)$$

For the dilution air

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

$$K_{w1} = \frac{1,608 * H_d}{1000 + (1,608 * H_d)}$$

$$H_d = \frac{6,220 * R_d * p_d}{p_B - p_d * R_d * 10^{-2}}$$

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

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

$$K_{w2} = \frac{1,608 * H_a}{1000 + (1,608 * H_a)}$$

$$H_a = \frac{6,220 * R_a * p_a}{p_B - p_a * R_a * 10^{-2}}$$

where,

H_a, H_d : g water per kg dry air

R_d, R_a = relative humidity of the dilution/intake air, %

p_d, p_a = saturation vapour pressure of the dilution/intake air, kPa

p_B = total barometric pressure, kPa

4.3. NO_x Correction for Humidity and Temperature¹

As the NO_x emission depends on ambient air conditions, the NO_x concentration shall be corrected for ambient air temperature and humidity with the factors given in the following formulae:

$$K_{H,D} = \frac{1}{1 + A * (H_a - 10,71) + B * (T_a - 298)}$$

with:

$$A = 0,309 G_{FUEL}/G_{AIRD} - 0,0266$$

$$B = -0,209 G_{FUEL}/G_{AIRD} + 0,00954$$

T_a = temperature of the air, K
H_a = humidity of the intake air, g water per kg dry air

in which,

$$H_a = \frac{6,220 * R_a * p_a}{p_B - p_a * R_a * 10^{-2}}$$

R_a = relative humidity of the intake air, %
p_a = saturation vapour pressure of the intake air, kPa
p_B = total barometric pressure, kPa

4.4. Calculation of the Emission Mass Flow Rates

The emission mass flow rates (g/h) for each mode shall be calculated as follows, assuming the exhaust gas density to be 1,293 kg/m³ at 273 K (0°C) and 101,3 kPa:

$$(1) \quad NO_{x\ mass} = 0,001587 * NO_{x\ conc} * K_{H,D} * G_{EXHW}$$

$$(2) \quad CO_{mass} = 0,000966 * CO_{conc} * G_{EXHW}$$

$$(3) \quad HC_{mass} = 0,000479 * HC_{conc} * G_{EXHW}$$

where NO_{x conc}, CO_{conc}, HC_{conc}¹ are the average concentrations (ppm) in the raw exhaust gas, as determined in section 4.1.

If, optionally, the gaseous emissions are determined with a full flow dilution system, the following formulae shall be applied:

$$(1) \quad NO_{x\ mass} = 0,001587 * NO_{x\ conc} * K_{H,D} * G_{TOTW}$$

$$(2) \quad CO_{mass} = 0,000966 * CO_{conc} * G_{TOTW}$$

$$(3) \quad HC_{mass} = 0,000479 * HC_{conc} * G_{TOTW}$$

where NO_{x conc}, CO_{conc}, HC_{conc}¹ are the average background corrected concentrations (ppm) of each mode in the diluted exhaust gas, as determined in Annex III, Appendix 2, section 4.3.1.1.

¹ Based on C1 equivalent

4.5. Calculation of the Specific Emissions

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

$$\overline{NO_x} = \frac{\sum NO_{x, mass} * WF_i}{\sum P(n)_i * WF_i}$$

$$\overline{CO} = \frac{\sum CO_{mass} * WF_i}{\sum P(n)_i * WF_i}$$

$$\overline{HC} = \frac{\sum HC_{mass} * WF_i}{\sum P(n)_i * WF_i}$$

The weighting factors (WF) used in the above calculation are according to section 2.7.1.

4.6. Calculation of the Area Control Values

For the three control points selected according to section 2.7.6, the NO_x emission shall be measured and calculated according to section 4.6.1 and also determined by interpolation from the modes of the test cycle closest to the respective control point according to section 4.6.2. The measured values are then compared to the interpolated values according to section 4.6.3.

4.6.1. Calculation of the Specific Emission

The NO_x emission for each of the control points (Z) shall be calculated as follows:

$$NO_{x, mass, Z} = 0,001587 * NO_{x, conc, Z} * K_{H,D} * G_{EXHW}$$

$$NO_{x, Z} = NO_{x, mass, Z} / P(n)_Z$$

4.6.2. Determination of the Emission Value from the Test Cycle

The NO_x emission for each of the control points shall be interpolated from the four closest modes of the test cycle that envelop the selected control point Z as shown in Figure 4. For these modes (R, S, T, U), the following definitions apply:

$$\text{Speed(R)} = \text{Speed(T)} = n_{RT}$$

$$\text{Speed(S)} = \text{Speed(U)} = n_{SU}$$

$$\text{Per cent load(R)} = \text{Per cent load(S)}$$

$$\text{Per cent load(T)} = \text{Per cent load(U)}$$

The NO_x emission of the selected control point Z shall be calculated as follows:

$$E_Z = E_{RS} + (E_{TU} - E_{RS}) \cdot (M_Z - M_{RS}) / (M_{TU} - M_{RS})$$

and:

$$E_{TU} = E_T + (E_U - E_T) \cdot (n_Z - n_{RT}) / (n_{SU} - n_{RT})$$

$$E_{RS} = E_R + (E_S - E_R) \cdot (n_Z - n_{RT}) / (n_{SU} - n_{RT})$$

$$M_{TU} = M_T + (M_U - M_T) \cdot (n_Z - n_{RT}) / (n_{SU} - n_{RT})$$

$$M_{RS} = M_R + (M_S - M_R) \cdot (n_Z - n_{RT}) / (n_{SU} - n_{RT})$$

where,

E_R, E_S, E_T, E_U = specific NO_x emission of the enveloping modes calculated in accordance with section 4.6.1.

M_R, M_S, M_T, M_U = engine torque of the enveloping modes

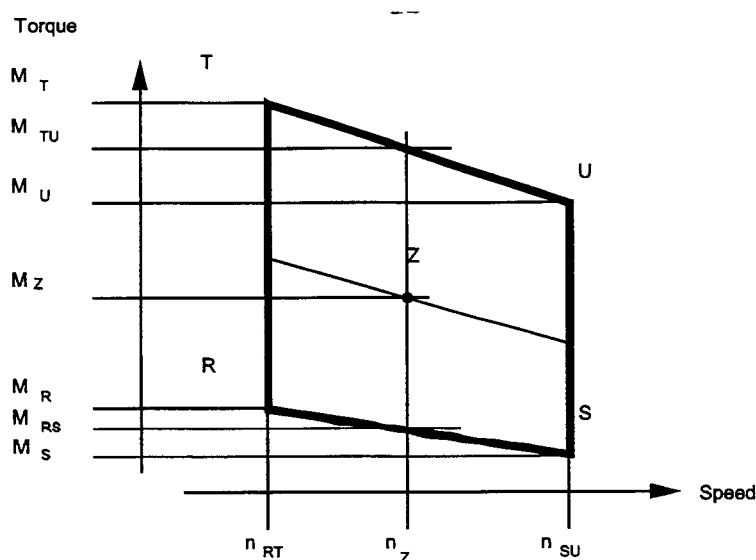


Figure 4 Interpolation of NO_x Control Point

4.6.3. Comparison of NO_x Emission Values

The measured specific NO_x emission of the control point Z (NO_{x,z}) is compared to the interpolated value (E_Z) as follows:

$$NO_{x,diff} = 100 * (NO_{x,z} - E_z) / E_z$$

5. CALCULATION OF THE PARTICULATE EMISSION

5.1. Data Evaluation

For the evaluation of the particulates, the total sample masses (M_{SAM,i}) through the filters shall be recorded for each mode.

The filters shall be returned to the weighing chamber and conditioned for at least one hour, but not more than 80 hours, and then weighed. The gross weight of the filters shall be recorded and the tare weight (see section 1 of this Appendix) subtracted. The particulate mass M_f is the sum of the particulate masses collected on the primary and back-up filters.

If background correction is to be applied, the dilution air mass (M_{DIL}) through the filters and the particulate mass (M_d) shall be recorded. If more than one measurement was made, the quotient M_d/M_{DIL} must be calculated for each single measurement and the values averaged.

5.2. Partial Flow Dilution System

The final reported test results of the particulate emission shall be determined through the following steps. Since various types of dilution rate control may be used, different calculation methods for G_{EDFW} apply. All calculations shall be based upon the average values of the individual modes during the sampling period.

5.2.1. **Isokinetic Systems**

$$G_{EDFW,i} = G_{EXHW,i} * q_i$$

$$q_i = \frac{G_{DILW,i} + (G_{EXHW,i} * r)}{(G_{EXHW,i} * r)}$$

where r corresponds to the ratio of the cross sectional areas of the isokinetic probe and the exhaust pipe:

$$r = \frac{A_p}{A_r}$$

5.2.2. **Systems with Measurement of CO₂ or NO_x Concentration**

$$G_{EDFW,i} = G_{EXHW,i} * q_i$$

$$q_i = \frac{conc_{E,i} - conc_{A,i}}{conc_{D,i} - conc_{A,i}}$$

where,

conc_E = wet concentration of the tracer gas in the raw exhaust

conc_D = wet concentration of the tracer gas in the diluted exhaust

conc_A = wet concentration of the tracer gas in the dilution air

Concentrations measured on a dry basis shall be converted to a wet basis according to section 4.2 of this Appendix.

5.2.3. **Systems with CO₂ Measurement and Carbon Balance Method¹**

$$G_{EDFW,i} = \frac{206,5 - G_{FUEL,i}}{CO_{2D,i} - CO_{2A,i}}$$

where,

CO_{2D} = CO₂ concentration of the diluted exhaust

CO_{2A} = CO₂ concentration of the dilution air

(concentrations in Vol % on wet basis)

This equation is based upon the carbon balance assumption (carbon atoms supplied to the engine are emitted as CO₂) and determined through the following steps:

$$G_{EDFW,i} = G_{EXHW,i} * q_i$$

$$q_i = \frac{206,5 * G_{FUEL,i}}{G_{EXHW,i} * (CO_{2D,i} - CO_{2A,i})}$$

and,

5.2.4. **Systems with Flow Measurement**

$$G_{EDFW,i} = G_{EXHW,i} * q_i$$

$$q_i = \frac{G_{TOTW,i}}{(G_{TOTW,i} - G_{DILW,i})}$$

¹ The value is only valid for the reference fuel specified in Annex I.

5.3. **Full Flow Dilution System**

The reported test results of the particulate emission shall be determined through the following steps. All calculations shall be based upon the average values of the individual modes during the sampling period.

$$G_{EDFW,i} = G_{TOTW,i}$$

5.4. **Calculation of the Particulate Mass Flow Rate**

The particulate mass flow rate shall be calculated as follows:

$$PT_{mass} = \frac{M_f}{M_{SAM}} * \frac{\overline{G_{EDFW}}}{1000}$$

where

$$\overline{G_{EDFW}} = \sum_{i=1}^{i=n} G_{EDFW,i} * WF_i$$

$$M_{SAM} = \sum_{i=1}^{i=n} M_{SAM,i}$$

i=1,...n

determined over the test cycle by summation of the average values of the individual modes during the sampling period.

The particulate mass flow rate may be background corrected as follows:

$$PT_{mass} = \left[\frac{M_f}{M_{SAM}} - \left(\frac{M_d}{M_{DIL}} * \left(\sum_{i=1}^{i=n} \left(1 - \frac{1}{DF_i} \right) * WF_i \right) \right) \right] * \frac{\overline{G_{EDFW}}}{1000}$$

If more than one measurement is made, (M_d/M_{DIL}) shall be replaced with $\overline{(m_d / M_{DIL})}$

$$DF_i = 13,4 / (\text{concCO}_2 + (\text{concCO} + \text{concHC}) * 10^{-4}) \quad \text{for the individual modes}$$

or,

$$DF_i = 13,4 / \text{concCO}_2 \quad \text{for the individual modes}$$

5.5. **Calculation of the Specific Emission**

The particulate emission shall be calculated in the following way:

$$\overline{PT} = \frac{PT_{mass}}{\sum P(n)_i * WF_i}$$

5.6. **Effective Weighting Factor**

The effective weighting factor WF_{E,i} for each mode shall be calculated in the following way:

$$WF_{E,i} = \frac{M_{SAM,i} * \overline{G_{EDFW}}}{M_{SAM} * G_{EDFW,i}}$$

The value of the effective weighting factors shall be within $\pm 0,003$ (0,005 for the idle mode) of the weighting factors listed in section 2.7.1.

6. CALCULATION OF THE SMOKE VALUES

6.1. Bessel Algorithm

The Bessel algorithm shall be used to compute the 1 s average values from the instantaneous smoke readings, converted in accordance with section 6.3.1. The algorithm emulates a low pass second order filter, and its use requires iterative calculations to determine the coefficients. These coefficients are a function of the response time of the opacimeter system and the sampling rate. Therefore, section 6.1.1 must be repeated whenever the system response time and/or sampling rate changes.

6.1.1. Calculation of Filter Response Time and Bessel Constants

The required Bessel response time (t_f) is a function of the physical and electrical response times of the opacimeter system, as specified in Annex III, Appendix 4, section 5.2.4, and shall be calculated by the following equation:

$$t_f = \sqrt{1 - (t_p^2 + t_e^2)}$$

where,

t_p = physical response time, s
 t_e = electrical response time, s

The calculations for estimating the filter cut-off frequency (f_c) are based on a step input of 0 to 1 in $\leq 0,01$ s (see Annex VII). The response time is defined as the time between when the Bessel output reaches 10% (t_{10}) and when it reaches 90% (t_{90}) of this step function. This must be obtained by iterating on f_c until $t_{90} - t_{10} \approx t_f$. The first iteration for f_c is given by the following formula :

$$f_c = \pi / (10 * t_f)$$

The Bessel constants E and K shall be calculated by the following equations:

$$E = \frac{1}{1 + \Omega * \sqrt{3} * D + D * \Omega^2}$$

$$K = 2 * E * (D * \Omega^2 - 1) - 1$$

where:

D = 0,618034
 Δt = 1 / sampling rate
 Ω = $1 / [\tan(\pi * \Delta t * f_c)]$

6.1.2. Calculation of the Bessel Algorithm

Using the values of E and K, the 1 s Bessel averaged response to a step input S_i shall be calculated as follows:

$$Y_i = Y_{i-1} + E * (S_i + 2 * S_{i-1} + S_{i-2} - 4 * Y_{i-2}) + K * (Y_{i-1} - Y_{i-2})$$

where

$S_{i-2} = S_{i-1} = 0$
 $S_i = 1$
 $Y_{i-2} = Y_{i-1} = 0$

The times t_{10} and t_{90} shall be interpolated. The difference in time between t_{90} and t_{10} defines the response time t_F for that value of f_c . If this response time is not close enough to the required response time, iteration shall be continued until the actual response time is within 1% of the required response as follows:

$$|(t_{90} - t_{10}) - t_F| \leq 0,01 * t_F$$

6.2 Data Evaluation

The smoke measurement values shall be sampled with a minimum rate of 20 Hz.

6.3 Determination of Smoke

6.3.1 Data Conversion

Since the basic measurement unit of all opacimeters is transmittance, the smoke values shall be converted from transmittance (τ) to the light absorption coefficient (k) as follows:

$$k = -\frac{1}{L_A} * \ln\left(1 - \frac{N}{100}\right)$$

and,

$$N = 100 - \tau$$

where,

| | | |
|--------|---|---|
| k | = | light absorption coefficient, m^{-1} |
| L_A | = | effective optical path length, as submitted by instrument manufacturer, m |
| N | = | opacity, % |
| τ | = | transmittance, % |

The conversion shall be applied, before any further data processing is made.

6.3.2 Calculation of Bessel Averaged Smoke

The proper cut-off frequency f_c is the one that produces the required filter response time t_F . Once this frequency has been determined through the iterative process of section 6.1.1, the proper Bessel algorithm constants E and K shall be calculated. The Bessel algorithm shall then be applied to the instantaneous smoke trace (k-value), as described in section 6.1.2:

$$Y_i = Y_{i-1} + E * (S_i + 2 * S_{i-1} + S_{i-2} - 4 * Y_{i-2}) + K * (Y_{i-1} - Y_{i-2})$$

The Bessel algorithm is recursive in nature. Thus, it needs some initial input values of S_{i-1} and S_{i-2} and initial output values Y_{i-1} and Y_{i-2} to get the algorithm started. These may be assumed to be 0.

For each load step of the three speeds A, B and C, the maximum 1s value Y_{max} shall be selected from the individual Y_i values of each smoke trace.

6.3.3 *Final Result*

The mean smoke values (SV) from each cycle (test speed) shall be calculated as follows:

For test speed A:

$$SV_A = (Y_{\max 1,A} + Y_{\max 2,A} + Y_{\max 3,A}) / 3$$

For test speed B:

$$SV_B = (Y_{\max 1,B} + Y_{\max 2,B} + Y_{\max 3,B}) / 3$$

For test speed C:

$$SV_C = (Y_{\max 1,C} + Y_{\max 2,C} + Y_{\max 3,C}) / 3$$

where,

$Y_{\max 1}$, $Y_{\max 2}$, $Y_{\max 3}$ = highest 1 s Bessel averaged smoke value at each of the three load steps

The final value shall be calculated as follows:

$$SV = (0,43 * SV_A) + (0,56 * SV_B) + (0,01 * SV_C)$$

ANNEX III - APPENDIX 2

ETC TEST CYCLE

1. ENGINE MAPPING PROCEDURE

1.1. Determination of the Mapping Speed Range

For generating the ETC on the test cell, the engine needs to be mapped prior to the test cycle for determining the speed vs. torque curve. The minimum and maximum mapping speeds are defined as follows:

Minimum mapping speed = idle speed

Maximum mapping speed = $n_{hi} * 1,02$ or speed where full load torque drops off to zero, whichever is lower

1.2. Performing the Engine Power Map

The engine shall be warmed up at maximum power in order to stabilise the engine parameters according to the recommendation of the manufacturer and good engineering practice. When the engine is stabilised, the engine map shall be performed as follows:

The engine shall be unloaded and operated at idle speed.

The engine shall be operated at full load setting of the injection pump at minimum mapping speed.

The engine speed shall be increased at an average rate of $8 \pm 1 \text{ min}^{-1} / \text{s}$ from minimum to maximum mapping speed. Engine speed and torque points shall be recorded at a sample rate of a least one point per second.

1.3. Mapping Curve Generation

All data points recorded under section 1.2 shall be connected using linear interpolation between points. The resulting torque curve is the mapping curve and shall be used to convert the normalised torque values of the engine cycle into actual torque values for the test cycle, as described in section 2.

1.4. Alternate Mapping

If a manufacturer believes that the above mapping techniques are unsafe or unrepresentative for any given engine, alternate mapping techniques may be used. These alternate techniques must satisfy the intent of the specified mapping procedures to determine the maximum available torque at all engine speeds achieved during the test cycles. Deviations from the mapping techniques specified in this section for reasons of safety or representativeness shall be approved by the Technical Service along with the justification for their use. In no case, however, shall descending continual sweeps of engine speed be used for governed or turbocharged engines.

1.5. Replicate Tests

An engine need not be mapped before each and every test cycle. An engine shall be remapped prior to a test cycle if:

- an unreasonable amount of time has transpired since the last map, as determined by engineering judgement,

or,

- physical changes or recalibrations have been made to the engine which may potentially affect engine performance.

2. GENERATION OF THE REFERENCE TEST CYCLE

The transient test cycle is described in Appendix 3 to this Annex. The normalised values for torque and speed shall be changed to the actual values, as follows, resulting in the reference cycle.

2.1. Actual Speed

The speed shall be unnormalised using the following equation:

$$\text{Actual speed} = \frac{\% \text{ speed (reference speed - idle speed)}}{100} + \text{idle speed}$$

The reference speed (n_{ref}) corresponds to the 100 % speed values specified in the engine dynamometer schedule of Appendix 3. It is defined as follows (see Figure 1 of Annex I):

$$n_{ref} = n_{lo} + 95 \% * (n_{hi} - n_{lo})$$

where n_{hi} and n_{lo} are either specified according to Annex I, section 2 or determined according to Annex III, Appendix 1, section 1.1

2.2. Actual Torque

The torque is normalised to the maximum torque at the respective speed. The torque values of the reference cycle shall be unnormalised, using the mapping curve determined according to section 1.3, as follows:

$$\text{Actual torque} = \frac{\% \text{ torque} * \text{max torque}}{100} \quad \text{for the respective actual speed as determined in section 2.1.}$$

The negative torque values of the motoring points ("m") shall take on, for purposes of reference cycle generation, unnormalised values determined in either of the following ways:

- _negative 40 % of the positive torque available at the associated speed point;
- _mapping of the negative torque required to motor the engine from minimum to maximum mapping speed;
- _determination of the negative torque required to motor the engine at idle and reference speeds and linear interpolation between these two points.

2.3 Example of the Unnormalisation Procedure

As an example, the following test point shall be unnormalised:

$$\begin{aligned} \% \text{ speed} &= 43 \\ \% \text{ torque} &= 82 \end{aligned}$$

Given the following values:

$$\begin{aligned} \text{reference speed} &= 2200 \text{ min}^{-1} \\ \text{idle speed} &= 600 \text{ min}^{-1} \end{aligned}$$

results in,

$$\text{actual speed} = \frac{43 * (2200 - 600)}{100} + 600 = 1288 \text{ min}^{-1}$$

$$\text{actual torque} = \frac{82 * 700}{100} = 574 \text{ Nm}$$

where the maximum torque observed from the mapping curve at 1288 min⁻¹ is 700 Nm.

3 EMISSIONS TEST RUN

At the manufacturers request, a dummy test may be run for conditioning of the engine and exhaust system before the measurement cycle.

NG and LPG fuelled engines shall be run-in using the ETC test. The engine shall be run over a minimum of two ETC cycles and until the CO emission measured over one ETC cycle does not exceed by more than 10% the CO emission measured over the previous ETC cycle.

3.1 Preparation of the Sampling Filters (Diesel Engines Only)

At least one hour before the test, each filter (pair) shall be placed in a closed, but unsealed petri dish and placed in a weighing chamber for stabilisation. At the end of the stabilisation period, each filter (pair) shall be weighed and the tare weight shall be recorded. The filter (pair) shall then be stored in a closed petri dish or sealed filter holder until needed for testing. If the filter (pair) is not used within eight hours of its removal from the weighing chamber, it must be conditioned and reweighed before use.

3.2. Installation of the Measuring Equipment

The instrumentation and sample probes shall be installed as required. The tailpipe shall be connected to the full flow dilution system.

3.3. Starting the Dilution System and the Engine

The dilution system and the engine shall be started and warmed up until all temperatures and pressures have stabilised at maximum power according to the recommendation of the manufacturer and good engineering practice.

3.4. Starting the Particulate Sampling System (Diesel Engines Only)

The particulate sampling system shall be started and running on by-pass. The particulate background level of the dilution air may be determined by passing dilution air through the particulate filters. If filtered dilution air is used, one measurement may be done prior to or after the test. If the dilution air is not filtered, measurements at the beginning and at the end of the cycle, may be done, and the values averaged.

3.5. Adjustment of the Full Flow Dilution System

The total diluted exhaust gas flow shall be set to eliminate water condensation in the system, and to obtain a maximum filter face temperature of 325 K (52°C) or less (see Annex V, section 2.3.1, DT).

3.6. Checking the Analysers

The emission analysers shall be set at zero and spanned. If sample bags are used, they shall be evacuated.

3.7. Engine Starting Procedure

--

The stabilised engine shall be started according to the manufacturer's recommended starting procedure in the owner's manual, using either a production starter motor or the dynamometer. Optionally, the test may start directly from the engine preconditioning phase without shutting the engine off, when the engine has reached the idle speed.

3.8. Test Cycle

3.8.1. Test Sequence

The test sequence shall be started, if the engine has reached idle speed. The test shall be performed according to the reference cycle as set out in section 2 of this Appendix. Engine speed and torque command set points shall be issued at 5 Hz (10 Hz recommended) or greater. Feedback engine speed and torque shall be recorded at least once every second during the test cycle, and the signals may be electronically filtered.

3.8.2. Analyser Response

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the measuring equipment shall be started, simultaneously:

- start collecting or analysing dilution air;
- start collecting or analysing diluted exhaust gas;
- start measuring the amount of diluted exhaust gas (CVS) and the required temperatures and pressures;
- start recording the feedback data of speed and torque of the dynamometer.

HC and NO_x shall be measured continuously in the dilution tunnel with a frequency of 2 Hz. The average concentrations shall be determined by integrating the analyser signals over the test cycle. The system response time shall be no greater than 20 s, and shall be coordinated with CVS flow fluctuations and sampling time/test cycle offsets, if necessary. CO, CO₂, NMHC and CH₄ shall be determined by integration or by analysing the concentrations in the sample bag, collected over the cycle. The concentrations of the gaseous pollutants in the dilution air shall be determined by integration or by collecting into the background bag. All other values shall be recorded with a minimum of one measurement per second (1 Hz).

3.8.3. Particulate Sampling (Diesel Engines Only)

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the particulate sampling system shall be switched from by-pass to collecting particulates.

If no flow compensation is used, the sample pump(s) shall be adjusted so that the flow rate through the particulate sample probe or transfer tube is maintained at a value within $\pm 5\%$ of the set flow rate. If flow compensation (i.e., proportional control of sample flow) is used, it must be demonstrated that the ratio of main tunnel flow to particulate sample flow does not change by more than $\pm 5\%$ of its set value (except for the first 10 seconds of sampling).

Note: For double dilution operation, sample flow is the net difference between the flow rate through the sample filters and the secondary dilution air flow rate.

The average temperature and pressure at the gas meter(s) or flow instrumentation inlet shall be recorded. If the set flow rate cannot be maintained over the complete cycle (within $\pm 5\%$) because of high particulate loading on the filter, the test shall be voided. The test shall be rerun using a lower flow rate and/or a larger diameter filter.

3.8.4. **Engine Stalling**

If the engine stalls anywhere during the test cycle, the engine shall be preconditioned and restarted, and the test repeated. If a malfunction occurs in any of the required test equipment during the test cycle, the test shall be voided.

3.8.5. **Operations After Test**

At the completion of the test, the measurement of the diluted exhaust gas volume, the gas flow into the collecting bags and the particulate sample pump shall be stopped. For an integrating analyser system, sampling shall continue until system response times have elapsed.

The concentrations of the collecting bags, if used, shall be analysed as soon as possible and in any case not later than 20 minutes after the end of the test cycle.

After the emission test, a zero gas and the same span gas shall be used for re-checking the analysers. The test will be considered acceptable if the difference between the pre-test and post-test results is less than 2 % of the span gas value.

For diesel engines only, the particulate filters shall be returned to the weighing chamber no later than one hour after completion of the test and shall be conditioned in a closed, but unsealed petri dish for at least one hour, but not more than 80 hours before weighing.

3.9. **Verification of the Test Run**

3.9.1. **Data Shift**

To minimise the biasing effect of the time lag between the feedback and reference cycle values, the entire engine speed and torque feedback signal sequence may be advanced or delayed in time with respect to the reference speed and torque sequence. If the feedback signals are shifted, both speed and torque must be shifted the same amount in the same direction.

3.9.2. **Calculation of the Cycle Work**

The actual cycle work W_{act} (kWh) shall be calculated using each pair of engine feedback speed and torque values recorded. This shall be done after any feedback data shift has occurred, if this option is selected. The actual cycle work W_{act} is used for comparison to the reference cycle work W_{ref} and for calculating the brake specific emissions (see sections 4.4 and 5.2). The same methodology shall be used for integrating both reference and actual engine power. If values are to be determined between adjacent reference or adjacent measured values, linear interpolation shall be used.

In integrating the reference and actual cycle work, all negative torque values shall be set equal to zero and included. If integration is performed at a frequency of less than 5 Hertz, and if, during a given time segment, the torque value changes from positive to negative or negative to positive, the negative portion shall be computed and set equal to zero. The positive portion shall be included in the integrated value.

W_{act} shall be between -15 % and + 5 % of W_{ref} .

3.9.3. *Validation Statistics of the Test Cycle* --

Linear regressions of the feedback values on the reference values shall be performed for speed, torque and power. This shall be done after any feedback data shift has occurred, if this option is selected. The method of least squares shall be used, with the best fit equation having the form:

$$y = mx + b$$

where:

- y = feedback (actual) value of speed (min^{-1}), torque (Nm), or power (kW)
- m = slope of the regression line
- x = reference value of speed (min^{-1}), torque (Nm), or power (kW)
- b = y intercept of the regression line

The standard error of estimate (SE) of y on x and the coefficient of determination (r^2) shall be calculated for each regression line.

It is recommended that this analysis be performed at 1 Hertz. All negative reference torque values and the associated feedback values shall be deleted from the calculation of cycle torque and power validation statistics. For a test to be considered valid, the criteria of table 6 must be met.

Table 6 Regression Line Tolerances

| | Speed | Torque | Power |
|---|----------------------------|--|--|
| Standard error of estimate (SE) of Y on X | max 100 min^{-1} | max 13 % of power map maximum engine torque | max 8% of power map maximum engine power |
| Slope of the regression line, m | 0,95 to 1,03 | 0,83 - 1,03 | 0,89 - 1,03 |
| Coefficient of determination, r^2 | min 0,9700 | min 0,8800 | min 0,9100 |
| Y intercept of the regression line, b | $\pm 50 \text{ min}^{-1}$ | $\pm 20 \text{ Nm}$ or $\pm 2 \%$ of max torque whichever is greater | $\pm 4 \text{ kW}$ or $\pm 2 \%$ of max power whichever is greater |

Point deletions from the regression analyses are permitted where noted in table 7.

Table 7 Permitted Point Deletions From Regression Analysis

| Condition | Points to be deleted |
|--|----------------------|
| Full load and torque feedback < torque reference | Torque and/or power |
| No load, not an idle point, and torque feedback > torque reference | Torque and/or power |
| No load/closed throttle, idle point and speed > reference idle speed | Speed and/or power |

4. CALCULATION OF THE GASEOUS EMISSIONS

4.1. Determination of the Diluted Exhaust Gas Flow

The total diluted exhaust gas flow over the cycle (kg/test) shall be calculated from the measurement values over the cycle and the corresponding calibration data of the flow measurement device (V_0 for PDP or K_v for CFV, as determined in Annex III, Appendix 5, section 2). The following formulae shall be applied, if the temperature of the diluted exhaust is kept constant over the cycle by using a heat exchanger (± 6 K for a PDP-CVS, ± 11 K for a CFV-CVS, see Annex V, section 2.3).

For the PDP-CVS system

$$M_{TOTW} = 1,293 * V_0 * N_P * (p_B - p_1) * 273 / (101,3 * T)$$

where,

- M_{TOTW} = mass of the diluted exhaust gas on wet basis over the cycle, kg
- V_0 = volume of gas pumped per revolution under test conditions, m³/rev
- N_P = total revolutions of pump per test
- p_B = atmospheric pressure in the test cell, kPa
- p_1 = pressure depression below atmospheric at pump inlet, kPa
- T = average temperature of the diluted exhaust gas at pump inlet over the cycle, K

For the CFV-CVS system

$$M_{TOTW} = 1,293 * t * K_v * p_A / T^{0,5}$$

where,

- M_{TOTW} = mass of the diluted exhaust gas on wet basis over the cycle, kg
- t = cycle time, s
- K_v = calibration coefficient of the critical flow venturi for standard conditions,
- p_A = absolute pressure at venturi inlet, kPa
- T = absolute temperature at venturi inlet, K

If a system with flow compensation is used (i.e. without heat exchanger), the instantaneous mass emissions shall be calculated and integrated over the cycle. In this case, the instantaneous mass of the diluted exhaust gas shall be calculated as follows.

For the PDP-CVS system:

$$M_{TOTW,i} = 1,293 * V_0 * N_{P,i} * (p_B - p_1) * 273 / (101,3 * T)$$

where,

- $M_{TOTW,i}$ = instantaneous mass of the diluted exhaust gas on wet basis, kg
- $N_{P,i}$ = total revolutions of pump per time interval

For the CFV-CVS system:

$$M_{TOTW,i} = 1,293 * \Delta t_i * K_v * p_A / T^{0,5}$$

where,

- $M_{TOTW,i}$ = instantaneous mass of the diluted exhaust gas on wet basis, kg
- Δt_i = time interval, s

If the total sample mass of particulates (MSAM) and gaseous pollutants exceeds 0,5 % of the total CVS flow (MTOTW), the CVS flow shall be corrected for MSAM or the particulate sample flow shall be returned to the CVS prior to the flow measuring device (PDP or CFV).

4.2. NOx Correction for Humidity

As the NOx emission depends on ambient air conditions, the NOx concentration shall be corrected for ambient air humidity with the factors given in the following formulae.

(a) for diesel engines:

$$K_{H,D} = \frac{1}{1 - 0,0182 * (H_a - 10,71)}$$

(b) for gas engines:

$$K_{H,G} = \frac{1}{1 - 0,0329 * (H_a - 10,71)}$$

where,

Ha = humidity of the intake air water per kg dry air

in which,

$$H_a = \frac{6,220 * R_a * p_a}{p_B - p_a * R_a * 10^{-2}}$$

Ra = relative humidity of the intake air, %

pa = saturation vapour pressure of the intake air, kPa

pB = total barometric pressure, kPa

4.3. Calculation of the Emission Mass Flow

4.3.1 Systems with Constant Mass Flow

For systems with heat exchanger, the mass of the pollutants (g/test) shall be determined from the following equations:

- | | | | |
|--------------|---|------------------------------------|-----------------------|
| (1) NOx mass | = | 0,001587 * NOx conc * KH,D * MTOTW | (diesel engines) |
| (2) NOx mass | = | 0,001587 * NOx conc * KH,G * MTOTW | (gas engines) |
| (3) COmass | = | 0,000966 * COconc * MTOTW | |
| (4) HCmass | = | 0,000479 * HCconc * MTOTW' | (diesel engines) |
| (5) HCmass | = | 0,000502 * HCconc * MTOTW' | (LPG fuelled engines) |
| (6) NMHCmass | = | 0,000516 * NMHCconc * MTOTW' | (NG fuelled engines) |
| (7) CH4 mass | = | 0,000552 * CH4 conc * MTOTW | (NG fuelled engines) |

where,

NO_x conc, COconc, Hcconc ⁽¹⁾, NMHC_{conc} = -- average background corrected concentrations over the cycle from integration (mandatory for NO_x and HC) or bag measurement, ppm

M_{TOTW} = total mass of diluted exhaust gas over the cycle as determined in section 4.1, kg

K_{H,D} = humidity correction factor for diesel engines as determined in section 4.2

K_{H,G} = humidity correction factor for gas engines as determined in section 4.2

Concentrations measured on a dry basis shall be converted to a wet basis in accordance with Annex III, Appendix 1, section 4.2.

The determination of NMHC_{conc} depends on the method used (see Annex III, Appendix 4, section 3.3.4). In both cases, the CH₄ concentration shall be determined and subtracted from the HC concentration as follows:

(a) GC method

$$NMHC_{conc} = HC_{conc} - CH_4_{conc}$$

(b) NMC method

$$NMHC_{conc} = \frac{HC(w/oCutter) * (1 - CE_M) - HC(wCutter)}{CE_C - CE_M}$$

where,

HC(wCutter) = HC concentration with the sample gas flowing through the NMC

HC(w/oCutter) = HC concentration with the sample gas bypassing the NMC

CE_M = methane efficiency as determined per Annex III, Appendix 5, section 1.8.4.1.

CE_E = ethane efficiency as determined per Annex III, Appendix 5, section 1.8.4.2.

⁽¹⁾ Based on C1 equivalent

4.3.1.1. Determination of the Background Corrected Concentrations

The average background concentration of the gaseous pollutants in the dilution air shall be subtracted from measured concentrations to get the net concentrations of the pollutants. The average values of the background concentrations can be determined by the sample bag method or by continuous measurement with integration. The following formula shall be used.

$$\text{conc} = \text{conc}_e - \text{conc}_d * (1 - (1/DF))$$

where,

conc = concentration of the respective pollutant in the diluted exhaust gas, corrected by the amount of the respective pollutant contained in the dilution air, ppm

conc_e = concentration of the respective pollutant measured in the diluted exhaust gas, ppm

conc_d = concentration of the respective pollutant measured in the dilution air, ppm

DF = dilution factor

The dilution factor shall be calculated as follows:

(a) for diesel and LPG fuelled gas engines

$$DF = \frac{F_s}{CO2_{conce} + (HC_{conce} + CO_{conce}) * 10^{-4}}$$

(b) for NG fuelled gas engines

$$DF = \frac{F_s}{CO2_{conce} + (NMHC_{conca} + CO_{conca}) * 10^{-4}}$$

where,

CO_{2,conce} = concentration of CO₂ in the diluted exhaust gas, % vol

HC_{conce} = concentration of HC in the diluted exhaust gas, ppm C1

NMHC_{conce} = concentration of NMHC in the diluted exhaust gas, ppm C1

CO_{conce} = concentration of CO in the diluted exhaust gas, ppm

F_s = stoichiometric factor

Concentrations measured on dry basis shall be converted to a wet basis in accordance with Annex III, Appendix 1, section 4.2.

The stoichiometric factor shall be calculated as follows:

$$F_s = 100 * \frac{x}{x + \frac{y}{2} + 3,76 * \left(x + \frac{y}{4}\right)}$$

where,

x,y = fuel composition C_xH_y

Alternatively, if the fuel composition is not known, the following stoichiometric factors may be used:

| | |
|--------------------------|------|
| F _S (diesel)= | 13,4 |
| F _S (LPG) = | 11,6 |
| F _S (NG) = | 9,5 |

4.3.2. Systems with Flow Compensation

For systems without heat exchanger, the mass of the pollutants (g/test) shall be determined by calculating the instantaneous mass emissions and integrating the instantaneous values over the cycle. Also, the background correction shall be applied directly to the instantaneous concentration value. The following formulae shall be applied:

(1) NO_{x mass} =

$$\sum_{i=1}^n (M_{TOTW,i} * NOx_{conce,i} * 0,001587 * K_{H,D}) - (M_{TOTW} * NOx_{concd} * (1-1/DF) * 0,001587 * K_{H,D})$$

(diesel engines)

(2) NO_{x mass} =

$$\sum_{i=1}^n (M_{TOTW,i} * NOx_{conce,i} * 0,001587 * K_{H,G}) - (M_{TOTW} * NOx_{concd} * (1-1/DF) * 0,001587 * K_{H,G})$$

(gas engines)

(3) CO_{mass} =

$$\sum_{i=1}^n (M_{TOTW,i} * CO_{conce,i} * 0,000966) - (M_{TOTW} * CO_{concd} * (1-1/DF) * 0,000966)$$

(4) HC_{mass} =

$$\sum_{i=1}^n (M_{TOTW,i} * HC_{conce,i} * 0,000479) - (M_{TOTW} * HC_{concd} * (1-1/DF) * 0,000479)$$

(diesel engines)

(5) HC_{mass} =

$$\sum_{i=1}^n (M_{TOTW,i} * HC_{conce,i} * 0,000502) - (M_{TOTW} * HC_{concd} * (1-1/DF) * 0,000502)$$

(LPG engines)

(6) NMHC_{mass} =

$$\sum_{i=1}^n (M_{TOTW,i} * NMHC_{conce,i} * 0,000516) - (M_{TOTW} * NMHC_{concd} * (1-1/DF) * 0,000516)$$

(NG engines)

(7) CH_{4 mass} =

$$\sum_{i=1}^n (M_{TOTW,i} * CH_{4conce,i} * 0,000552) - (M_{TOTW} * CH_{4concd} * (1-1/DF) * 0,000552)$$

(NG engines)

where,

| | | |
|---------------------|---|--|
| conc _e | = | concentration of the respective pollutant measured in the diluted exhaust gas, ppm |
| conc _d | = | concentration of the respective pollutant measured in the dilution air, ppm |
| M _{TOTW,i} | = | instantaneous mass of the diluted exhaust gas (see section 4.1), kg |
| M _{TOTW} | = | total mass of diluted exhaust gas over the cycle (see section 4.1), kg |
| K _{H,D} | = | humidity correction factor for diesel engines as determined in section 4.2 |
| K _{H,G} | = | humidity correction factor for gas engines as determined in section 4.2 |
| DF | = | dilution factor as determined in section 4.3.1.1 |

4.4. Calculation of the Specific Emissions

--

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

$$\overline{NO_x} = NOx_{mass} / W_{act} \quad (\text{diesel and gas engines})$$

$$\overline{CO} = CO_{mass} / W_{act} \quad (\text{diesel and gas engines})$$

$$\overline{HC} = HC_{mass} / W_{act} \quad (\text{diesel and LPG fuelled gas engines})$$

$$\overline{NMHC} = NMHC_{mass} / W_{act} \quad (\text{NG fuelled gas engines})$$

$$\overline{CH_4} = CH_{4mass} / W_{act} \quad (\text{NG fuelled gas engines})$$

where,

W_{act} = actual cycle work as determined in section 3.9.2, kWh

5. CALCULATION OF THE PARTICULATE EMISSION (DIESEL ENGINES ONLY)

5.1. Calculation of the Mass Flow

The particulate mass (g/test) shall be calculated as follows:

$$PT_{mass} = \frac{M_f}{M_{SAM}} * \frac{M_{TOTW}}{1000}$$

where,

M_f = particulate mass sampled over the cycle, mg
 M_{TOTW} = total mass of diluted exhaust gas over the cycle as determined in section 4.1, kg
 M_{SAM} = mass of diluted exhaust gas taken from the dilution tunnel for collecting particulates, kg

and,

M_f = $M_{f,p} + M_{f,b}$, if weighed separately, mg
 $M_{f,p}$ = particulate mass collected on the primary filter, mg
 $M_{f,b}$ = particulate mass collected on the back-up filter, mg

If a double dilution system is used, the mass of the secondary dilution air shall be subtracted from the total mass of the double diluted exhaust gas sampled through the particulate filters.

$$M_{SAM} = M_{TOT} - M_{SEC}$$

where,

M_{TOT} = mass of double diluted exhaust gas through particulate filter, kg
 M_{SEC} = mass of secondary dilution air, kg

If the particulate background level of the dilution air $\bar{a}ir$ is determined in accordance with section 3.4, the particulate mass may be background corrected. In this case, the particulate mass (g/test) shall be calculated as follows:

$$PT_{mass} = \left[\frac{M_f}{M_{SAM}} - \left(\frac{M_d}{M_{DIL}} * \left(1 - \frac{1}{DF} \right) \right) \right] * \frac{M_{TOTW}}{1000}$$

where,

M_f, M_{SAM}, M_{TOTW} = see above
 M_{DIL} = mass of primary dilution air sampled by background particulate sampler, kg
 M_d = mass of the collected background particulates of the primary dilution air, mg
 DF = dilution factor as determined in section 4.3.1.1

5.2. Calculation of the Specific Emission

The particulate emission (g/kWh) shall be calculated in the following way:

$$\overline{PT} = PT_{mass} / W_{act}$$

where,

W_{act} = actual cycle work as determined in section 3.9.2, kWh

ANNEX III- APPENDIX 3

ETC ENGINE DYNAMOMETER SCHEDULE

| Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|------|-------------|--------------|------|-------------|--------------|
| s | % | % | s | % | % | s | % | % |
| 1 | 0 | 0 | 52 | 0 | 0 | 103 | 0 | 0 |
| 2 | 0 | 0 | 53 | 0 | 0 | 104 | 0 | 0 |
| 3 | 0 | 0 | 54 | 0 | 0 | 105 | 0 | 0 |
| 4 | 0 | 0 | 55 | 0 | 0 | 106 | 0 | 0 |
| 5 | 0 | 0 | 56 | 0 | 0 | 107 | 0 | 0 |
| 6 | 0 | 0 | 57 | 0 | 0 | 108 | 11,6 | 14,8 |
| 7 | 0 | 0 | 58 | 0 | 0 | 109 | 0 | 0 |
| 8 | 0 | 0 | 59 | 0 | 0 | 110 | 27,2 | 74,8 |
| 9 | 0 | 0 | 60 | 0 | 0 | 111 | 17 | 76,9 |
| 10 | 0 | 0 | 61 | 0 | 0 | 112 | 36 | 78 |
| 11 | 0 | 0 | 62 | 25,5 | 11,1 | 113 | 59,7 | 86 |
| 12 | 0 | 0 | 63 | 28,5 | 20,9 | 114 | 80,8 | 17,9 |
| 13 | 0 | 0 | 64 | 32 | 73,9 | 115 | 49,7 | 0 |
| 14 | 0 | 0 | 65 | 4 | 82,3 | 116 | 65,6 | 86 |
| 15 | 0 | 0 | 66 | 34,5 | 80,4 | 117 | 78,6 | 72,2 |
| 16 | 0,1 | 1,5 | 67 | 64,1 | 86 | 118 | 64,9 | "m" |
| 17 | 23,1 | 21,5 | 68 | 58 | 0 | 119 | 44,3 | "m" |
| 18 | 12,6 | 28,5 | 69 | 50,3 | 83,4 | 120 | 51,4 | 83,4 |
| 19 | 21,8 | 71 | 70 | 66,4 | 99,1 | 121 | 58,1 | 97 |
| 20 | 19,7 | 76,8 | 71 | 81,4 | 99,6 | 122 | 69,3 | 99,3 |
| 21 | 54,6 | 80,9 | 72 | 88,7 | 73,4 | 123 | 72 | 20,8 |
| 22 | 71,3 | 4,9 | 73 | 52,5 | 0 | 124 | 72,1 | "m" |
| 23 | 55,9 | 18,1 | 74 | 46,4 | 58,5 | 125 | 65,3 | "m" |
| 24 | 72 | 85,4 | 75 | 48,6 | 90,9 | 126 | 64 | "m" |
| 25 | 86,7 | 61,8 | 76 | 55,2 | 99,4 | 127 | 59,7 | "m" |
| 26 | 51,7 | 0 | 77 | 62,3 | 99 | 128 | 52,8 | "m" |
| 27 | 53,4 | 48,9 | 78 | 68,4 | 91,5 | 129 | 45,9 | "m" |
| 28 | 34,2 | 87,6 | 79 | 74,5 | 73,7 | 130 | 38,7 | "m" |
| 29 | 45,5 | 92,7 | 80 | 38 | 0 | 131 | 32,4 | "m" |
| 30 | 54,6 | 99,5 | 81 | 41,8 | 89,6 | 132 | 27 | "m" |
| 31 | 64,5 | 96,8 | 82 | 47,1 | 99,2 | 133 | 21,7 | "m" |
| 32 | 71,7 | 85,4 | 83 | 52,5 | 99,8 | 134 | 19,1 | 0,4 |
| 33 | 79,4 | 54,8 | 84 | 56,9 | 80,8 | 135 | 34,7 | 14 |
| 34 | 89,7 | 99,4 | 85 | 58,3 | 11,8 | 136 | 16,4 | 48,6 |
| 35 | 57,4 | 0 | 86 | 56,2 | "m" | 137 | 0 | 11,2 |
| 36 | 59,7 | 30,6 | 87 | 52 | "m" | 138 | 1,2 | 2,1 |
| 37 | 90,1 | "m" | 88 | 43,3 | "m" | 139 | 30,1 | 19,3 |
| 38 | 82,9 | "m" | 89 | 36,1 | "m" | 140 | 30 | 73,9 |
| 39 | 51,3 | "m" | 90 | 27,6 | "m" | 141 | 54,4 | 74,4 |
| 40 | 28,5 | "m" | 91 | 21,1 | "m" | 142 | 77,2 | 55,6 |
| 41 | 29,3 | "m" | 92 | 8 | 0 | 143 | 58,1 | 0 |
| 42 | 26,7 | "m" | 93 | 0 | 0 | 144 | 45 | 82,1 |
| 43 | 20,4 | "m" | 94 | 0 | 0 | 145 | 68,7 | 98,1 |
| 44 | 14,1 | 0 | 95 | 0 | 0 | 146 | 85,7 | 67,2 |
| 45 | 6,5 | 0 | 96 | 0 | 0 | 147 | 60,2 | 0 |
| 46 | 0 | 0 | 97 | 0 | 0 | 148 | 59,4 | 98 |
| 47 | 0 | 0 | 98 | 0 | 0 | 149 | 72,7 | 99,6 |
| 48 | 0 | 0 | 99 | 0 | 0 | 150 | 79,9 | 45 |
| 49 | 0 | 0 | 100 | 0 | 0 | 151 | 44,3 | 0 |
| 50 | 0 | 0 | 101 | 0 | 0 | 152 | 41,5 | 84,4 |
| 51 | 0 | 0 | 102 | 0 | 0 | 153 | 56,2 | 98,2 |

| Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|------|-------------|--------------|------|-------------|--------------|
| s | % | % | s | % | % | s | % | % |
| 154 | 65,7 | 99,1 | 205 | 0 | 0 | 256 | 51,7 | 17 |
| 155 | 74,4 | 84,7 | 206 | 0 | 0 | 257 | 56,2 | 78,7 |
| 156 | 54,4 | 0 | 207 | 0 | 0 | 258 | 59,5 | 94,7 |
| 157 | 47,9 | 89,7 | 208 | 0 | 0 | 259 | 65,5 | 99,1 |
| 158 | 54,5 | 99,5 | 209 | 0 | 0 | 260 | 71,2 | 99,5 |
| 159 | 62,7 | 96,8 | 210 | 0 | 0 | 261 | 76,6 | 99,9 |
| 160 | 62,3 | 0 | 211 | 0 | 0 | 262 | 79 | 0 |
| 161 | 46,2 | 54,2 | 212 | 0 | 0 | 263 | 52,9 | 97,5 |
| 162 | 44,3 | 83,2 | 213 | 0 | 0 | 264 | 53,1 | 99,7 |
| 163 | 48,2 | 13,3 | 214 | 0 | 0 | 265 | 59 | 99,1 |
| 164 | 51 | "m" | 215 | 0 | 0 | 266 | 62,2 | 99 |
| 165 | 50 | "m" | 216 | 0 | 0 | 267 | 65 | 99,1 |
| 166 | 49,2 | "m" | 217 | 0 | 0 | 268 | 69 | 83,1 |
| 167 | 49,3 | "m" | 218 | 0 | 0 | 269 | 69,9 | 28,4 |
| 168 | 49,9 | "m" | 219 | 0 | 0 | 270 | 70,6 | 12,5 |
| 169 | 51,6 | "m" | 220 | 0 | 0 | 271 | 68,9 | 8,4 |
| 170 | 49,7 | "m" | 221 | 0 | 0 | 272 | 69,8 | 9,1 |
| 171 | 48,5 | "m" | 222 | 0 | 0 | 273 | 69,6 | 7 |
| 172 | 50,3 | 72,5 | 223 | 0 | 0 | 274 | 65,7 | "m" |
| 173 | 51,1 | 84,5 | 224 | 0 | 0 | 275 | 67,1 | "m" |
| 174 | 54,6 | 64,8 | 225 | 21,2 | 62,7 | 276 | 66,7 | "m" |
| 175 | 56,6 | 76,5 | 226 | 30,8 | 75,1 | 277 | 65,6 | "m" |
| 176 | 58 | "m" | 227 | 5,9 | 82,7 | 278 | 64,5 | "m" |
| 177 | 53,6 | "m" | 228 | 34,6 | 80,3 | 279 | 62,9 | "m" |
| 178 | 40,8 | "m" | 229 | 59,9 | 87 | 280 | 59,3 | "m" |
| 179 | 32,9 | "m" | 230 | 84,3 | 86,2 | 281 | 54,1 | "m" |
| 180 | 26,3 | "m" | 231 | 68,7 | "m" | 282 | 51,3 | "m" |
| 181 | 20,9 | "m" | 232 | 43,6 | "m" | 283 | 47,9 | "m" |
| 182 | 10 | 0 | 233 | 41,5 | 85,4 | 284 | 43,6 | "m" |
| 183 | 0 | 0 | 234 | 49,9 | 94,3 | 285 | 39,4 | "m" |
| 184 | 0 | 0 | 235 | 60,8 | 99 | 286 | 34,7 | "m" |
| 185 | 0 | 0 | 236 | 70,2 | 99,4 | 287 | 29,8 | "m" |
| 186 | 0 | 0 | 237 | 81,1 | 92,4 | 288 | 20,9 | 73,4 |
| 187 | 0 | 0 | 238 | 49,2 | 0 | 289 | 36,9 | "m" |
| 188 | 0 | 0 | 239 | 56 | 86,2 | 290 | 35,5 | "m" |
| 189 | 0 | 0 | 240 | 56,2 | 99,3 | 291 | 20,9 | "m" |
| 190 | 0 | 0 | 241 | 61,7 | 99 | 292 | 49,7 | 11,9 |
| 191 | 0 | 0 | 242 | 69,2 | 99,3 | 293 | 42,5 | "m" |
| 192 | 0 | 0 | 243 | 74,1 | 99,8 | 294 | 32 | "m" |
| 193 | 0 | 0 | 244 | 72,4 | 8,4 | 295 | 23,6 | "m" |
| 194 | 0 | 0 | 245 | 71,3 | 0 | 296 | 19,1 | 0 |
| 195 | 0 | 0 | 246 | 71,2 | 9,1 | 297 | 15,7 | 73,5 |
| 196 | 0 | 0 | 247 | 67,1 | "m" | 298 | 25,1 | 76,8 |
| 197 | 0 | 0 | 248 | 65,5 | "m" | 299 | 34,5 | 81,4 |
| 198 | 0 | 0 | 249 | 64,4 | "m" | 300 | 44,1 | 87,4 |
| 199 | 0 | 0 | 250 | 62,9 | 25,6 | 301 | 52,8 | 98,6 |
| 200 | 0 | 0 | 251 | 62,2 | 35,6 | 302 | 63,6 | 99 |
| 201 | 0 | 0 | 252 | 62,9 | 24,4 | 303 | 73,6 | 99,7 |
| 202 | 0 | 0 | 253 | 58,8 | "m" | 304 | 62,2 | "m" |
| 203 | 0 | 0 | 254 | 56,9 | "m" | 305 | 29,2 | "m" |
| 204 | 0 | 0 | 255 | 54,5 | "m" | 306 | 46,4 | 22 |

| Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|------|-------------|--------------|------|-------------|--------------|
| s | % | % | s | % | % | s | % | % |
| 307 | 47,3 | 13,8 | 358 | 72,6 | 99,6 | 409 | 56,3 | 72,3 |
| 308 | 47,2 | 12,5 | 359 | 82,4 | 99,5 | 410 | 59,7 | 99,1 |
| 309 | 47,9 | 11,5 | 360 | 88 | 99,4 | 411 | 62,3 | 99 |
| 310 | 47,8 | 35,5 | 361 | 46,4 | 0 | 412 | 67,9 | 99,2 |
| 311 | 49,2 | 83,3 | 362 | 53,4 | 95,2 | 413 | 69,5 | 99,3 |
| 312 | 52,7 | 96,4 | 363 | 58,4 | 99,2 | 414 | 73,1 | 99,7 |
| 313 | 57,4 | 99,2 | 364 | 61,5 | 99 | 415 | 77,7 | 99,8 |
| 314 | 61,8 | 99 | 365 | 64,8 | 99 | 416 | 79,7 | 99,7 |
| 315 | 66,4 | 60,9 | 366 | 68,1 | 99,2 | 417 | 82,5 | 99,5 |
| 316 | 65,8 | "m" | 367 | 73,4 | 99,7 | 418 | 85,3 | 99,4 |
| 317 | 59 | "m" | 368 | 73,3 | 29,8 | 419 | 86,6 | 99,4 |
| 318 | 50,7 | "m" | 369 | 73,5 | 14,6 | 420 | 89,4 | 99,4 |
| 319 | 41,8 | "m" | 370 | 68,3 | 0 | 421 | 62,2 | 0 |
| 320 | 34,7 | "m" | 371 | 45,4 | 49,9 | 422 | 52,7 | 96,4 |
| 321 | 28,7 | "m" | 372 | 47,2 | 75,7 | 423 | 50,2 | 99,8 |
| 322 | 25,2 | "m" | 373 | 44,5 | 9 | 424 | 49,3 | 99,6 |
| 323 | 43 | 24,8 | 374 | 47,8 | 10,3 | 425 | 52,2 | 99,8 |
| 324 | 38,7 | 0 | 375 | 46,8 | 15,9 | 426 | 51,3 | 100 |
| 325 | 48,1 | 31,9 | 376 | 46,9 | 12,7 | 427 | 51,3 | 100 |
| 326 | 40,3 | 61 | 377 | 46,8 | 8,9 | 428 | 51,1 | 100 |
| 327 | 42,4 | 52,1 | 378 | 46,1 | 6,2 | 429 | 51,1 | 100 |
| 328 | 46,4 | 47,7 | 379 | 46,1 | "m" | 430 | 51,8 | 99,9 |
| 329 | 46,9 | 30,7 | 380 | 45,5 | "m" | 431 | 51,3 | 100 |
| 330 | 46,1 | 23,1 | 381 | 44,7 | "m" | 432 | 51,1 | 100 |
| 331 | 45,7 | 23,2 | 382 | 43,8 | "m" | 433 | 51,3 | 100 |
| 332 | 45,5 | 31,9 | 383 | 41 | "m" | 434 | 52,3 | 99,8 |
| 333 | 46,4 | 73,6 | 384 | 41,1 | 6,4 | 435 | 52,9 | 99,7 |
| 334 | 51,3 | 60,7 | 385 | 38 | 6,3 | 436 | 53,8 | 99,6 |
| 335 | 51,3 | 51,1 | 386 | 35,9 | 0,3 | 437 | 51,7 | 99,9 |
| 336 | 53,2 | 46,8 | 387 | 33,5 | 0 | 438 | 53,5 | 99,6 |
| 337 | 53,9 | 50 | 388 | 53,1 | 48,9 | 439 | 52 | 99,8 |
| 338 | 53,4 | 52,1 | 389 | 48,3 | "m" | 440 | 51,7 | 99,9 |
| 339 | 53,8 | 45,7 | 390 | 49,9 | "m" | 441 | 53,2 | 99,7 |
| 340 | 50,6 | 22,1 | 391 | 48 | "m" | 442 | 54,2 | 99,5 |
| 341 | 47,8 | 26 | 392 | 45,3 | "m" | 443 | 55,2 | 99,4 |
| 342 | 41,6 | 17,8 | 393 | 41,6 | 3,1 | 444 | 53,8 | 99,6 |
| 343 | 38,7 | 29,8 | 394 | 44,3 | 79 | 445 | 53,1 | 99,7 |
| 344 | 35,9 | 71,6 | 395 | 44,3 | 89,5 | 446 | 55 | 99,4 |
| 345 | 34,6 | 47,3 | 396 | 43,4 | 98,8 | 447 | 57 | 99,2 |
| 346 | 34,8 | 80,3 | 397 | 44,3 | 98,9 | 448 | 61,5 | 99 |
| 347 | 35,9 | 87,2 | 398 | 43 | 98,8 | 449 | 59,4 | 5,7 |
| 348 | 38,8 | 90,8 | 399 | 42,2 | 98,8 | 450 | 59 | 0 |
| 349 | 41,5 | 94,7 | 400 | 42,7 | 98,8 | 451 | 57,3 | 59,8 |
| 350 | 47,1 | 99,2 | 401 | 45 | 99 | 452 | 64,1 | 99 |
| 351 | 53,1 | 99,7 | 402 | 43,6 | 98,9 | 453 | 70,9 | 90,5 |
| 352 | 46,4 | 0 | 403 | 42,2 | 98,8 | 454 | 58 | 0 |
| 353 | 42,5 | 0,7 | 404 | 44,8 | 99 | 455 | 41,5 | 59,8 |
| 354 | 43,6 | 58,6 | 405 | 43,4 | 98,8 | 456 | 44,1 | 92,6 |
| 355 | 47,1 | 87,5 | 406 | 45 | 99 | 457 | 46,8 | 99,2 |
| 356 | 54,1 | 99,5 | 407 | 42,2 | 54,3 | 458 | 47,2 | 99,3 |
| 357 | 62,9 | 99 | 408 | 61,2 | 31,9 | 459 | 51 | 100 |

| Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|------|-------------|--------------|------|-------------|--------------|
| s | % | % | s | % | % | s | % | % |
| 460 | 53,2 | 99,7 | 511 | 0 | 0 | 562 | 58,7 | "m" |
| 461 | 53,1 | 99,7 | 512 | 0 | 0 | 563 | 56 | "m" |
| 462 | 55,9 | 53,1 | 513 | 0 | 0 | 564 | 53,9 | "m" |
| 463 | 53,9 | 13,9 | 514 | 30,5 | 25,6 | 565 | 52,1 | "m" |
| 464 | 52,5 | "m" | 515 | 19,7 | 56,9 | 566 | 49,9 | "m" |
| 465 | 51,7 | "m" | 516 | 16,3 | 45,1 | 567 | 46,4 | "m" |
| 466 | 51,5 | 52,2 | 517 | 27,2 | 4,6 | 568 | 43,6 | "m" |
| 467 | 52,8 | 80 | 518 | 21,7 | 1,3 | 569 | 40,8 | "m" |
| 468 | 54,9 | 95 | 519 | 29,7 | 28,6 | 570 | 37,5 | "m" |
| 469 | 57,3 | 99,2 | 520 | 36,6 | 73,7 | 571 | 27,8 | "m" |
| 470 | 60,7 | 99,1 | 521 | 61,3 | 59,5 | 572 | 17,1 | 0,6 |
| 471 | 62,4 | "m" | 522 | 40,8 | 0 | 573 | 12,2 | 0,9 |
| 472 | 60,1 | "m" | 523 | 36,6 | 27,8 | 574 | 11,5 | 1,1 |
| 473 | 53,2 | "m" | 524 | 39,4 | 80,4 | 575 | 8,7 | 0,5 |
| 474 | 44 | "m" | 525 | 51,3 | 88,9 | 576 | 8 | 0,9 |
| 475 | 35,2 | "m" | 526 | 58,5 | 11,1 | 577 | 5,3 | 0,2 |
| 476 | 30,5 | "m" | 527 | 60,7 | "m" | 578 | 4 | 0 |
| 477 | 26,5 | "m" | 528 | 54,5 | "m" | 579 | 3,9 | 0 |
| 478 | 22,5 | "m" | 529 | 51,3 | "m" | 580 | 0 | 0 |
| 479 | 20,4 | "m" | 530 | 45,5 | "m" | 581 | 0 | 0 |
| 480 | 19,1 | "m" | 531 | 40,8 | "m" | 582 | 0 | 0 |
| 481 | 19,1 | "m" | 532 | 38,9 | "m" | 583 | 0 | 0 |
| 482 | 13,4 | "m" | 533 | 36,6 | "m" | 584 | 0 | 0 |
| 483 | 6,7 | "m" | 534 | 36,1 | 72,7 | 585 | 0 | 0 |
| 484 | 3,2 | "m" | 535 | 44,8 | 78,9 | 586 | 0 | 0 |
| 485 | 14,3 | 63,8 | 536 | 51,6 | 91,1 | 587 | 8,7 | 22,8 |
| 486 | 34,1 | 0 | 537 | 59,1 | 99,1 | 588 | 16,2 | 49,4 |
| 487 | 23,9 | 75,7 | 538 | 66 | 99,1 | 589 | 23,6 | 56 |
| 488 | 31,7 | 79,2 | 539 | 75,1 | 99,9 | 590 | 21,1 | 56,1 |
| 489 | 32,1 | 19,4 | 540 | 81 | 8 | 591 | 23,6 | 56 |
| 490 | 35,9 | 5,8 | 541 | 39,1 | 0 | 592 | 46,2 | 68,8 |
| 491 | 36,6 | 0,8 | 542 | 53,8 | 89,7 | 593 | 68,4 | 61,2 |
| 492 | 38,7 | "m" | 543 | 59,7 | 99,1 | 594 | 58,7 | "m" |
| 493 | 38,4 | "m" | 544 | 64,8 | 99 | 595 | 31,6 | "m" |
| 494 | 39,4 | "m" | 545 | 70,6 | 96,1 | 596 | 19,9 | 8,8 |
| 495 | 39,7 | "m" | 546 | 72,6 | 19,6 | 597 | 32,9 | 70,2 |
| 496 | 40,5 | "m" | 547 | 72 | 6,3 | 598 | 43 | 79 |
| 497 | 40,8 | "m" | 548 | 68,9 | 0,1 | 599 | 57,4 | 98,9 |
| 498 | 39,7 | "m" | 549 | 67,7 | "m" | 600 | 72,1 | 73,8 |
| 499 | 39,2 | "m" | 550 | 66,8 | "m" | 601 | 53 | 0 |
| 500 | 38,7 | "m" | 551 | 64,3 | 16,9 | 602 | 48,1 | 86 |
| 501 | 32,7 | "m" | 552 | 64,9 | 7 | 603 | 56,2 | 99 |
| 502 | 30,1 | "m" | 553 | 63,6 | 12,5 | 604 | 65,4 | 98,9 |
| 503 | 21,9 | "m" | 554 | 63 | 7,7 | 605 | 72,9 | 99,7 |
| 504 | 12,8 | 0 | 555 | 64,4 | 38,2 | 606 | 67,5 | "m" |
| 505 | 0 | 0 | 556 | 63 | 11,8 | 607 | 39 | "m" |
| 506 | 0 | 0 | 557 | 63,6 | 0 | 608 | 41,9 | 38,1 |
| 507 | 0 | 0 | 558 | 63,3 | 5 | 609 | 44,1 | 80,4 |
| 508 | 0 | 0 | 559 | 60,1 | 9,1 | 610 | 46,8 | 99,4 |
| 509 | 0 | 0 | 560 | 61 | 8,4 | 611 | 48,7 | 99,9 |
| 510 | 0 | 0 | 561 | 59,7 | 0,9 | 612 | 50,5 | 99,7 |

| Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|
| s | % | % |
| 613 | 52,5 | 90,3 |
| 614 | 51 | 1,8 |
| 615 | 50 | "m" |
| 616 | 49,1 | "m" |
| 617 | 47 | "m" |
| 618 | 43,1 | "m" |
| 619 | 39,2 | "m" |
| 620 | 40,6 | 0,5 |
| 621 | 41,8 | 53,4 |
| 622 | 44,4 | 65,1 |
| 623 | 48,1 | 67,8 |
| 624 | 53,8 | 99,2 |
| 625 | 58,6 | 98,9 |
| 626 | 63,6 | 98,8 |
| 627 | 68,5 | 99,2 |
| 628 | 72,2 | 89,4 |
| 629 | 77,1 | 0 |
| 630 | 57,8 | 79,1 |
| 631 | 60,3 | 98,8 |
| 632 | 61,9 | 98,8 |
| 633 | 63,8 | 98,8 |
| 634 | 64,7 | 98,9 |
| 635 | 65,4 | 46,5 |
| 636 | 65,7 | 44,5 |
| 637 | 65,6 | 3,5 |
| 638 | 49,1 | 0 |
| 639 | 50,4 | 73,1 |
| 640 | 50,5 | "m" |
| 641 | 51 | "m" |
| 642 | 49,4 | "m" |
| 643 | 49,2 | "m" |
| 644 | 48,6 | "m" |
| 645 | 47,5 | "m" |
| 646 | 46,5 | "m" |
| 647 | 46 | 11,3 |
| 648 | 45,6 | 42,8 |
| 649 | 47,1 | 83 |
| 650 | 46,2 | 99,3 |
| 651 | 47,9 | 99,7 |
| 652 | 49,5 | 99,9 |
| 653 | 50,6 | 99,7 |
| 654 | 51 | 99,6 |
| 655 | 53 | 99,3 |
| 656 | 54,9 | 99,1 |
| 657 | 55,7 | 99 |
| 658 | 56 | 99 |
| 659 | 56,1 | 9,3 |
| 660 | 55,6 | "m" |
| 661 | 55,4 | "m" |
| 662 | 54,9 | 51,3 |
| 663 | 54,9 | 59,8 |

| Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|
| s | % | % |
| 664 | 54 | 39,3 |
| 665 | 53,8 | "m" |
| 666 | 52 | "m" |
| 667 | 50,4 | "m" |
| 668 | 50,6 | 0 |
| 669 | 49,3 | 41,7 |
| 670 | 50 | 73,2 |
| 671 | 50,4 | 99,7 |
| 672 | 51,9 | 99,5 |
| 673 | 53,6 | 99,3 |
| 674 | 54,6 | 99,1 |
| 675 | 56 | 99 |
| 676 | 55,8 | 99 |
| 677 | 58,4 | 98,9 |
| 678 | 59,9 | 98,8 |
| 679 | 60,9 | 98,8 |
| 680 | 63 | 98,8 |
| 681 | 64,3 | 98,9 |
| 682 | 64,8 | 64 |
| 683 | 65,9 | 46,5 |
| 684 | 66,2 | 28,7 |
| 685 | 65,2 | 1,8 |
| 686 | 65 | 6,8 |
| 687 | 63,6 | 53,6 |
| 688 | 62,4 | 82,5 |
| 689 | 61,8 | 98,8 |
| 690 | 59,8 | 98,8 |
| 691 | 59,2 | 98,8 |
| 692 | 59,7 | 98,8 |
| 693 | 61,2 | 98,8 |
| 694 | 62,2 | 49,4 |
| 695 | 62,8 | 37,2 |
| 696 | 63,5 | 46,3 |
| 697 | 64,7 | 72,3 |
| 698 | 64,7 | 72,3 |
| 699 | 65,4 | 77,4 |
| 700 | 66,1 | 69,3 |
| 701 | 64,3 | "m" |
| 702 | 64,3 | "m" |
| 703 | 63 | "m" |
| 704 | 62,2 | "m" |
| 705 | 61,6 | "m" |
| 706 | 62,4 | "m" |
| 707 | 62,2 | "m" |
| 708 | 61 | "m" |
| 709 | 58,7 | "m" |
| 710 | 55,5 | "m" |
| 711 | 51,7 | "m" |
| 712 | 49,2 | "m" |
| 713 | 48,8 | 40,4 |
| 714 | 47,9 | "m" |

| Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|
| s | % | % |
| 715 | 46,2 | "m" |
| 716 | 45,6 | 9,8 |
| 717 | 45,6 | 34,5 |
| 718 | 45,5 | 37,1 |
| 719 | 43,8 | "m" |
| 720 | 41,9 | "m" |
| 721 | 41,3 | "m" |
| 722 | 41,4 | "m" |
| 723 | 41,2 | "m" |
| 724 | 41,8 | "m" |
| 725 | 41,8 | "m" |
| 726 | 43,2 | 17,4 |
| 727 | 45 | 29 |
| 728 | 44,2 | "m" |
| 729 | 43,9 | "m" |
| 730 | 38 | 10,7 |
| 731 | 56,8 | "m" |
| 732 | 57,1 | "m" |
| 733 | 52 | "m" |
| 734 | 44,4 | "m" |
| 735 | 40,2 | "m" |
| 736 | 39,2 | 16,5 |
| 737 | 38,9 | 73,2 |
| 738 | 39,9 | 89,8 |
| 739 | 42,3 | 98,6 |
| 740 | 43,7 | 98,8 |
| 741 | 45,5 | 99,1 |
| 742 | 45,6 | 99,2 |
| 743 | 48,1 | 99,7 |
| 744 | 49 | 100 |
| 745 | 49,8 | 99,9 |
| 746 | 49,8 | 99,9 |
| 747 | 51,9 | 99,5 |
| 748 | 52,3 | 99,4 |
| 749 | 53,3 | 99,3 |
| 750 | 52,9 | 99,3 |
| 751 | 54,3 | 99,2 |
| 752 | 55,5 | 99,1 |
| 753 | 56,7 | 99 |
| 754 | 61,7 | 98,8 |
| 755 | 64,3 | 47,4 |
| 756 | 64,7 | 1,8 |
| 757 | 66,2 | "m" |
| 758 | 49,1 | "m" |
| 759 | 52,1 | 46 |
| 760 | 52,6 | 61 |
| 761 | 52,9 | 0 |
| 762 | 52,3 | 20,4 |
| 763 | 54,2 | 56,7 |
| 764 | 55,4 | 59,8 |
| 765 | 56,1 | 49,2 |

| Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|------|-------------|--------------|------|-------------|--------------|
| s | % | % | s | % | % | s | % | % |
| 766 | 56,8 | 33,7 | 817 | 61,7 | 46,2 | 868 | 53 | 99,3 |
| 767 | 57,2 | 96 | 818 | 59,8 | 45,1 | 869 | 54,2 | 99,2 |
| 768 | 58,6 | 98,9 | 819 | 57,4 | 43,9 | 870 | 55,5 | 99,1 |
| 769 | 59,5 | 98,8 | 820 | 54,8 | 42,8 | 871 | 56,7 | 99 |
| 770 | 61,2 | 98,8 | 821 | 54,3 | 65,2 | 872 | 57,3 | 98,9 |
| 771 | 62,1 | 98,8 | 822 | 52,9 | 62,1 | 873 | 58 | 98,9 |
| 772 | 62,7 | 98,8 | 823 | 52,4 | 30,6 | 874 | 60,5 | 31,1 |
| 773 | 62,8 | 98,8 | 824 | 50,4 | "m" | 875 | 60,2 | "m" |
| 774 | 64 | 98,9 | 825 | 48,6 | "m" | 876 | 60,3 | "m" |
| 775 | 63,2 | 46,3 | 826 | 47,9 | "m" | 877 | 60,5 | 6,3 |
| 776 | 62,4 | "m" | 827 | 46,8 | "m" | 878 | 61,4 | 19,3 |
| 777 | 60,3 | "m" | 828 | 46,9 | 9,4 | 879 | 60,3 | 1,2 |
| 778 | 58,7 | "m" | 829 | 49,5 | 41,7 | 880 | 60,5 | 2,9 |
| 779 | 57,2 | "m" | 830 | 50,5 | 37,8 | 881 | 61,2 | 34,1 |
| 780 | 56,1 | "m" | 831 | 52,3 | 20,4 | 882 | 61,6 | 13,2 |
| 781 | 56 | 9,3 | 832 | 54,1 | 30,7 | 883 | 61,5 | 16,4 |
| 782 | 55,2 | 26,3 | 833 | 56,3 | 41,8 | 884 | 61,2 | 16,4 |
| 783 | 54,8 | 42,8 | 834 | 58,7 | 26,5 | 885 | 61,3 | "m" |
| 784 | 55,7 | 47,1 | 835 | 57,3 | "m" | 886 | 63,1 | "m" |
| 785 | 56,6 | 52,4 | 836 | 59 | "m" | 887 | 63,2 | 4,8 |
| 786 | 58 | 50,3 | 837 | 59,8 | "m" | 888 | 62,3 | 22,3 |
| 787 | 58,6 | 20,6 | 838 | 60,3 | "m" | 889 | 62 | 38,5 |
| 788 | 58,7 | "m" | 839 | 61,2 | "m" | 890 | 61,6 | 29,6 |
| 789 | 59,3 | "m" | 840 | 61,8 | "m" | 891 | 61,6 | 26,6 |
| 790 | 58,6 | "m" | 841 | 62,5 | "m" | 892 | 61,8 | 28,1 |
| 791 | 60,5 | 9,7 | 842 | 62,4 | "m" | 893 | 62 | 29,6 |
| 792 | 59,2 | 9,6 | 843 | 61,5 | "m" | 894 | 62 | 16,3 |
| 793 | 59,9 | 9,6 | 844 | 63,7 | "m" | 895 | 61,1 | "m" |
| 794 | 59,6 | 9,6 | 845 | 61,9 | "m" | 896 | 61,2 | "m" |
| 795 | 59,9 | 6,2 | 846 | 61,6 | 29,7 | 897 | 60,7 | 19,2 |
| 796 | 59,9 | 9,6 | 847 | 60,3 | "m" | 898 | 60,7 | 32,5 |
| 797 | 60,5 | 13,1 | 848 | 59,2 | "m" | 899 | 60,9 | 17,8 |
| 798 | 60,3 | 20,7 | 849 | 57,3 | "m" | 900 | 60,1 | 19,2 |
| 799 | 59,9 | 31 | 850 | 52,3 | "m" | 901 | 59,3 | 38,2 |
| 800 | 60,5 | 42 | 851 | 49,3 | "m" | 902 | 59,9 | 45 |
| 801 | 61,5 | 52,5 | 852 | 47,3 | "m" | 903 | 59,4 | 32,4 |
| 802 | 60,9 | 51,4 | 853 | 46,3 | 38,8 | 904 | 59,2 | 23,5 |
| 803 | 61,2 | 57,7 | 854 | 46,8 | 35,1 | 905 | 59,5 | 40,8 |
| 804 | 62,8 | 98,8 | 855 | 46,6 | "m" | 906 | 58,3 | "m" |
| 805 | 63,4 | 96,1 | 856 | 44,3 | "m" | 907 | 58,2 | "m" |
| 806 | 64,6 | 45,4 | 857 | 43,1 | "m" | 908 | 57,6 | "m" |
| 807 | 64,1 | 5 | 858 | 42,4 | 2,1 | 909 | 57,1 | "m" |
| 808 | 63 | 3,2 | 859 | 41,8 | 2,4 | 910 | 57 | 0,6 |
| 809 | 62,7 | 14,9 | 860 | 43,8 | 68,8 | 911 | 57 | 26,3 |
| 810 | 63,5 | 35,8 | 861 | 44,6 | 89,2 | 912 | 56,5 | 29,2 |
| 811 | 64,1 | 73,3 | 862 | 46 | 99,2 | 913 | 56,3 | 20,5 |
| 812 | 64,3 | 37,4 | 863 | 46,9 | 99,4 | 914 | 56,1 | "m" |
| 813 | 64,1 | 21 | 864 | 47,9 | 99,7 | 915 | 55,2 | "m" |
| 814 | 63,7 | 21 | 865 | 50,2 | 99,8 | 916 | 54,7 | 17,5 |
| 815 | 62,9 | 18 | 866 | 51,2 | 99,6 | 917 | 55,2 | 29,2 |
| 816 | 62,4 | 32,7 | 867 | 52,3 | 99,4 | 918 | 55,2 | 29,2 |

| Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|
| s | % | % |
| 919 | 55,9 | 16 |
| 920 | 55,9 | 26,3 |
| 921 | 56,1 | 36,5 |
| 922 | 55,8 | 19 |
| 923 | 55,9 | 9,2 |
| 924 | 55,8 | 21,9 |
| 925 | 56,4 | 42,8 |
| 926 | 56,4 | 38 |
| 927 | 56,4 | 11 |
| 928 | 56,4 | 35,1 |
| 929 | 54 | 7,3 |
| 930 | 53,4 | 5,4 |
| 931 | 52,3 | 27,6 |
| 932 | 52,1 | 32 |
| 933 | 52,3 | 33,4 |
| 934 | 52,2 | 34,9 |
| 935 | 52,8 | 60,1 |
| 936 | 53,7 | 69,7 |
| 937 | 54 | 70,7 |
| 938 | 55,1 | 71,7 |
| 939 | 55,2 | 46 |
| 940 | 54,7 | 12,6 |
| 941 | 52,5 | 0 |
| 942 | 51,8 | 24,7 |
| 943 | 51,4 | 43,9 |
| 944 | 50,9 | 71,1 |
| 945 | 51,2 | 76,8 |
| 946 | 50,3 | 87,5 |
| 947 | 50,2 | 99,8 |
| 948 | 50,9 | 100 |
| 949 | 49,9 | 99,7 |
| 950 | 50,9 | 100 |
| 951 | 49,8 | 99,7 |
| 952 | 50,4 | 99,8 |
| 953 | 50,4 | 99,8 |
| 954 | 49,7 | 99,7 |
| 955 | 51 | 100 |
| 956 | 50,3 | 99,8 |
| 957 | 50,2 | 99,8 |
| 958 | 49,9 | 99,7 |
| 959 | 50,9 | 100 |
| 960 | 50 | 99,7 |
| 961 | 50,2 | 99,8 |
| 962 | 50,2 | 99,8 |
| 963 | 49,9 | 99,7 |
| 964 | 50,4 | 99,8 |
| 965 | 50,2 | 99,8 |
| 966 | 50,3 | 99,8 |
| 967 | 49,9 | 99,7 |
| 968 | 51,1 | 100 |
| 969 | 50,6 | 99,9 |

| Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|
| s | % | % |
| 970 | 49,9 | 99,7 |
| 971 | 49,6 | 99,6 |
| 972 | 49,4 | 99,6 |
| 973 | 49 | 99,5 |
| 974 | 49,8 | 99,7 |
| 975 | 50,9 | 100 |
| 976 | 50,4 | 99,8 |
| 977 | 49,8 | 99,7 |
| 978 | 49,1 | 99,5 |
| 979 | 50,4 | 99,8 |
| 980 | 49,8 | 99,7 |
| 981 | 49,3 | 99,5 |
| 982 | 49,1 | 99,5 |
| 983 | 49,9 | 99,7 |
| 984 | 49,1 | 99,5 |
| 985 | 50,4 | 99,8 |
| 986 | 50,9 | 100 |
| 987 | 51,4 | 99,9 |
| 988 | 51,5 | 99,9 |
| 989 | 52,2 | 99,7 |
| 990 | 52,8 | 74,1 |
| 991 | 53,3 | 46 |
| 992 | 53,6 | 36,4 |
| 993 | 53,4 | 33,5 |
| 994 | 53,9 | 58,9 |
| 995 | 55,2 | 73,8 |
| 996 | 55,8 | 52,4 |
| 997 | 55,7 | 9,2 |
| 998 | 55,8 | 2,2 |
| 999 | 56,4 | 33,6 |
| 1000 | 55,4 | "m" |
| 1001 | 55,2 | "m" |
| 1002 | 55,8 | 26,3 |
| 1003 | 55,8 | 23,3 |
| 1004 | 56,4 | 50,2 |
| 1005 | 57,6 | 68,3 |
| 1006 | 58,8 | 90,2 |
| 1007 | 59,9 | 98,9 |
| 1008 | 62,3 | 98,8 |
| 1009 | 63,1 | 74,4 |
| 1010 | 63,7 | 49,4 |
| 1011 | 63,3 | 9,8 |
| 1012 | 48 | 0 |
| 1013 | 47,9 | 73,5 |
| 1014 | 49,9 | 99,7 |
| 1015 | 49,9 | 48,8 |
| 1016 | 49,6 | 2,3 |
| 1017 | 49,9 | "m" |
| 1018 | 49,3 | "m" |
| 1019 | 49,7 | 47,5 |
| 1020 | 49,1 | "m" |

| Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|
| s | % | % |
| 1021 | 49,4 | "m" |
| 1022 | 48,3 | "m" |
| 1023 | 49,4 | "m" |
| 1024 | 48,5 | "m" |
| 1025 | 48,7 | "m" |
| 1026 | 48,7 | "m" |
| 1027 | 49,1 | "m" |
| 1028 | 49 | "m" |
| 1029 | 49,8 | "m" |
| 1030 | 48,7 | "m" |
| 1031 | 48,5 | "m" |
| 1032 | 49,3 | 31,3 |
| 1033 | 49,7 | 45,3 |
| 1034 | 48,3 | 44,5 |
| 1035 | 49,8 | 61 |
| 1036 | 49,4 | 64,3 |
| 1037 | 49,8 | 64,4 |
| 1038 | 50,5 | 65,6 |
| 1039 | 50,3 | 64,5 |
| 1040 | 51,2 | 82,9 |
| 1041 | 50,5 | 86 |
| 1042 | 50,6 | 89 |
| 1043 | 50,4 | 81,4 |
| 1044 | 49,9 | 49,9 |
| 1045 | 49,1 | 20,1 |
| 1046 | 47,9 | 24 |
| 1047 | 48,1 | 36,2 |
| 1048 | 47,5 | 34,5 |
| 1049 | 46,9 | 30,3 |
| 1050 | 47,7 | 53,5 |
| 1051 | 46,9 | 61,6 |
| 1052 | 46,5 | 73,6 |
| 1053 | 48 | 84,6 |
| 1054 | 47,2 | 87,7 |
| 1055 | 48,7 | 80 |
| 1056 | 48,7 | 50,4 |
| 1057 | 47,8 | 38,6 |
| 1058 | 48,8 | 63,1 |
| 1059 | 47,4 | 5 |
| 1060 | 47,3 | 47,4 |
| 1061 | 47,3 | 49,8 |
| 1062 | 46,9 | 23,9 |
| 1063 | 46,7 | 44,6 |
| 1064 | 46,8 | 65,2 |
| 1065 | 46,9 | 60,4 |
| 1066 | 46,7 | 61,5 |
| 1067 | 45,5 | "m" |
| 1068 | 45,5 | "m" |
| 1069 | 44,2 | "m" |
| 1070 | 43 | "m" |
| 1071 | 42,5 | "m" |

| Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|------|-------------|--------------|------|-------------|--------------|
| s | % | % | s | % | % | s | % | % |
| 1072 | 41 | "m" | 1123 | 55 | "m" | 1174 | 56,9 | "m" |
| 1073 | 39,9 | "m" | 1124 | 53,7 | "m" | 1175 | 56,4 | 4 |
| 1074 | 39,9 | 38,2 | 1125 | 52,1 | "m" | 1176 | 57 | 23,4 |
| 1075 | 40,1 | 48,1 | 1126 | 51,1 | "m" | 1177 | 56,4 | 41,7 |
| 1076 | 39,9 | 48 | 1127 | 49,7 | 25,8 | 1178 | 57 | 49,2 |
| 1077 | 39,4 | 59,3 | 1128 | 49,1 | 46,1 | 1179 | 57,7 | 56,6 |
| 1078 | 43,8 | 19,8 | 1129 | 48,7 | 46,9 | 1180 | 58,6 | 56,6 |
| 1079 | 52,9 | 0 | 1130 | 48,2 | 46,7 | 1181 | 58,9 | 64 |
| 1080 | 52,8 | 88,9 | 1131 | 48 | 70 | 1182 | 59,4 | 68,2 |
| 1081 | 53,4 | 99,5 | 1132 | 48 | 70 | 1183 | 58,8 | 71,4 |
| 1082 | 54,7 | 99,3 | 1133 | 47,2 | 67,6 | 1184 | 60,1 | 71,3 |
| 1083 | 56,3 | 99,1 | 1134 | 47,3 | 67,6 | 1185 | 60,6 | 79,1 |
| 1084 | 57,5 | 99 | 1135 | 46,6 | 74,7 | 1186 | 60,7 | 83,3 |
| 1085 | 59 | 98,9 | 1136 | 47,4 | 13 | 1187 | 60,7 | 77,1 |
| 1086 | 59,8 | 98,9 | 1137 | 46,3 | "m" | 1188 | 60 | 73,5 |
| 1087 | 60,1 | 98,9 | 1138 | 45,4 | "m" | 1189 | 60,2 | 55,5 |
| 1088 | 61,8 | 48,3 | 1139 | 45,5 | 24,8 | 1190 | 59,7 | 54,4 |
| 1089 | 61,8 | 55,6 | 1140 | 44,8 | 73,8 | 1191 | 59,8 | 73,3 |
| 1090 | 61,7 | 59,8 | 1141 | 46,6 | 99 | 1192 | 59,8 | 77,9 |
| 1091 | 62 | 55,6 | 1142 | 46,3 | 98,9 | 1193 | 59,8 | 73,9 |
| 1092 | 62,3 | 29,6 | 1143 | 48,5 | 99,4 | 1194 | 60 | 76,5 |
| 1093 | 62 | 19,3 | 1144 | 49,9 | 99,7 | 1195 | 59,5 | 82,3 |
| 1094 | 61,3 | 7,9 | 1145 | 49,1 | 99,5 | 1196 | 59,9 | 82,8 |
| 1095 | 61,1 | 19,2 | 1146 | 49,1 | 99,5 | 1197 | 59,8 | 65,8 |
| 1096 | 61,2 | 43 | 1147 | 51 | 100 | 1198 | 59 | 48,6 |
| 1097 | 61,1 | 59,7 | 1148 | 51,5 | 99,9 | 1199 | 58,9 | 62,2 |
| 1098 | 61,1 | 98,8 | 1149 | 50,9 | 100 | 1200 | 59,1 | 70,4 |
| 1099 | 61,3 | 98,8 | 1150 | 51,6 | 99,9 | 1201 | 58,9 | 62,1 |
| 1100 | 61,3 | 26,6 | 1151 | 52,1 | 99,7 | 1202 | 58,4 | 67,4 |
| 1101 | 60,4 | "m" | 1152 | 50,9 | 100 | 1203 | 58,7 | 58,9 |
| 1102 | 58,8 | "m" | 1153 | 52,2 | 99,7 | 1204 | 58,3 | 57,7 |
| 1103 | 57,7 | "m" | 1154 | 51,5 | 98,3 | 1205 | 57,5 | 57,8 |
| 1104 | 56 | "m" | 1155 | 51,5 | 47,2 | 1206 | 57,2 | 57,6 |
| 1105 | 54,7 | "m" | 1156 | 50,8 | 78,4 | 1207 | 57,1 | 42,6 |
| 1106 | 53,3 | "m" | 1157 | 50,3 | 83 | 1208 | 57 | 70,1 |
| 1107 | 52,6 | 23,2 | 1158 | 50,3 | 31,7 | 1209 | 56,4 | 59,6 |
| 1108 | 53,4 | 84,2 | 1159 | 49,3 | 31,3 | 1210 | 56,7 | 39 |
| 1109 | 53,9 | 99,4 | 1160 | 48,8 | 21,5 | 1211 | 55,9 | 68,1 |
| 1110 | 54,9 | 99,3 | 1161 | 47,8 | 59,4 | 1212 | 56,3 | 79,1 |
| 1111 | 55,8 | 99,2 | 1162 | 48,1 | 77,1 | 1213 | 56,7 | 89,7 |
| 1112 | 57,1 | 99 | 1163 | 48,4 | 87,6 | 1214 | 56 | 89,4 |
| 1113 | 56,5 | 99,1 | 1164 | 49,6 | 87,5 | 1215 | 56 | 93,1 |
| 1114 | 58,9 | 98,9 | 1165 | 51 | 81,4 | 1216 | 56,4 | 93,1 |
| 1115 | 58,7 | 98,9 | 1166 | 51,6 | 66,7 | 1217 | 56,7 | 94,4 |
| 1116 | 59,8 | 98,9 | 1167 | 53,3 | 63,2 | 1218 | 56,9 | 94,8 |
| 1117 | 61 | 98,8 | 1168 | 55,2 | 62 | 1219 | 57 | 94,1 |
| 1118 | 60,7 | 19,2 | 1169 | 55,7 | 43,9 | 1220 | 57,7 | 94,3 |
| 1119 | 59,4 | "m" | 1170 | 56,4 | 30,7 | 1221 | 57,5 | 93,7 |
| 1120 | 57,9 | "m" | 1171 | 56,8 | 23,4 | 1222 | 58,4 | 93,2 |
| 1121 | 57,6 | "m" | 1172 | 57 | "m" | 1223 | 58,7 | 93,2 |
| 1122 | 56,3 | "m" | 1173 | 57,6 | "m" | 1224 | 58,2 | 93,7 |

| Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|
| s | % | % |
| 1225 | 58,5 | 93,1 |
| 1226 | 58,8 | 86,2 |
| 1227 | 59 | 72,9 |
| 1228 | 58,2 | 59,9 |
| 1229 | 57,6 | 8,5 |
| 1230 | 57,1 | 47,6 |
| 1231 | 57,2 | 74,4 |
| 1232 | 57 | 79,1 |
| 1233 | 56,7 | 67,2 |
| 1234 | 56,8 | 69,1 |
| 1235 | 56,9 | 71,3 |
| 1236 | 57 | 77,3 |
| 1237 | 57,4 | 78,2 |
| 1238 | 57,3 | 70,6 |
| 1239 | 57,7 | 64 |
| 1240 | 57,5 | 55,6 |
| 1241 | 58,6 | 49,6 |
| 1242 | 58,2 | 41,1 |
| 1243 | 58,8 | 40,6 |
| 1244 | 58,3 | 21,1 |
| 1245 | 58,7 | 24,9 |
| 1246 | 59,1 | 24,8 |
| 1247 | 58,6 | "m" |
| 1248 | 58,8 | "m" |
| 1249 | 58,8 | "m" |
| 1250 | 58,7 | "m" |
| 1251 | 59,1 | "m" |
| 1252 | 59,1 | "m" |
| 1253 | 59,4 | "m" |
| 1254 | 60,6 | 2,6 |
| 1255 | 59,6 | "m" |
| 1256 | 60,1 | "m" |
| 1257 | 60,6 | "m" |
| 1258 | 59,6 | 4,1 |
| 1259 | 60,7 | 7,1 |
| 1260 | 60,5 | "m" |
| 1261 | 59,7 | "m" |
| 1262 | 59,6 | "m" |
| 1263 | 59,8 | "m" |
| 1264 | 59,6 | 4,9 |
| 1265 | 60,1 | 5,9 |
| 1266 | 59,9 | 6,1 |
| 1267 | 59,7 | "m" |
| 1268 | 59,6 | "m" |
| 1269 | 59,7 | 22 |
| 1270 | 59,8 | 10,3 |
| 1271 | 59,9 | 10 |
| 1272 | 60,6 | 6,2 |
| 1273 | 60,5 | 7,3 |
| 1274 | 60,2 | 14,8 |
| 1275 | 60,6 | 8,2 |

| Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|
| s | % | % |
| 1276 | 60,6 | 5,5 |
| 1277 | 61 | 14,3 |
| 1278 | 61 | 12 |
| 1279 | 61,3 | 34,2 |
| 1280 | 61,2 | 17,1 |
| 1281 | 61,5 | 15,7 |
| 1282 | 61 | 9,5 |
| 1283 | 61,1 | 9,2 |
| 1284 | 60,5 | 4,3 |
| 1285 | 60,2 | 7,8 |
| 1286 | 60,2 | 5,9 |
| 1287 | 60,2 | 5,3 |
| 1288 | 59,9 | 4,6 |
| 1289 | 59,4 | 21,5 |
| 1290 | 59,6 | 15,8 |
| 1291 | 59,3 | 10,1 |
| 1292 | 58,9 | 9,4 |
| 1293 | 58,8 | 9 |
| 1294 | 58,9 | 35,4 |
| 1295 | 58,9 | 30,7 |
| 1296 | 58,9 | 25,9 |
| 1297 | 58,7 | 22,9 |
| 1298 | 58,7 | 24,4 |
| 1299 | 59,3 | 61 |
| 1300 | 60,1 | 56 |
| 1301 | 60,5 | 50,6 |
| 1302 | 59,5 | 16,2 |
| 1303 | 59,7 | 50 |
| 1304 | 59,7 | 31,4 |
| 1305 | 60,1 | 43,1 |
| 1306 | 60,8 | 38,4 |
| 1307 | 60,9 | 40,2 |
| 1308 | 61,3 | 49,7 |
| 1309 | 61,8 | 45,9 |
| 1310 | 62 | 45,9 |
| 1311 | 62,2 | 45,8 |
| 1312 | 62,6 | 46,8 |
| 1313 | 62,7 | 44,3 |
| 1314 | 62,9 | 44,4 |
| 1315 | 63,1 | 43,7 |
| 1316 | 63,5 | 46,1 |
| 1317 | 63,6 | 40,7 |
| 1318 | 64,3 | 49,5 |
| 1319 | 63,7 | 27 |
| 1320 | 63,8 | 15 |
| 1321 | 63,6 | 18,7 |
| 1322 | 63,4 | 8,4 |
| 1323 | 63,2 | 8,7 |
| 1324 | 63,3 | 21,6 |
| 1325 | 62,9 | 19,7 |
| 1326 | 63 | 22,1 |

| Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|
| s | % | % |
| 1327 | 63,1 | 20,3 |
| 1328 | 61,8 | 19,1 |
| 1329 | 61,6 | 17,1 |
| 1330 | 61 | 0 |
| 1331 | 61,2 | 22 |
| 1332 | 60,8 | 40,3 |
| 1333 | 61,1 | 34,3 |
| 1334 | 60,7 | 16,1 |
| 1335 | 60,6 | 16,6 |
| 1336 | 60,5 | 18,5 |
| 1337 | 60,6 | 29,8 |
| 1338 | 60,9 | 19,5 |
| 1339 | 60,9 | 22,3 |
| 1340 | 61,4 | 35,8 |
| 1341 | 61,3 | 42,9 |
| 1342 | 61,5 | 31 |
| 1343 | 61,3 | 19,2 |
| 1344 | 61 | 9,3 |
| 1345 | 60,8 | 44,2 |
| 1346 | 60,9 | 55,3 |
| 1347 | 61,2 | 56 |
| 1348 | 60,9 | 60,1 |
| 1349 | 60,7 | 59,1 |
| 1350 | 60,9 | 56,8 |
| 1351 | 60,7 | 58,1 |
| 1352 | 59,6 | 78,4 |
| 1353 | 59,6 | 84,6 |
| 1354 | 59,4 | 66,6 |
| 1355 | 59,3 | 75,5 |
| 1356 | 58,9 | 49,6 |
| 1357 | 59,1 | 75,8 |
| 1358 | 59 | 77,6 |
| 1359 | 59 | 67,8 |
| 1360 | 59 | 56,7 |
| 1361 | 58,8 | 54,2 |
| 1362 | 58,9 | 59,6 |
| 1363 | 58,9 | 60,8 |
| 1364 | 59,3 | 56,1 |
| 1365 | 58,9 | 48,5 |
| 1366 | 59,3 | 42,9 |
| 1367 | 59,4 | 41,4 |
| 1368 | 59,6 | 38,9 |
| 1369 | 59,4 | 32,9 |
| 1370 | 59,3 | 30,6 |
| 1371 | 59,4 | 30 |
| 1372 | 59,4 | 25,3 |
| 1373 | 58,8 | 18,6 |
| 1374 | 59,1 | 18 |
| 1375 | 58,5 | 10,6 |
| 1376 | 58,8 | 10,5 |
| 1377 | 58,5 | 8,2 |

| Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|------|-------------|--------------|------|-------------|--------------|
| s | % | % | s | % | % | s | % | % |
| 1378 | 58,7 | 13,7 | 1429 | 62,3 | 37,4 | 1480 | 60,1 | 4,7 |
| 1379 | 59,1 | 7,8 | 1430 | 62,3 | 35,7 | 1481 | 59,9 | 0 |
| 1380 | 59,1 | 6 | 1431 | 62,8 | 34,4 | 1482 | 60,4 | 36,2 |
| 1381 | 59,1 | 6 | 1432 | 62,8 | 31,5 | 1483 | 60,7 | 32,5 |
| 1382 | 59,4 | 13,1 | 1433 | 62,9 | 31,7 | 1484 | 59,9 | 3,1 |
| 1383 | 59,7 | 22,3 | 1434 | 62,9 | 29,9 | 1485 | 59,7 | "m" |
| 1384 | 60,7 | 10,5 | 1435 | 62,8 | 29,4 | 1486 | 59,5 | "m" |
| 1385 | 59,8 | 9,8 | 1436 | 62,7 | 28,7 | 1487 | 59,2 | "m" |
| 1386 | 60,2 | 8,8 | 1437 | 61,5 | 14,7 | 1488 | 58,8 | 0,6 |
| 1387 | 59,9 | 8,7 | 1438 | 61,9 | 17,2 | 1489 | 58,7 | "m" |
| 1388 | 61 | 9,1 | 1439 | 61,5 | 6,1 | 1490 | 58,7 | "m" |
| 1389 | 60,6 | 28,2 | 1440 | 61 | 9,9 | 1491 | 57,9 | "m" |
| 1390 | 60,6 | 22 | 1441 | 60,9 | 4,8 | 1492 | 58,2 | "m" |
| 1391 | 59,6 | 23,2 | 1442 | 60,6 | 11,1 | 1493 | 57,6 | "m" |
| 1392 | 59,6 | 19 | 1443 | 60,3 | 6,9 | 1494 | 58,3 | 9,5 |
| 1393 | 60,6 | 38,4 | 1444 | 60,8 | 7 | 1495 | 57,2 | 6 |
| 1394 | 59,8 | 41,6 | 1445 | 60,2 | 9,2 | 1496 | 57,4 | 27,3 |
| 1395 | 60 | 47,3 | 1446 | 60,5 | 21,7 | 1497 | 58,3 | 59,9 |
| 1396 | 60,5 | 55,4 | 1447 | 60,2 | 22,4 | 1498 | 58,3 | 7,3 |
| 1397 | 60,9 | 58,7 | 1448 | 60,7 | 31,6 | 1499 | 58,8 | 21,7 |
| 1398 | 61,3 | 37,9 | 1449 | 60,9 | 28,9 | 1500 | 58,8 | 38,9 |
| 1399 | 61,2 | 38,3 | 1450 | 59,6 | 21,7 | 1501 | 59,4 | 26,2 |
| 1400 | 61,4 | 58,7 | 1451 | 60,2 | 18 | 1502 | 59,1 | 25,5 |
| 1401 | 61,3 | 51,3 | 1452 | 59,5 | 16,7 | 1503 | 59,1 | 26 |
| 1402 | 61,4 | 71,1 | 1453 | 59,8 | 15,7 | 1504 | 59 | 39,1 |
| 1403 | 61,1 | 51 | 1454 | 59,6 | 15,7 | 1505 | 59,5 | 52,3 |
| 1404 | 61,5 | 56,6 | 1455 | 59,3 | 15,7 | 1506 | 59,4 | 31 |
| 1405 | 61 | 60,6 | 1456 | 59 | 7,5 | 1507 | 59,4 | 27 |
| 1406 | 61,1 | 75,4 | 1457 | 58,8 | 7,1 | 1508 | 59,4 | 29,8 |
| 1407 | 61,4 | 69,4 | 1458 | 58,7 | 16,5 | 1509 | 59,4 | 23,1 |
| 1408 | 61,6 | 69,9 | 1459 | 59,2 | 50,7 | 1510 | 58,9 | 16 |
| 1409 | 61,7 | 59,6 | 1460 | 59,7 | 60,2 | 1511 | 59 | 31,5 |
| 1410 | 61,8 | 54,8 | 1461 | 60,4 | 44 | 1512 | 58,8 | 25,9 |
| 1411 | 61,6 | 53,6 | 1462 | 60,2 | 35,3 | 1513 | 58,9 | 40,2 |
| 1412 | 61,3 | 53,5 | 1463 | 60,4 | 17,1 | 1514 | 58,8 | 28,4 |
| 1413 | 61,3 | 52,9 | 1464 | 59,9 | 13,5 | 1515 | 58,9 | 38,9 |
| 1414 | 61,2 | 54,1 | 1465 | 59,9 | 12,8 | 1516 | 59,1 | 35,3 |
| 1415 | 61,3 | 53,2 | 1466 | 59,6 | 14,8 | 1517 | 58,8 | 30,3 |
| 1416 | 61,2 | 52,2 | 1467 | 59,4 | 15,9 | 1518 | 59 | 19 |
| 1417 | 61,2 | 52,3 | 1468 | 59,4 | 22 | 1519 | 58,7 | 3 |
| 1418 | 61 | 48 | 1469 | 60,4 | 38,4 | 1520 | 57,9 | 0 |
| 1419 | 60,9 | 41,5 | 1470 | 59,5 | 38,8 | 1521 | 58 | 2,4 |
| 1420 | 61 | 32,2 | 1471 | 59,3 | 31,9 | 1522 | 57,1 | "m" |
| 1421 | 60,7 | 22 | 1472 | 60,9 | 40,8 | 1523 | 56,7 | "m" |
| 1422 | 60,7 | 23,3 | 1473 | 60,7 | 39 | 1524 | 56,7 | 5,3 |
| 1423 | 60,8 | 38,8 | 1474 | 60,9 | 30,1 | 1525 | 56,6 | 2,1 |
| 1424 | 61 | 40,7 | 1475 | 61 | 29,3 | 1526 | 56,8 | "m" |
| 1425 | 61 | 30,6 | 1476 | 60,6 | 28,4 | 1527 | 56,3 | "m" |
| 1426 | 61,3 | 62,6 | 1477 | 60,9 | 36,3 | 1528 | 56,3 | "m" |
| 1427 | 61,7 | 55,9 | 1478 | 60,8 | 30,5 | 1529 | 56 | "m" |
| 1428 | 62,3 | 43,4 | 1479 | 60,7 | 26,7 | 1530 | 56,7 | "m" |

| Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|------|-------------|--------------|------|-------------|--------------|
| s | % | % | s | % | % | s | % | % |
| 1531 | 56,6 | 3,8 | 1582 | 59,9 | 73,6 | 1633 | 62,5 | 31 |
| 1532 | 56,9 | "m" | 1583 | 59,8 | 74,1 | 1634 | 62,3 | 31,3 |
| 1533 | 56,9 | "m" | 1584 | 59,6 | 84,6 | 1635 | 62,6 | 31,7 |
| 1534 | 57,4 | "m" | 1585 | 59,4 | 76,1 | 1636 | 62,3 | 22,8 |
| 1535 | 57,4 | "m" | 1586 | 60,1 | 76,9 | 1637 | 62,7 | 12,6 |
| 1536 | 58,3 | 13,9 | 1587 | 59,5 | 84,6 | 1638 | 62,2 | 15,2 |
| 1537 | 58,5 | "m" | 1588 | 59,8 | 77,5 | 1639 | 61,9 | 32,6 |
| 1538 | 59,1 | "m" | 1589 | 60,6 | 67,9 | 1640 | 62,5 | 23,1 |
| 1539 | 59,4 | "m" | 1590 | 59,3 | 47,3 | 1641 | 61,7 | 19,4 |
| 1540 | 59,6 | "m" | 1591 | 59,3 | 43,1 | 1642 | 61,7 | 10,8 |
| 1541 | 59,5 | "m" | 1592 | 59,4 | 38,3 | 1643 | 61,6 | 10,2 |
| 1542 | 59,6 | 0,5 | 1593 | 58,7 | 38,2 | 1644 | 61,4 | "m" |
| 1543 | 59,3 | 9,2 | 1594 | 58,8 | 39,2 | 1645 | 60,8 | "m" |
| 1544 | 59,4 | 11,2 | 1595 | 59,1 | 67,9 | 1646 | 60,7 | "m" |
| 1545 | 59,1 | 26,8 | 1596 | 59,7 | 60,5 | 1647 | 61 | 12,4 |
| 1546 | 59 | 11,7 | 1597 | 59,5 | 32,9 | 1648 | 60,4 | 5,3 |
| 1547 | 58,8 | 6,4 | 1598 | 59,6 | 20 | 1649 | 61 | 13,1 |
| 1548 | 58,7 | 5 | 1599 | 59,6 | 34,4 | 1650 | 60,7 | 29,6 |
| 1549 | 57,5 | "m" | 1600 | 59,4 | 23,9 | 1651 | 60,5 | 28,9 |
| 1550 | 57,4 | "m" | 1601 | 59,6 | 15,7 | 1652 | 60,8 | 27,1 |
| 1551 | 57,1 | 1,1 | 1602 | 59,9 | 41 | 1653 | 61,2 | 27,3 |
| 1552 | 57,1 | 0 | 1603 | 60,5 | 26,3 | 1654 | 60,9 | 20,6 |
| 1553 | 57 | 4,5 | 1604 | 59,6 | 14 | 1655 | 61,1 | 13,9 |
| 1554 | 57,1 | 3,7 | 1605 | 59,7 | 21,2 | 1656 | 60,7 | 13,4 |
| 1555 | 57,3 | 3,3 | 1606 | 60,9 | 19,6 | 1657 | 61,3 | 26,1 |
| 1556 | 57,3 | 16,8 | 1607 | 60,1 | 34,3 | 1658 | 60,9 | 23,7 |
| 1557 | 58,2 | 29,3 | 1608 | 59,9 | 27 | 1659 | 61,4 | 32,1 |
| 1558 | 58,7 | 12,5 | 1609 | 60,8 | 25,6 | 1660 | 61,7 | 33,5 |
| 1559 | 58,3 | 12,2 | 1610 | 60,6 | 26,3 | 1661 | 61,8 | 34,1 |
| 1560 | 58,6 | 12,7 | 1611 | 60,9 | 26,1 | 1662 | 61,7 | 17 |
| 1561 | 59 | 13,6 | 1612 | 61,1 | 38 | 1663 | 61,7 | 2,5 |
| 1562 | 59,8 | 21,9 | 1613 | 61,2 | 31,6 | 1664 | 61,5 | 5,9 |
| 1563 | 59,3 | 20,9 | 1614 | 61,4 | 30,6 | 1665 | 61,3 | 14,9 |
| 1564 | 59,7 | 19,2 | 1615 | 61,7 | 29,6 | 1666 | 61,5 | 17,2 |
| 1565 | 60,1 | 15,9 | 1616 | 61,5 | 28,8 | 1667 | 61,1 | "m" |
| 1566 | 60,7 | 16,7 | 1617 | 61,7 | 27,8 | 1668 | 61,4 | "m" |
| 1567 | 60,7 | 18,1 | 1618 | 62,2 | 20,3 | 1669 | 61,4 | 8,8 |
| 1568 | 60,7 | 40,6 | 1619 | 61,4 | 19,6 | 1670 | 61,3 | 8,8 |
| 1569 | 60,7 | 59,7 | 1620 | 61,8 | 19,7 | 1671 | 61 | 18 |
| 1570 | 61,1 | 66,8 | 1621 | 61,8 | 18,7 | 1672 | 61,5 | 13 |
| 1571 | 61,1 | 58,8 | 1622 | 61,6 | 17,7 | 1673 | 61 | 3,7 |
| 1572 | 60,8 | 64,7 | 1623 | 61,7 | 8,7 | 1674 | 60,9 | 3,1 |
| 1573 | 60,1 | 63,6 | 1624 | 61,7 | 1,4 | 1675 | 60,9 | 4,7 |
| 1574 | 60,7 | 83,2 | 1625 | 61,7 | 5,9 | 1676 | 60,6 | 4,1 |
| 1575 | 60,4 | 82,2 | 1626 | 61,2 | 8,1 | 1677 | 60,6 | 6,7 |
| 1576 | 60 | 80,5 | 1627 | 61,9 | 45,8 | 1678 | 60,6 | 12,8 |
| 1577 | 59,9 | 78,7 | 1628 | 61,4 | 31,5 | 1679 | 60,7 | 11,9 |
| 1578 | 60,8 | 67,9 | 1629 | 61,7 | 22,3 | 1680 | 60,6 | 12,4 |
| 1579 | 60,4 | 57,7 | 1630 | 62,4 | 21,7 | 1681 | 60,1 | 12,4 |
| 1580 | 60,2 | 60,6 | 1631 | 62,8 | 21,9 | 1682 | 60,5 | 12 |
| 1581 | 59,6 | 72,7 | 1632 | 62,2 | 22,2 | 1683 | 60,4 | 11,8 |

| Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque | Time | Norm. Speed | Norm. Torque |
|------|-------------|--------------|------|-------------|--------------|------|-------------|--------------|
| s | % | % | s | % | % | s | % | % |
| 1684 | 59,9 | 12,4 | 1735 | 61,1 | 25,6 | 1786 | 0 | 0 |
| 1685 | 59,6 | 12,4 | 1736 | 61 | 14,6 | 1787 | 0 | 0 |
| 1686 | 59,6 | 9,1 | 1737 | 61 | 10,4 | 1788 | 0 | 0 |
| 1687 | 59,9 | 0 | 1738 | 60,6 | "m" | 1789 | 0 | 0 |
| 1688 | 59,9 | 20,4 | 1739 | 60,9 | "m" | 1790 | 0 | 0 |
| 1689 | 59,8 | 4,4 | 1740 | 60,8 | 4,8 | 1791 | 0 | 0 |
| 1690 | 59,4 | 3,1 | 1741 | 59,9 | "m" | 1792 | 0 | 0 |
| 1691 | 59,5 | 26,3 | 1742 | 59,8 | "m" | 1793 | 0 | 0 |
| 1692 | 59,6 | 20,1 | 1743 | 59,1 | "m" | 1794 | 0 | 0 |
| 1693 | 59,4 | 35 | 1744 | 58,8 | "m" | 1795 | 0 | 0 |
| 1694 | 60,9 | 22,1 | 1745 | 58,8 | "m" | 1796 | 0 | 0 |
| 1695 | 60,5 | 12,2 | 1746 | 58,2 | "m" | 1797 | 0 | 0 |
| 1696 | 60,1 | 11 | 1747 | 58,5 | 14,3 | 1798 | 0 | 0 |
| 1697 | 60,1 | 8,2 | 1748 | 57,5 | 4,4 | 1799 | 0 | 0 |
| 1698 | 60,5 | 6,7 | 1749 | 57,9 | 0 | 1800 | 0 | 0 |
| 1699 | 60 | 5,1 | 1750 | 57,8 | 20,9 | | | |
| 1700 | 60 | 5,1 | 1751 | 58,3 | 9,2 | | | |
| 1701 | 60 | 9 | 1752 | 57,8 | 8,2 | | | |
| 1702 | 60,1 | 5,7 | 1753 | 57,5 | 15,3 | | | |
| 1703 | 59,9 | 8,5 | 1754 | 58,4 | 38 | | | |
| 1704 | 59,4 | 6 | 1755 | 58,1 | 15,4 | | | |
| 1705 | 59,5 | 5,5 | 1756 | 58,8 | 11,8 | | | |
| 1706 | 59,5 | 14,2 | 1757 | 58,3 | 8,1 | | | |
| 1707 | 59,5 | 6,2 | 1758 | 58,3 | 5,5 | | | |
| 1708 | 59,4 | 10,3 | 1759 | 59 | 4,1 | | | |
| 1709 | 59,6 | 13,8 | 1760 | 58,2 | 4,9 | | | |
| 1710 | 59,5 | 13,9 | 1761 | 57,9 | 10,1 | | | |
| 1711 | 60,1 | 18,9 | 1762 | 58,5 | 7,5 | | | |
| 1712 | 59,4 | 13,1 | 1763 | 57,4 | 7 | | | |
| 1713 | 59,8 | 5,4 | 1764 | 58,2 | 6,7 | | | |
| 1714 | 59,9 | 2,9 | 1765 | 58,2 | 6,6 | | | |
| 1715 | 60,1 | 7,1 | 1766 | 57,3 | 17,3 | | | |
| 1716 | 59,6 | 12 | 1767 | 58 | 11,4 | | | |
| 1717 | 59,6 | 4,9 | 1768 | 57,5 | 47,4 | | | |
| 1718 | 59,4 | 22,7 | 1769 | 57,4 | 28,8 | | | |
| 1719 | 59,6 | 22 | 1770 | 58,8 | 24,3 | | | |
| 1720 | 60,1 | 17,4 | 1771 | 57,7 | 25,5 | | | |
| 1721 | 60,2 | 16,6 | 1772 | 58,4 | 35,5 | | | |
| 1722 | 59,4 | 28,6 | 1773 | 58,4 | 29,3 | | | |
| 1723 | 60,3 | 22,4 | 1774 | 59 | 33,8 | | | |
| 1724 | 59,9 | 20 | 1775 | 59 | 18,7 | | | |
| 1725 | 60,2 | 18,6 | 1776 | 58,8 | 9,8 | | | |
| 1726 | 60,3 | 11,9 | 1777 | 58,8 | 23,9 | | | |
| 1727 | 60,4 | 11,6 | 1778 | 59,1 | 48,2 | | | |
| 1728 | 60,6 | 10,6 | 1779 | 59,4 | 37,2 | | | |
| 1729 | 60,8 | 16 | 1780 | 59,6 | 29,1 | | | |
| 1730 | 60,9 | 17 | 1781 | 50 | 25 | | | |
| 1731 | 60,9 | 16,1 | 1782 | 40 | 20 | | | |
| 1732 | 60,7 | 11,4 | 1783 | 30 | 15 | | | |
| 1733 | 60,9 | 11,3 | 1784 | 20 | 10 | | | |
| 1734 | 61,1 | 11,2 | 1785 | 10 | 5 | | | |

"m" = motoring

A graphical display of the ETC dynamometer schedule is shown in Figure 5.

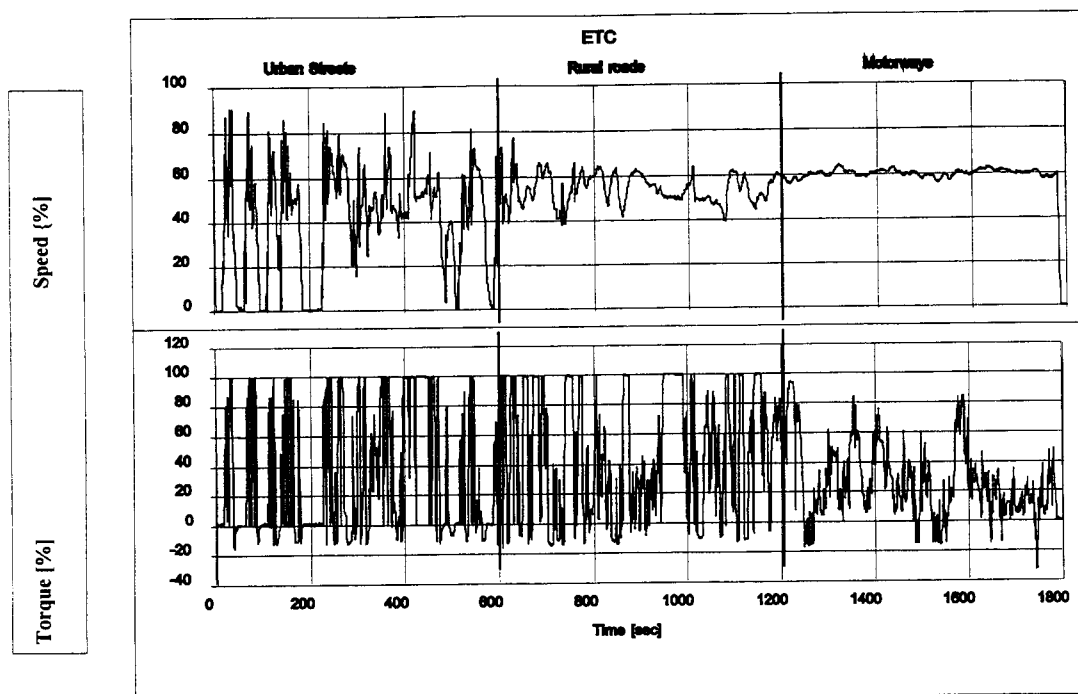


Figure 5 ETC Dynamometer Schedule

ANNEX III - APPENDIX 4

MEASUREMENT AND SAMPLING PROCEDURES

1. INTRODUCTION

Gaseous components, particulates, and smoke emitted by the engine submitted for testing shall be measured by the methods described in Annex V. The respective sections of Annex V describe the recommended analytical systems for the gaseous emissions (section 1), the recommended particulate dilution and sampling systems (section 2), and the recommended opacimeters for smoke measurement (section 3).

For the ESC, the gaseous components shall be determined in the raw exhaust gas. Optionally, they may be determined in the diluted exhaust gas, if a full flow dilution system is used for particulate determination. Particulates shall be determined with either a partial flow or a full flow dilution system.

For the ETC, only a full flow dilution system shall be used for determining gaseous and particulate emissions, and is considered the reference system. However, partial flow dilution systems may be approved by the Technical Service, if their equivalency according to section 6.2 to Annex I is proven, and if a detailed description of the data evaluation and calculation procedures is submitted to the Technical Service.

2. DYNAMOMETER AND TEST CELL EQUIPMENT

The following equipment shall be used for emission tests of engines on engine dynamometers.

2.1. Engine Dynamometer

An engine dynamometer shall be used with adequate characteristics to perform the test cycles described in Appendices 1 and 2 to this Annex. The speed measuring system shall have an accuracy of $\pm 2\%$ of reading. The torque measuring system shall have an accuracy of $\pm 3\%$ of reading in the range $> 20\%$ of full scale, and an accuracy of $\pm 0,6\%$ of full scale in the range $\leq 20\%$ of full scale.

2.2. Other Instruments

Measuring instruments for fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and intake manifold depression, exhaust gas temperature, air intake temperature, atmospheric pressure, humidity and fuel temperature shall be used, as required. These instruments shall satisfy the requirements given in table 8:

Table 8 Accuracy of Measuring Instruments

| Measuring Instrument | Accuracy |
|-----------------------------------|-------------------------------------|
| Fuel Consumption | $\pm 2\%$ of Engine's Maximum Value |
| Air Consumption | $\pm 2\%$ of Engine's Maximum Value |
| Temperatures ≤ 600 K (327°C) | ± 2 K Absolute |
| Temperatures ≥ 600 K (327°C) | $\pm 1\%$ of Reading |
| Atmospheric Pressure | $\pm 0,1$ kPa Absolute |
| Exhaust Gas Pressure | $\pm 0,2$ kPa Absolute |
| Intake Depression | $\pm 0,05$ kPa Absolute |
| Other Pressures | $\pm 0,1$ kPa Absolute |
| Relative Humidity | $\pm 3\%$ Absolute |
| Absolute Humidity | $\pm 5\%$ of Reading |

2.3. Exhaust Gas Flow

--

For calculation of the emissions in the raw exhaust, it is necessary to know the exhaust gas flow (see section 4.4 of Appendix 1). For the determination of the exhaust flow either of the following methods may be used:

Direct measurement of the exhaust flow by flow nozzle or equivalent metering system;

Measurement of the air flow and the fuel flow by suitable metering systems and calculation of the exhaust flow by the following equation:

$$G_{\text{EXHW}} = G_{\text{AIRW}} + G_{\text{FUEL}} \quad (\text{for wet exhaust mass})$$

The accuracy of exhaust flow determination shall be $\pm 2,5\%$ of reading or better.

2.4. Diluted Exhaust Gas Flow

For calculation of the emissions in the diluted exhaust using a full flow dilution system (mandatory for the ETC), it is necessary to know the diluted exhaust gas flow (see section 4.3 of Appendix 2). The total mass flow rate of the diluted exhaust (G_{TOTW}) or the total mass of the diluted exhaust gas over the cycle (M_{TOTW}) shall be measured with a PDP or CFV (Annex V, section 2.3.1). The accuracy shall be $\pm 2\%$ of reading or better, and shall be determined according to the provisions of Annex III, Appendix 5, section 2.4.

3. DETERMINATION OF THE GASEOUS COMPONENTS

3.1. General Analyser Specifications

The analysers shall have a measuring range appropriate for the accuracy required to measure the concentrations of the exhaust gas components (section 3.1.1). It is recommended that the analysers be operated such that the measured concentration falls between 15 % and 100 % of full scale.

If read-out systems (computers, data loggers) can provide sufficient accuracy and resolution below 15 % of full scale, measurements below 15 % of full scale are also acceptable. In this case, additional calibrations of at least 4 non-zero nominally equally spaced points are to be made to ensure the accuracy of the calibration curves according to Annex III, Appendix 5, section 1.5.5.2.

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

3.1.1. Measurement Error

The total measurement error, including the cross sensitivity to other gases (see Annex III, Appendix 5, section 1.9), shall not exceed $\pm 5\%$ of the reading or $\pm 3,5\%$ of full scale, whichever is smaller. For concentrations of less than 100 ppm the measurement error shall not exceed ± 4 ppm.

3.1.2. **Repeatability**

The repeatability, defined as 2,5 times the standard deviation of 10 repetitive responses to a given calibration or span gas, has to be not greater than $\pm 1\%$ of full scale concentration for each range used above 155 ppm (or ppmC) or $\pm 2\%$ of each range used below 155 ppm (or ppmC).

3.1.3. **Noise**

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

3.1.4. **Zero Drift**

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

3.1.5. **Span Drift**

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

3.2. **Gas Drying**

The optional gas drying device 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.

3.3. **Analysers**

Sections 3.3.1. to 3.3.4 describe the measurement principles to be used. A detailed description of the measurement systems is given in Annex V. The gases to be measured shall be analysed with the following instruments. For non-linear analysers, the use of linearising circuits is permitted.

3.3.1. **Carbon Monoxide (CO) Analysis**

The carbon monoxide analyser shall be of the Non-Dispersive InfraRed (NDIR) absorption type.

3.3.2. **Carbon Dioxide (CO₂) Analysis**

The carbon dioxide analyser shall be of the Non-Dispersive InfraRed (NDIR) absorption type.

3.3.3. **Hydrocarbon (HC) Analysis**

For diesel and LPG fuelled gas engines, 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 $463\text{K} \pm 10\text{K}$ ($190 \pm 10^\circ\text{C}$). For NG fuelled gas engines, the hydrocarbon analyser may be of the non heated Flame Ionisation Detector (FID) type depending upon the method used (see Annex V, section 1.3).

3.3.4. ***Non-Methane Hydrocarbon (NMHC) Analysis (NG Fuelled Gas Engines Only)***

Non-methane hydrocarbons shall be determined by either of the following methods:

3.3.4.1 **Gas Chromatographic (GC) Method**

Non-methane hydrocarbons shall be determined by subtraction of the methane analysed with a Gas Chromatograph (GC) conditioned at 423 K (150°C) from the hydrocarbons measured according to section 3.3.3.

3.3.4.2. **Non-Methane Cutter (NMC) Method**

The determination of the non-methane fraction shall be performed with a heated NMC operated in line with an FID as per section 3.3.3 by subtraction of the methane from the hydrocarbons.

3.3.5. ***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 NO₂/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 (see Annex III, Appendix 5, section 1.9.2.2) is satisfied.

3.4. **Sampling of Gaseous Emissions**

3.4.1. ***Raw Exhaust Gas (ESC only)***

The gaseous emissions sampling probes must be fitted at least 0,5 m or 3 times the diameter of the exhaust pipe - whichever is the larger - upstream of the exit of the exhaust gas system as far as applicable and sufficiently close to the engine as to ensure an exhaust gas temperature of at least 343 K (70°C) at the probe.

In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multi-cylinder engines having distinct groups of manifolds, such as in a "Vee" engine configuration, it is permissible to acquire a sample from each group individually and calculate an average exhaust emission. Other methods which have been shown to correlate with the above methods may be used. For exhaust emission calculation the total exhaust mass flow must be used.

If the engine is equipped with an exhaust aftertreatment system, the exhaust sample shall be taken downstream of the exhaust aftertreatment system.

3.4.2. *Diluted Exhaust Gas (mandatory for ETC, optional for ESC)*

The exhaust pipe between the engine and the full flow dilution system shall conform to the requirements of Annex V, section 2.3.1, EP.

The gaseous emissions sample probe(s) shall be installed in the dilution tunnel at a point where the dilution air and exhaust gas are well mixed, and in close proximity to the particulates sampling probe.

For the ETC, sampling can generally be done in two ways:

- the pollutants are sampled into a sampling bag over the cycle and measured after completion of the test;
- the pollutants are sampled continuously and integrated over the cycle; this method is mandatory for HC and NO_x.

4. DETERMINATION OF THE PARTICULATES

The determination of the particulates requires a dilution system. Dilution may be accomplished by a partial flow dilution system (ESC only) or a full flow dilution system (mandatory for ETC). The flow capacity of the dilution system shall be large enough to completely eliminate water condensation in the dilution and sampling systems, and maintain the temperature of the diluted exhaust gas at or below 325K (52°C) immediately upstream of the filter holders. Dehumidifying the dilution air before entering the dilution system is permitted, and especially useful if dilution air humidity is high. The temperature of the dilution air shall be 298 K ± 5 K (25°C ± 5°C). If the ambient temperature is below 293K (20°C), dilution air pre-heating above the upper temperature limit of 303K (30°C) is recommended. However, the dilution air temperature must not exceed 325 K (52°C) prior to the introduction of the exhaust in the dilution tunnel.

The partial flow dilution system has to be designed to split the exhaust stream into two fractions, the smaller one being diluted with air and subsequently used for particulate measurement. For this it is essential that the dilution ratio be determined very accurately. Different splitting methods can be applied, whereby the type of splitting used dictates to a significant degree the sampling hardware and procedures to be used (Annex V, section 2.2). The particulate sampling probe shall be installed in close proximity to the gaseous emissions sampling probe, and the installation shall comply with the provisions of section 3.4.1.

To determine the mass of the particulates, a particulate sampling system, particulate sampling filters, a microgram balance, and a temperature and humidity controlled weighing chamber, are required.

For particulate sampling, the single filter method shall be applied which uses one pair of filters (see section 4.1.3) for the whole test cycle. For the ESC, considerable attention must be paid to sampling times and flows during the sampling phase of the test.

4.1. Particulate Sampling Filters

4.1.1. Filter Specification

Fluorocarbon coated glass fibre filters or fluorocarbon based membrane filters are required. All filter types shall have a 0,3 µm DOP (di-octylphthalate) collection efficiency of at least 95 % at a gas face velocity between 35 and 80 cm/s.

4.1.2. Filter Size

Particulate filters must have a minimum diameter of 47 mm (37 mm stain diameter). Larger diameter filters are acceptable (section 4.1.5).

4.1.3. Primary and Back-up Filters

The diluted exhaust shall be sampled by a pair of filters placed in series (one primary and one back-up filter) during the test sequence. The back-up filter shall be located no more than 100 mm downstream of, and shall not be in contact with the primary filter. The filters may be weighed separately or as a pair with the filters placed stain side to stain side.

4.1.4. Filter Face Velocity

A gas face velocity through the filter of 35 to 80 cm/s shall be achieved. The pressure drop increase between the beginning and the end of the test shall be no more than 25 kPa.

4.1.5. Filter Loading

The recommended minimum filter loading shall be 0,5 mg/1075 mm² stain area. For the most common filter sizes the values are shown in table 9.

Table 9 Recommended Filter Loadings

| Filter Diameter (mm) | Recommended Stain | Recommended Minimum |
|----------------------|-------------------|---------------------|
| 47 | 37 | 0,5 |
| 70 | 60 | 1,3 |
| 90 | 80 | 2,3 |
| 110 | 100 | 3,6 |

4.2. Weighing Chamber and Analytical Balance Specifications

4.2.1. Weighing Chamber Conditions

The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed shall be maintained to within 295K ± 3 K (22°C ± 3°C) during all filter conditioning and weighing. The humidity shall be maintained to a dewpoint of 282,5K ± 3 K (9,5°C ± 3°C) and a relative humidity of 45% ± 8 %.

4.2.2. *Reference Filter Weighing*

The chamber (or room) environment shall be free of any ambient contaminants (such as dust) that would settle on the particulate filters during their stabilisation. Disturbances to weighing room specifications as outlined in section 4.2.1 will be allowed if the duration of the disturbances does not exceed 30 minutes. The weighing room should meet the required specifications prior to personal entrance into the weighing room. At least two unused reference filters or reference filter pairs shall be weighed within 4 hours of, but preferably at the same time as the sample filter (pair) weighings. They shall be the same size and material as the sample filters.

If the average weight of the reference filters (reference filter pairs) changes between sample filter weighings by more than $\pm 5\%$ ($\pm 7,5\%$ for the filter pair respectively) of the recommended minimum filter loading (section 4.1.5.), then all sample filters shall be discarded and the emissions test repeated.

If the weighing room stability criteria outlined in section 4.2.1. is not met, but the reference filter (pair) weighings meet the above criteria, the engine manufacturer has the option of accepting the sample filter weights or voiding the tests, fixing the weighing room control system and rerunning the test.

4.2.3. *Analytical Balance*

The analytical balance used to determine the weights of all filters shall have a precision (standard deviation) of $20\ \mu\text{g}$ and a resolution of $10\ \mu\text{g}$ (1 digit = $10\ \mu\text{g}$). For filters less than 70 mm diameter, the precision and resolution shall be $2\ \mu\text{g}$ and $1\ \mu\text{g}$, respectively.

4.2.4. *Elimination of Static Electricity Effects*

To eliminate the effects of static electricity, the filters should be neutralised prior to weighing, e.g. by a Polonium neutraliser or a device of similar effect.

4.3. **Additional Specifications for Particulate Measurement**

All parts of the dilution system and the sampling system from the exhaust pipe up to the filter holder, which are in contact with raw and diluted exhaust gas, must be designed to minimise deposition or alteration of the particulates. All parts must be made of electrically conductive materials that do not react with exhaust gas components, and must be electrically grounded to prevent electrostatic effects.

5. **DETERMINATION OF SMOKE**

This section provides specifications for the required and optional test equipment to be used for the ELR test. The smoke shall be measured with an opacimeter having an opacity and a light absorption coefficient readout mode. The opacity readout mode shall only be used for calibration and checking of the opacimeter. The smoke values of the test cycle shall be measured in the light absorption coefficient readout mode.

5.1. **General Requirements**

The ELR requires the use of a smoke measurement and data processing system which includes three functional units. These units may be integrated into a single component or provided as a system of interconnected components. The three functional units are:

- An opacimeter meeting the specifications of Annex V, section 3.
- A data processing unit capable of performing the functions described in Annex III, Appendix 1, section 6.
- A printer and/or electronic storage medium to record and output the required smoke values specified in Annex III, Appendix 1, section 6.3.

5.2. Specific Requirements --

5.2.1. *Linearity*

The linearity shall be within $\pm 2\%$ opacity.

5.2.2. *Zero Drift*

The zero drift during a one hour period shall not exceed $\pm 1\%$ opacity.

5.2.3. *Opacimeter Display and Range*

For display in opacity, the range shall be 0 - 100% opacity, and the readability 0,1% opacity. For display in light absorption coefficient, the range shall be 0 - 30 m^{-1} light absorption coefficient, and the readability 0,01 m^{-1} light absorption coefficient.

5.2.4. *Instrument Response Time*

The physical response time of the opacimeter shall not exceed 0,2 s. The physical response time is the difference between the times when the output of a rapid response receiver reaches 10 and 90 % of the full deviation when the opacity of the gas being measured is changed in less than 0,1 s.

The electrical response time of the opacimeter shall not exceed 0,05 s. The electrical response time is the difference between the times when the opacimeter output reaches 10 and 90 % of the full scale when the light source is interrupted or completely extinguished in less than 0,01 s.

5.2.5. *Neutral Density Filters*

Any neutral density filter used in conjunction with opacimeter calibration, linearity measurements, or setting span shall have its value known to within 1,0% opacity. The filter's nominal value must be checked for accuracy at least yearly using a reference traceable to a national or international standard.

Neutral density filters are precision devices and can easily be damaged during use. Handling should be minimised and, when required, should be done with care to avoid scratching or soiling of the filter.

ANNEX III - APPENDIX 5
CALIBRATION PROCEDURE

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 Directive. The calibration method that shall be used is described in this section for the analysers indicated in Annex III, Appendix 4, section 3 and Annex V, section 1.

1.2. Calibration Gases

The shelf life of all calibration gases must be respected.
The expiration 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 C1, ≤ 1 ppm CO, ≤ 400 ppm CO₂, ≤ 0.1 ppm NO)

Purified oxygen
(Purity ≥ 99.5 % vol O₂)

Hydrogen-helium mixture
(40 ± 2 % hydrogen, balance helium)
(Contamination ≤ 1 ppm C1, ≤ 400 ppm CO₂)

Purified synthetic air
(Contamination ≤ 1 ppm C1, ≤ 1 ppm CO, ≤ 400 ppm CO₂, ≤ 0.1 ppm NO)
(Oxygen content between 18-21 % vol.)

Purified propane or CO for the CVS verification

1.2.2. Calibration and Span Gases

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

C₃H₈ and purified synthetic air (see section 1.2.1);
CO and purified nitrogen;
NO_x and purified nitrogen (the amount of NO₂ contained in this calibration gas must not exceed 5 % of the NO content);
CO₂ and purified nitrogen
CH₄ and purified synthetic air
C₂H₆ 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 must 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 a gas divider, diluting with purified N₂ or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the diluted calibration gases may be determined to within $\pm 2\%$.

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.

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.

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.

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 1.8.1).

1.5.4. ***Calibration***

Each normally used operating range shall be calibrated.

Using purified synthetic air (or nitrogen), the CO, CO₂, NO_x and HC analysers shall be set at zero.

The appropriate calibration gases shall be introduced to the analysers, the values recorded, and the calibration curve established according to section 1.5.5.

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

1.5.5. *Establishment of the Calibration Curve* --

1.5.5.1. General Guidelines

The analyser calibration curve shall be established by at least five calibration points (excluding zero) spaced as uniformly as possible. The highest nominal concentration must be equal to or higher than 90 % of full scale.

The calibration curve shall be calculated by the method of least squares. If the resulting polynomial degree is greater than 3, the number of calibration points (zero included) must be at least equal to this polynomial degree plus 2.

The calibration curve must not differ by more than $\pm 2\%$ from the nominal value of each calibration point and by more than $\pm 1\%$ of full scale at zero.

From the calibration curve and the calibration points, it is possible to verify that the calibration has been carried out correctly. The different characteristic parameters of the analyser must be indicated, particularly:

- the measuring range;
- the sensitivity;
- the date of carrying out the calibration..

1.5.5.2. Calibration below 15 % of Full Scale

The analyser calibration curve shall be established by at least 4 additional calibration points (excluding zero) spaced nominally equally below 15 % of full scale.

The calibration curve is calculated by the method of least squares.

The calibration curve must not differ by more than $\pm 4\%$ from the nominal value of each calibration point and by more than $\pm 1\%$ of full scale at zero.

1.5.5.3. 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 shall be 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 $\pm 4\%$ of full scale from the declared reference value, the adjustment parameters may be modified. Should this not be the case, a new calibration curve shall be established in accordance with section 1.5.5.

1.7. **Efficiency test of the NO_x Converter**

The efficiency of the converter used for the conversion of NO₂ into NO shall be tested as given in sections 1.7.1 to 1.7.8 (Figure 6).

1.7.1. **Test Set-up**

Using the test set-up as shown in Figure 6 (see also Annex III, Appendix 4, section 3.3.5) and the procedure below, the efficiency of converters can be tested by means of an ozonator.

1.7.2. **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 NO₂ 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.

1.7.3. **Calculation**

The efficiency of the NO_x converter is calculated as follows:

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

where,

- a is the NO_x concentration according to section 1.7.6
- b is the NO_x concentration according to section 1.7.7
- c is the NO concentration according to section 1.7.4
- d is the NO concentration according to section 1.7.5

1.7.4. **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 1.7.2 (*The analyser is in the NO mode*). The indicated concentration c shall be recorded. The ozonator is kept deactivated throughout the process.

1.7.5. **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 1.7.2. The indicated concentration d shall be recorded (*The analyser is in the NO mode*).

1.7.6. **NO_x Mode**

The NO analyser is then switched to the NO_x mode so that the gas mixture (consisting of NO, NO₂, O₂ and N₂) now passes through the converter. The indicated concentration a shall be recorded. (*The analyser is in the NO_x mode*).

1.7.7. **Deactivation of the Ozonator**

The ozonator is now deactivated. The mixture of gases described in section 1.7.6 passes through the converter into the detector. The indicated concentration b shall be recorded. (*The analyser is in the NO_x mode*).

1.7.8. **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 1.7.2. (*The analyser is in the NO mode*).

1.7.9. **Test Interval**

The efficiency of the converter must be tested prior to each calibration of the NO_x analyser.

1.7.10. **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 1.7.5, then the highest range which will give the reduction shall be used.

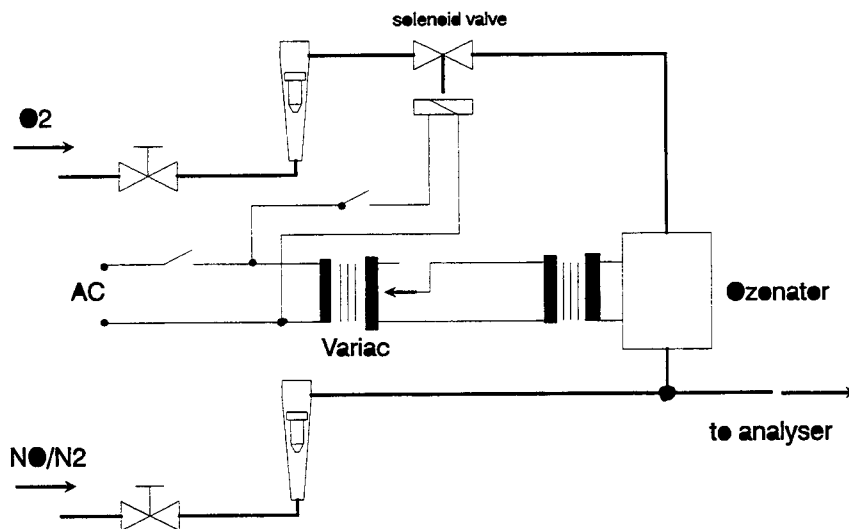


Figure 6 Schematic of NO₂ converter efficiency device

1.8. **Adjustment of the FID**

1.8.1. **Optimisation of the Detector Response**

The FID 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 air flow 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.

1.8.2. *Hydrocarbon Response Factors*

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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 $298 \text{ K} \pm 5 \text{ K}$ ($25^\circ\text{C} \pm 5^\circ\text{C}$).

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.

1.8.3. *Oxygen Interference Check*

The oxygen interference check shall be determined when introducing an analyser into service and after major service intervals.

The response factor is defined and shall be determined as described in section 1.8.2. The test gas to be used and the recommended relative response factor range are as follows:

| | |
|----------------------|---------------------------|
| Propane and nitrogen | $0,95 \leq R_f \leq 1,05$ |
|----------------------|---------------------------|

This value is relative to the response factor (R_f) of 1,00 for propane and purified synthetic air.

The FID burner air oxygen concentration must be within ± 1 mole % of the oxygen concentration of the burner air used in the latest oxygen interference check. If the difference is greater, the oxygen interference must be checked and the analyser adjusted, if necessary.

1.8.4. *Efficiency of the Non-Methane Cutter (NMC, For NG Fuelled Gas Engines Only)*

The NMC is used for the removal of the non-methane hydrocarbons from the sample gas by oxidising all hydrocarbons except methane. Ideally, the conversion for methane is 0 %, and for the other hydrocarbons represented by ethane is 100 %. For the accurate measurement of NMHC, the two efficiencies shall be determined and used for the calculation of the NMHC emission mass flow rate (see Annex III, Appendix 2, section 4.3).

1.8.4.1. Methane Efficiency

Methane calibration gas shall be flown through the FID with and without bypassing the NMC and the two concentrations recorded. The efficiency shall be determined as follows:

$$CE_M = 1 - \frac{conc_w}{conc_{w/o}}$$

where,

$conc_w$ = HC concentration with CH_4 flowing through the NMC
 $conc_{w/o}$ = HC concentration with CH_4 bypassing the NMC

1.8.4.2. Ethane Efficiency

--

Ethane calibration gas shall be flown through the FID with and without bypassing the NMC and the two concentrations recorded. The efficiency shall be determined as follows:

$$CE_E = 1 - \frac{conc_w}{conc_{w/o}}$$

where,

$conc_w$ = HC concentration with C_2H_6 flowing through the NMC

$conc_{w/o}$ = HC concentration with C_2H_6 bypassing the NMC

1.9. **Interference Effects with CO, CO₂, and NO_x Analysers**

Gases present in the exhaust other than the one being analysed can interfere with the reading in several ways. Positive interference occurs in NDIR 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 1.9.1. and 1.9.2. shall be performed prior to an analyser's initial use and after major service intervals.

1.9.1. ***CO Analyser Interference Check***

Water and CO₂ can interfere with the CO analyser performance. Therefore, a CO₂ 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.

1.9.2. ***NO_x Analyser Quench Checks***

The two gases of concern for CLD (and HCLD) analysers are CO₂ and water vapour. Quench responses to these gases are proportional to their concentrations, and therefore require test techniques to determine the quench at the highest expected concentrations experienced during testing.

1.9.2.1. **CO₂ Quench Check**

A CO₂ 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 CO₂ 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 CO₂ and NO values recorded as B and C, respectively. The CO₂ shall then be shut off and only the NO span gas be passed through the (H)CLD and the NO value recorded as D.

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

$$\%Quench = \left[1 - \left(\frac{(C * A)}{(D * A) - (D * B)} \right) \right] * 100$$

where,

- A is the undiluted CO₂ concentration measured with NDIR in %
- B is the diluted CO₂ concentration measured with NDIR in %
- C is the diluted NO concentration measured with (H)CLD in ppm
- D is the undiluted NO concentration measured with (H)CLD in ppm

Alternative methods of diluting and quantifying of CO₂ and NO span gas values such as dynamic mixing/blending can be used.

1.9.2.2. 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 of 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 analyser's absolute operating pressure and the water temperature shall be determined and recorded as E and F, respectively. 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 (H, in %) of the mixture shall be calculated as follows:

$$H = 100 * (G/E)$$

The expected diluted NO span gas (in water vapour) concentration (De) shall be calculated as follows:

$$De = D * (1 - H/100)$$

For diesel exhaust, the maximum exhaust water vapour concentration (Hm, in %) expected during testing shall be estimated, under the assumption of a fuel atom H/C ratio of 1,8:1, from the undiluted CO₂ span gas concentration (A, as measured in section 1.9.2.1) as follows:

$$Hm = 0,9 * A$$

The water quench, which must not be greater than 3%, shall be calculated as follows:

$$\%Quench = 100 * ((De - C) / De) * (Hm / H)$$

where,

- De is the expected diluted NO concentration in ppm
- C is the diluted NO concentration in ppm
- Hm is the maximum water vapour concentration in %
- H is the actual water vapour concentration in %

Note: It is important that the NO span gas contains minimal NO₂ concentration for this check, since absorption of NO₂ in water has not been accounted for in the quench calculations.

1.10. **Calibration Intervals**

The analysers shall be calibrated according to section 1.5 at least every 3 months or whenever a system repair or change is made that could influence calibration.

2. CALIBRATION OF THE CVS-SYSTEM

2.1. General

The CVS system shall be calibrated by using an accurate flowmeter traceable to national or international standards and a restricting device. The flow through the system shall be measured at different restriction settings, and the control parameters of the system shall be measured and related to the flow.

Various types of flowmeters may be used, e. g. calibrated venturi, calibrated laminar flowmeter, calibrated turbinometer.

2.2. Calibration of the Positive Displacement Pump (PDP)

All parameters related to the pump shall be simultaneously measured with the parameters related to the flowmeter which is connected in series with the pump. The calculated flow rate (in m³/min at pump inlet, absolute pressure and temperature) shall be plotted versus a correlation function which is the value of a specific combination of pump parameters. The linear equation which relates the pump flow and the correlation function shall then be determined. If a CVS has a multiple speed drive, the calibration shall be performed for each range used. Temperature stability shall be maintained during calibration.

2.2.1. Data Analysis

The air flowrate (Q_s) at each restriction setting (minimum 6 settings) shall be calculated in standard m³/min from the flowmeter data using the manufacturer's prescribed method. The air flow rate shall then be converted to pump flow (V_0) in m³/rev at absolute pump inlet temperature and pressure as follows:

$$V_0 = \frac{Q_s}{n} * \frac{T}{273} * \frac{101,3}{P_A}$$

where,

| | | |
|-------|---|--|
| Q_s | = | air flow rate at standard conditions (101,3 kPa, 273 K), m ³ /s |
| T | = | temperature at pump inlet, K |
| p_A | = | absolute pressure at pump inlet ($p_B - p_1$), kPa |
| n | = | pump speed, rev/s |

To account for the interaction of pressure variations at the pump and the pump slip rate, the correlation function (X_0) between pump speed, pressure differential from pump inlet to pump outlet and absolute pump outlet pressure shall be calculated as follows:

$$X_0 = \frac{1}{n} * \sqrt{\frac{\Delta p_A}{\rho_A}}$$

where,

| | | |
|--------------|---|---|
| Δp_P | = | pressure differential from pump inlet to pump outlet, kPa |
| p_A | = | absolute outlet pressure at pump outlet, kPa |

A linear least-square fit shall be performed to generate the calibration equation as follows:

$$V_0 = D_0 - m * (X_0)$$

D_0 and m are the intercept and slope constants, respectively, describing the regression lines.

For a CVS system with multiple speeds, the calibration curves generated for the different pump flow ranges shall be approximately parallel, and the intercept values (D_0) shall increase as the pump flow range decreases.

The calculated values from the equation shall be within $\pm 0,5 \%$ of the measured value of V_0 . Values of m will vary from one pump to another. Particulate influx over time will cause the pump slip to decrease, as reflected by lower values for m . Therefore, calibration shall be performed at pump start-up, after major maintenance, and if the total system verification (section 2.4) indicates a change of the slip rate.

2.3. Calibration of the Critical Flow Venturi (CFV)

Calibration of the CFV is based upon the flow equation for a critical venturi. Gas flow is a function of inlet pressure and temperature, as shown below:

$$Q_s = \frac{K_v \rho_A}{\sqrt{T}}$$

where,

K_v = calibration coefficient
 p_A = absolute pressure at venturi inlet, kPa
 T = temperature at venturi inlet, K

2.3.1. Data Analysis

The air flowrate (Q_s) at each restriction setting (minimum 8 settings) shall be calculated in standard m^3/min from the flowmeter data using the manufacturer's prescribed method. The calibration coefficient shall be calculated from the calibration data for each setting as follows:

$$K_v = \frac{Q_s * \sqrt{T}}{\rho_A}$$

where,

Q_s = air flow rate at standard conditions (101,3 kPa, 273 K), m^3/s
 T = temperature at the venturi inlet, K
 p_A = absolute pressure at venturi inlet, kPa

To determine the range of critical flow, K_v shall be plotted as a function of venturi inlet pressure. For critical (choked) flow, K_v will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_v decreases, which indicates that the CFV is operated outside the permissible range.

For a minimum of eight points in the region of critical flow, the average K_v and the standard deviation shall be calculated. The standard deviation shall not exceed $\pm 0,3 \%$ of the average K_v .

2.4. Total System Verification

The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of a pollutant gas into the system while it is being operated in the normal manner. The pollutant is analysed, and the mass calculated according to Annex III, Appendix 2, section 4.3 except in the case of propane where a factor of 0,000472 is used in place of 0,000479 for HC. Either of the following two techniques shall be used.

2.4.1. *Metering with a Critical Flow Orifice*

A known quantity of pure gas (carbon monoxide or propane) shall be fed into the CVS system through a calibrated critical orifice. If the inlet pressure is high enough, the flow rate, which is adjusted by means of the critical flow orifice, is independent of the orifice outlet pressure (\equiv critical flow). The CVS system shall be operated as in a normal exhaust emission test for about 5 to 10 minutes. A gas sample shall be analysed with the usual equipment (sampling bag or integrating method), and the mass of the gas calculated. The mass so determined shall be within $\pm 3\%$ of the known mass of the gas injected.

2.4.2. *Metering by Means of a Gravimetric Technique*

The weight of a small cylinder filled with carbon monoxide or propane shall be determined with a precision of $\pm 0,01$ gram. For about 5 to 10 minutes, the CVS system shall be operated as in a normal exhaust emission test, while carbon monoxide or propane is injected into the system. The quantity of pure gas discharged shall be determined by means of differential weighing. A gas sample shall be analysed with the usual equipment (sampling bag or integrating method), and the mass of the gas calculated. The mass so determined shall be within $\pm 3\%$ of the known mass of the gas injected.

3. CALIBRATION OF THE PARTICULATE MEASURING SYSTEM

3.1. Introduction

Each component shall be calibrated as often as necessary to fulfil the accuracy requirements of this Directive. The calibration method to be used is described in this section for the components indicated in Annex III, Appendix 4, section 4 and Annex V, section 2.

3.2. Flow Measurement

The calibration of gas flow meters or flow measurement instrumentation shall be traceable to international and/or national standards. The maximum error of the measured value shall be within $\pm 2\%$ of reading.

If the gas flow is determined by differential flow measurement, the maximum error of the difference shall be such that the accuracy of G_{EDF} is within $\pm 4\%$ (see also Annex V, section 2.2.1, EGA). It can be calculated by taking the Root-Mean-Square of the errors of each instrument.

3.3. Checking the Partial Flow Conditions

The range of the exhaust gas velocity and the pressure oscillations shall be checked and adjusted according to the requirements of Annex V, section 2.2.1, EP, if applicable.

3.4. Calibration Intervals

The flow measurement instrumentation shall be calibrated at least every 3 months or whenever a system repair or change is made that could influence calibration.

4. CALIBRATION OF THE SMOKE MEASUREMENT EQUIPMENT

4.1. Introduction

The opacimeter shall be calibrated as often as necessary to fulfil the accuracy requirements of this Directive. The calibration method to be used is described in this section for the components indicated in Annex III, Appendix 4, section 5 and Annex V, section 3.

4.2. Calibration Procedure

4.2.1. *Warming-up Time*

The opacimeter shall be warmed up and stabilised according to the manufacturer's recommendations. If the opacimeter is equipped with a purge air system to prevent sooting of the instrument optics, this system should also be activated and adjusted according to the manufacturer's recommendations.

4.2.2. *Establishment of the Linearity Response*

The linearity of the opacimeter shall be checked in the opacity readout mode as per the manufacturer's recommendations. Three neutral density filters of known transmittance, which shall meet the requirements of Annex III, Appendix 4, section 5.2.5, shall be introduced to the opacimeter and the value recorded. The neutral density filters shall have nominal opacities of approximately 10%, 20% and 40%.

The linearity must not differ by more than ± 2 % opacity from the nominal value of the neutral density filter. Any non-linearity exceeding the above value must be corrected prior to the test.

4.3. Calibration Intervals

The opacimeter shall be calibrated according to section 4.2.2 at least every 3 months or whenever a system repair or change is made that could influence calibration.

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

1 **DIESEL FUEL ⁽⁶⁾**

| Parameter | Unit | Limits ⁽¹⁾ | | Test Method ⁽²⁾ |
|-------------------------------------|--------------------|-----------------------|---------|----------------------------|
| | | Minimum | Maximum | |
| Cetane number ⁽⁵⁾ | | 52 | 54 | ISO 5165 |
| Density at 15 °C | kg/m ³ | 833 | 837 | ISO 3675 |
| Distillation ⁽⁴⁾ : | | | | |
| - 50 % point | °C | 245 | | ISO 3405 |
| - 95 % point | °C | 345 | 350 | ISO 3405 |
| - final boiling point | °C | --- | 370 | ISO 3405 |
| Flash point | °C | 55 | --- | ASTM D 93 |
| CFPP | °C | --- | -5 | EN 116 |
| Viscosity at 40 °C | mm ² /s | 2,5 | 3,5 | ASTM D 445 |
| Polycyclic aromatic hydrocarbons | % m/m | 3,0 | 6,0 | pr IP 391 |
| Sulphur content | % m/m | --- | 0,03 | ISO 8754 |
| Copper corrosion | | --- | 1 | ASTM D 130 |
| Conradson carbon residue (10 % DR) | % m/m | --- | 0,2 | ASTM D 189 |
| Ash content | % m/m | --- | 0,01 | ASTM D 482 |
| Water content | % m/m | --- | 0,05 | ASTM D 95/D 1744 |
| Neutralisation (strong acid) number | KOH/g | --- | 0,02 | |
| Oxidation stability ⁽⁵⁾ | mg/100 ml | --- | 2,5 | ASTM D 2274 |

- (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 a fuel 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 specification, the terms of ISO 4259 should be applied.
- (2) The month of publication will be completed in due course.

- (3) The range for cetane number is not in accordance with the requirement of a minimum range of 4R. However, in the case of dispute between fuel supplier and fuel user, the terms in ISO 4259 can be used to resolve such disputes provided replicate measurements, of sufficient number to achieve the necessary precision, are made in preference to single determinations.
- (4) The actual sulphur content of the fuel used for the test shall be reported. In addition, the sulphur content of the reference fuel used to approve a vehicle or engine against the limit values set out in row B of the Table in section 6.2.1 of Annex I to this Directive shall have a maximum sulphur content of 50 ppm. The Commission will as soon as possible, but no later than 31 December 1999, bring forward a modification of this Annex reflecting the market average for fuel sulphur content in respect of the fuel defined in Annex IV of Directive 98/70/EC.
- (5) Even though oxidation stability is controlled, it is likely that shelf life will be limited. Advice should be sought from the supplier as to storage conditions and life.
- (6) If it is required to calculate the thermal efficiency of an engine or vehicle, the calorific value of the fuel can be calculated from:
 Specific energy (calorific value) (net) in MJ/kg = $(46,423 - 8,792d^2 + 3,170d) (1 - (x + y + s)) + 9,420s - 2,499x$
 where,
 d = the density at 15 °C
 x = the proportion by mass of water (% divided by 100)
 y = the proportion by mass of ash (% divided by 100)
 s = the proportion by mass of sulphur (% divided by 100).

2. NATURAL GAS (NG)

European market fuels are available in two ranges:

- the H range, whose extreme reference fuels are G₂₀ and G₂₃;
- the L range, whose extreme reference fuels are G₂₃ and G₂₅.

The characteristics of G₂₀, G₂₃ and G₂₅ reference fuels are summarised below:

Reference fuel G₂₀

| Characteristics | Units | Basis | Limits | | Test Method |
|--|-----------------------|-------|--------|------|-------------|
| | | | Min. | Max. | |
| <i>Composition:</i> | | | | | |
| Methane | | 100 | 99 | 100 | ISO 6974 |
| Balance [Inerts +C ₂ /C ₂ +] N ₂ | %mole | - | - | 1 | |
| Sulphur content | mg/m ³ (*) | - | - | 50 | |

Reference fuel G₂₃

| Characteristics | Units | Basis | Limits | | Test Method |
|--|-----------------------|-------|--------|------|-------------|
| | | | Min. | Max. | |
| <i>Composition:</i> | | | | | |
| Methane | | 92.5 | 91.5 | 93.5 | ISO 6974 |
| Balance [Inerts +C ₂ /C ₂ +] N ₂ | %mole | - | - | 1 | |
| Sulphur content | mg/m ³ (*) | - | - | 50 | |

(*) value to be determined at standard conditions (293.2 K (20°C) and 101.3 kPa).

Reference fuel G₂₅

| Characteristics | Units | Basis | Limits | | Test Method |
|---|-----------------------|-------|--------|------|-------------|
| | | | Min. | Max. | |
| <i>Composition:</i> | | | | | |
| Methane | %mole | 86 | 84 | 88 | ISO 6974 |
| Balance | | - | - | 1 | |
| [Inerts +C ₂ /C ₂ +] | | 14 | 12 | 16 | |
| N ₂ | | | | | |
| Sulphur content | mg/m ³ (*) | - | - | 50 | ISO 6326-5 |

(*) value to be determined at standard conditions (293.2 K (20°C) and 101.3 kPa).

3. LIQUEFIED PETROLEUM GAS (LPG)

| Parameter | Unit | Limits Fuel A | | Limits Fuel B | | Test Method |
|------------------------|---------------------------|---------------|---------|---------------|---------|-------------------------|
| | | Minimum | Maximum | Minimum | Maximum | |
| Motor Octane Number | | 93.5 | | 93.5 | | EN 589 Annex B |
| Composition | | | | | | |
| C3 content | % vol | 48 | 52 | 83 | 87 | ISO 7941 |
| C4 content | % vol | 48 | 52 | 13 | 17 | |
| Olefins | % vol | 0 | 12 | 9 | 15 | NFM 41-015 |
| Evaporation residue | mg/kg | | 50 | | 50 | |
| Total sulphur content | ppm weight ⁽¹⁾ | | 50 | | 50 | EN 24260 |
| Hydrogen sulphide | --- | | None | | None | ISO 8819 |
| Copper strip corrosion | rating | | class 1 | | class 1 | ISO 6251 ⁽²⁾ |
| Water at 0°C | | | free | | free | visual inspection |

(1) Value to be determined at standard conditions 293,2 K (20 °C) and 101,3 kPa

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

ANALYTICAL AND SAMPLING SYSTEMS

1. DETERMINATION OF THE GASEOUS EMISSIONS

1.1. Introduction

Section 1.2 and figures 7 and 8 contain detailed descriptions of the recommended sampling and analysing systems. Since various configurations can produce equivalent results, exact conformance with figures 7 and 8 is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgement.

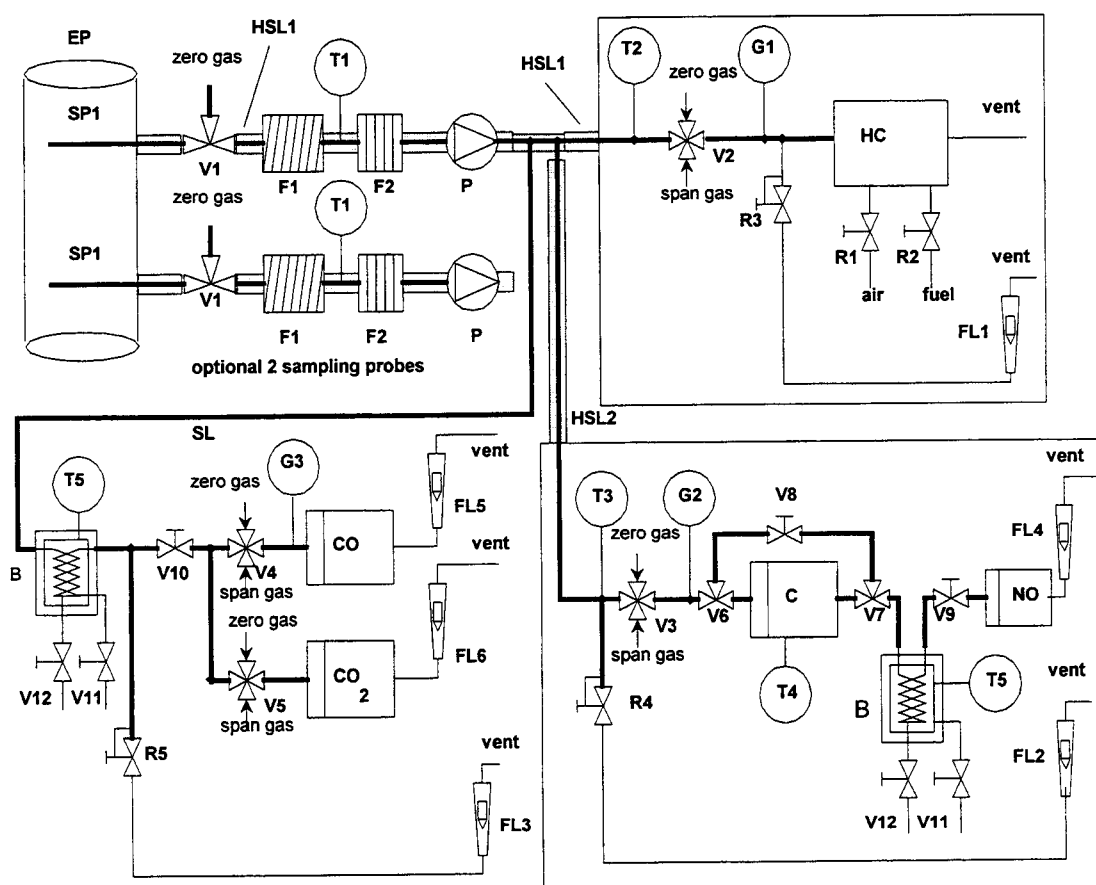


Figure 7 Flow diagram of raw exhaust gas analysis system for CO, CO₂, NO_x, HC
ESC Only

1.2. Description of the Analytical System

An analytical system for the determination of the gaseous emissions in the raw (Figure 7, ESC only) or diluted (Figure 8, ETC and ESC) exhaust gas is described based on the use of:

- HFID analyser for the measurement of hydrocarbons;
- NDIR analysers for the measurement of carbon monoxide and carbon dioxide;
- HCLD or equivalent analyser for the measurement of the oxides of nitrogen;

The sample for all components may be taken with one sampling probe or with two sampling probes located in close proximity and internally split to the different analysers. Care must be taken that no condensation of exhaust components (including water and sulphuric acid) occurs at any point of the analytical system.

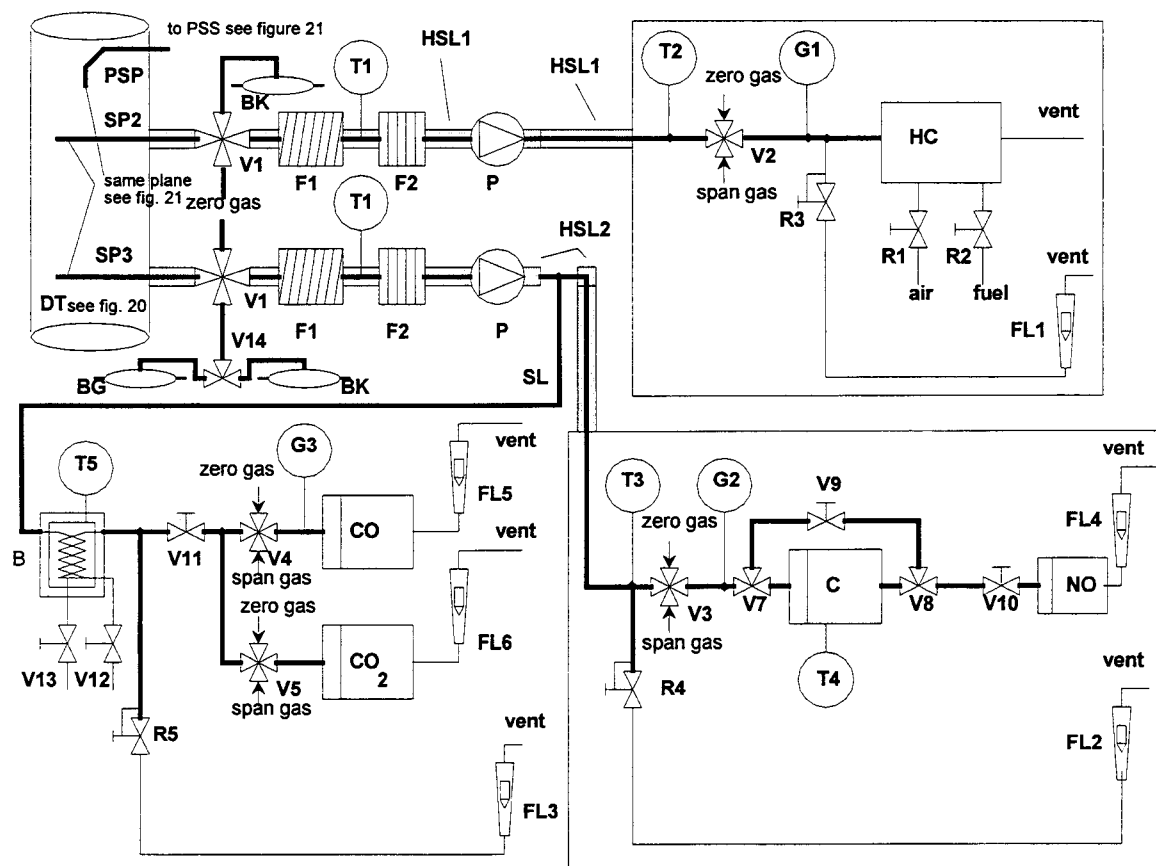


Figure 8 Flow diagram of diluted exhaust gas analysis system for CO, CO₂, NO_x, HC (ETC, Optional for Economic and Social Committee)

1.2.1. Components of figures 7 and 8

EP Exhaust pipe

SP1 Exhaust gas sampling probe (Figure 7 only)

A stainless steel straight closed end multi-hole probe is recommended. The inside diameter shall not be greater than the inside diameter of the sampling line. The wall thickness of the probe shall not be greater than 1 mm. There shall be a minimum of 3 holes in 3 different radial planes sized to sample approximately the same flow. The probe must extend across at least 80 % of the diameter of the exhaust pipe. One or two sampling probes may be used.

SP2 Diluted exhaust gas HC sampling probe (Figure 8 only)

The probe shall:

- be defined as the first 254 mm to 762 mm of the heated sampling line HSL1;
- have a 5 mm minimum inside diameter;
- be installed in the dilution tunnel DT (see section 2.3, Figure 20) at a point where the dilution air and exhaust gas are well mixed (i.e. approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel);
- be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies;
- be heated so as to increase the gas stream temperature to $463\text{ K} \pm 10\text{ K}$ ($190^{\circ}\text{C} \pm 10^{\circ}\text{C}$) at the exit of the probe.

SP3 Diluted exhaust gas CO, CO₂, NO_x sampling probe (Figure 8 only)

The probe shall:

- be in the same plane as SP 2;
- be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies;
- be heated and insulated over its entire length to a minimum temperature of 328 K (55°C) to prevent water condensation.

HSL1 Heated sampling line

The sampling line provides a gas sample from a single probe to the split point(s) and the HC analyser.

The sampling line shall:

- have a 5 mm minimum and a 13,5 mm maximum inside diameter;
- be made of stainless steel or PTFE.
- maintain a wall temperature of $463\text{ K} \pm 10\text{ K}$ ($190^{\circ}\text{C} \pm 10^{\circ}\text{C}$) as measured at every separately controlled heated section, if the temperature of the exhaust gas at the sampling probe is equal to or below 463 K (190°C);
- maintain a wall temperature greater than 453 K (180°C), if the temperature of the exhaust gas at the sampling probe is above 463 K (190°C);
- maintain a gas temperature of $463\text{ K} \pm 10\text{ K}$ ($190^{\circ}\text{C} \pm 10^{\circ}\text{C}$) immediately before the heated filter F2 and the HFID;

HSL2 Heated NO_x sampling line

The sampling line shall:

- maintain a wall temperature of 328 K to 473 K (55°C to 200°C), up to the converter C when using a cooling bath B, and up to the analyser when a cooling bath B is not used.
- be made of stainless steel or PTFE.

SL Sampling line for CO and CO₂

The line shall be made of PTFE or stainless steel. It may be heated or unheated.

BK Background bag (optional; Figure 8 only)

For the sampling of the background concentrations

BG Sample bag (optional; Figure 8 CO and CO₂ only)

For the sampling of the sample concentrations.

F1 Heated pre-filter (optional)

The temperature shall be the same as HSL1.

F2 Heated filter

The filter shall extract any solid particles from the gas sample prior to the analyser. The temperature shall be the same as HSL1. The filter shall be changed as needed.

P Heated sampling pump

The pump shall be heated to the temperature of HSL1.

HC

Heated flame ionisation detector (HFID) for the determination of the hydrocarbons. The temperature shall be kept at 453 K to 473 K (180°C to 200°C).

CO, CO₂

NDIR analysers for the determination of carbon monoxide and carbon dioxide (optional for the determination of the dilution ratio for PT measurement).

NO

CLD or HCLD analyser for the determination of the oxides of nitrogen. If a HCLD is used it shall be kept at a temperature of 328 K to 473 K (55°C to 200°C).

C Converter

A converter shall be used for the catalytic reduction of NO₂ to NO prior to analysis in the CLD or HCLD.

B Cooling bath (optional)

To cool and condense water from the exhaust sample. The bath shall be maintained at a temperature of 273 K to 277 K (0°C to 4°C) by ice or refrigeration. It is optional if the analyser is free from water vapour interference as determined in Annex III, Appendix 5, sections 1.9.1 and 1.9.2. If water is removed by condensation, the sample gas temperature or dew point shall be monitored either within the water trap or downstream. The sample gas temperature or dew point must not exceed 280 K (7°C). Chemical dryers are not allowed for removing water from the sample.

T1, T2, T3 Temperature sensor

To monitor the temperature of the gas stream.

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T4 Temperature sensor

To monitor the temperature of the NO₂ - NO converter.

T5 Temperature sensor

To monitor the temperature of the cooling bath.

G1, G2, G3 Pressure gauge

To measure the pressure in the sampling lines.

R1, R2 Pressure regulator

To control the pressure of the air and the fuel, respectively, for the HFID.

R3, R4, R5 Pressure regulator

To control the pressure in the sampling lines and the flow to the analysers.

FL1, FL2, FL3 Flowmeter

To monitor the sample by-pass flow rate.

FL4 to FL6 Flowmeter (optional)

To monitor the flow rate through the analysers.

V1 to V5 Selector valve

Suitable valving for selecting sample, span gas or zero gas flow to the analysers.

V6, V7 Solenoid valve

To by-pass the NO₂ - NO converter.

V8 Needle valve

To balance the flow through the NO₂ - NO converter C and the by-pass.

V9, V10 Needle valve

To regulate the flows to the analysers.

V11, V12 Toggle valve (optional)

To drain the condensate from the bath B.

1.3. **NMHC Analysis (NG Fuelled Gas Engines Only)**

1.3.1. ***Gas Chromatographic Method (GC, Figure 9)***

When using the GC method, a small measured volume of a sample is injected onto an analytical column through which it is swept by an inert carrier gas. The column separates various components according to their boiling points so that they elute from the column at different times. They then pass through a detector which gives an electrical signal that depends on their concentration. Since it is not a continuous analysis technique, it can only be used in conjunction with the bag sampling method as described in Annex III, Appendix 4, section 3.4.2.

For NMHC an automated GC with a FID shall be used. The exhaust gas shall be sampled into a sampling bag from which a part shall be taken and injected into the GC. The sample is separated into two parts ($\text{CH}_4/\text{Air}/\text{CO}$ and $\text{NMHC}/\text{CO}_2/\text{H}_2\text{O}$) on the Porapak column. The molecular sieve column separates CH_4 from the air and CO before passing it to the FID where its concentration is measured. A complete cycle from injection of one sample to injection of a second can be made in 30 s. To determine NMHC, the CH_4 concentration shall be subtracted from the total HC concentration (see Annex III, Appendix 2, section 4.3.1).

Figure 9 shows a typical GC assembled to routinely determine CH_4 . Other GC methods can also be used based on good engineering judgement.

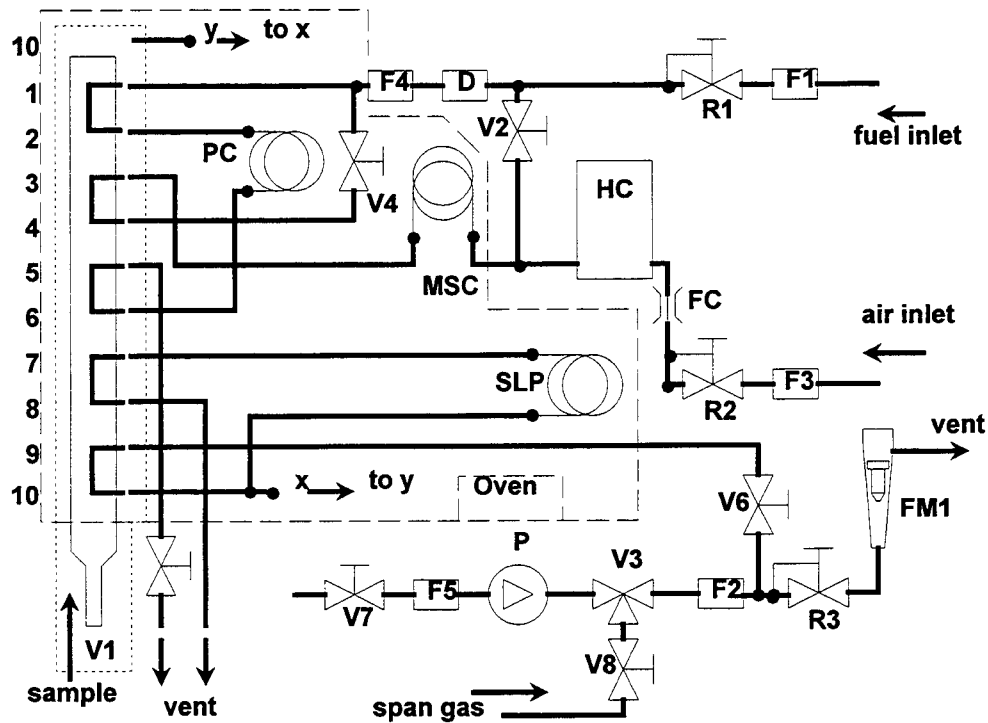


Figure 9 Flow Diagram for Methane Analysis (GC Method)

Components of Figure 9

PC Porapak column

Porapak N, 180/300 μm (50/80 mesh), 610 mm length x 2,16 mm ID shall be used and conditioned at least 12 h at 423 K (150°C) with carrier gas prior to initial use.

MSC Molecular sieve column

Type 13X, 250/350 μm (45/60 mesh), 1220 mm length x 2,16 mm ID shall be used and conditioned at least 12 h at 423 K (150°C) with carrier gas prior to initial use.

OV Oven

To maintain columns and valves at stable temperature for analyser operation, and to condition the columns at 423 K (150°C).

SLP Sample loop

A sufficient length of stainless steel tubing to obtain approximately 1 cm³ volume.

P Pump

To bring the sample to the gas chromatograph.

D Dryer

A dryer containing molecular sieve shall be used to remove water and other contaminants which might be present in the carrier gas.

HC

Flame ionisation detector (FID) to measure the concentration of methane.

V1 Sample injection valve

To inject the sample taken from the sampling bag via SL of Figure 8. It shall be low dead volume, gas tight, and heatable to 423 K (150°C).

V3 Selector valve

To select span gas, sample, or no flow.

V2, V4, V5, V6, V7, V8 Needle valve

To set the flows in the system.

R1, R2, R3 Pressure regulator

To control the flows of the fuel (= carrier gas), the sample, and the air, respectively.

FC Flow capillary

To control the rate of air flow to the FID

G1, G2, G3 Pressure gauge

To control the flows of the fuel (= carrier gas), the sample, and the air, respectively.

F1, F2, F3, F4, F5 Filter

Sintered metal filters to prevent grit from entering the pump or the instrument.

FL 1

To measure the sample bypass flow rate.

1.3.2. *Non-Methane Cutter Method (NMC, Figure 10)*

The cutter oxidises all hydrocarbons except CH₄ to CO₂ and H₂O, so that by passing the sample through the NMC only CH₄ is detected by the FID. If bag sampling is used, a flow diverter system shall be installed at SL (see section 1.2, Figure 8) with which the flow can be alternatively passed through or around the cutter according to the upper part of Figure 10. For NMHC measurement, both values (HC and CH₄) shall be observed on the FID and recorded. If the integration method is used, an NMC in line with a second FID shall be installed parallel to the regular FID into HSL1 (see section 1.2, Figure 8) according to the lower part of Figure 10. For NMHC measurement, the values of the two FID's (HC and CH₄) shall be observed and recorded.

The cutter shall be characterised at or above 600 K (327°C) prior to test work with respect to its catalytic effect on CH₄ and C₂H₆ at H₂O values representative of exhaust stream conditions. The dewpoint and O₂ level of the sampled exhaust stream must be known. The relative response of the FID to CH₄ must be recorded (see Annex III, Appendix 5, section 1.8.2).

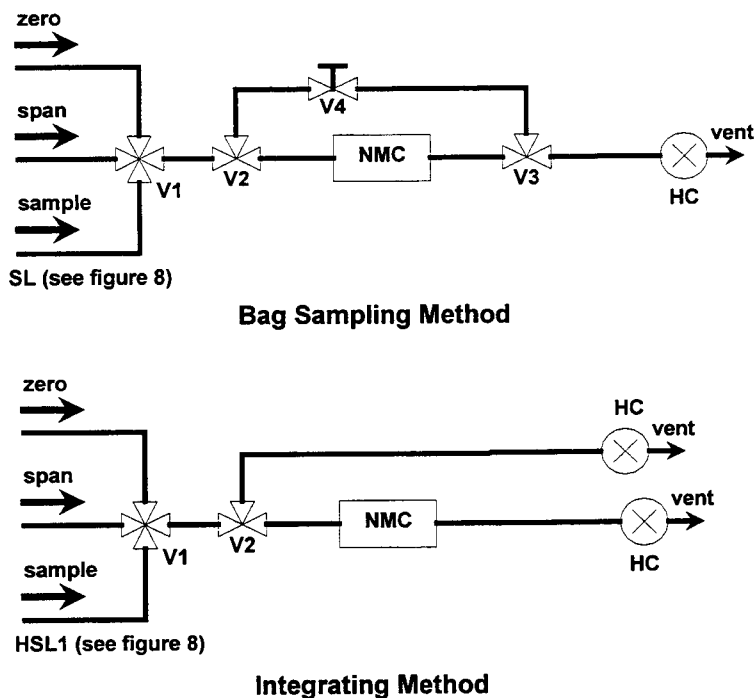


Figure 10 Flow diagram for methane analysis with the Non-Methane Cutter (NMC)

Components of Figure 10

NMC Non-methane cutter

To oxidise all hydrocarbons except methane.

HC

Heated flame ionisation detector (HFID) to measure the HC and CH₄ concentrations. The temperature shall be kept at 453 K to 473 K (180°C to 200°C).

V1 Selector valve

To select sample, zero and span gas. V1 is identical with V2 of Figure 8.

V2, V3 Solenoid valve

To by-pass the NMC

V4 Needle valve

To balance the flow through the NMC and the by-pass.

R1 Pressure regulator

To control the pressure in the sampling line and the flow to the HFID. R1 is identical with R3 of Figure 8.

FL1 Flowmeter

To measure the sample by-pass flow rate. FL1 is identical with FL1 of Figure 8.

2. **EXHAUST GAS DILUTION AND DETERMINATION OF THE PARTICULATES**

2.1. **Introduction**

Sections 2.2, 2.3 and 2.4 and figures 11 to 22 contain detailed descriptions of the recommended dilution and sampling systems. Since various configurations can produce equivalent results, exact conformance with these figures is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgement.

2.2. **Partial Flow Dilution System**

A dilution system is described in figures 11 to 19 based upon the dilution of a part of the exhaust stream. Splitting of the exhaust stream and the following dilution process may be done by different dilution system types. For subsequent collection of the particulates, the entire dilute exhaust gas or only a portion of the dilute exhaust gas is passed to the particulate sampling system (section 2.4, Figure 21). The first method is referred to as *total sampling type*, the second method as *fractional sampling type*.

The calculation of the dilution ratio depends upon the type of system used. The following types are recommended:

Isokinetic systems (Figures 11,12)

With these systems, the flow into the transfer tube is matched to the bulk exhaust flow in terms of gas velocity and/or pressure, thus requiring an undisturbed and uniform exhaust flow at the sampling probe. This is usually achieved by using a resonator and a straight approach tube upstream of the sampling point. The split ratio is then calculated from easily measurable values like tube diameters. It should be noted that isokinetic is only used for matching the flow conditions and not for matching the size distribution. The latter is typically not necessary, as the particles are sufficiently small as to follow the fluid streamlines.

Flow controlled systems with concentration measurement (Figures 13 to 17)

With these systems, a sample is taken from the bulk exhaust stream by adjusting the dilution air flow and the total dilute exhaust flow. The dilution ratio is determined from the concentrations of tracer gases, such as CO₂ or NO_x, naturally occurring in the engine exhaust. The concentrations in the dilute exhaust gas and in the dilution air are measured, whereas the concentration in the raw exhaust gas can be either measured directly or determined from fuel flow and the carbon balance equation, if the fuel composition is known. The systems may be controlled by the calculated dilution ratio (figures 13,14) or by the flow into the transfer tube (figures 12,13,14).

Flow controlled systems with flow measurement (Figures 18,19)

With these systems, a sample is taken from the bulk exhaust stream by setting the dilution air flow and the total dilute exhaust flow. The dilution ratio is determined from the difference of the two flow rates. Accurate calibration of the flow meters relative to one another is required, since the relative magnitude of the two flow rates can lead to significant errors at higher dilution ratios (of 15 and above). Flow control is very straightforward by keeping the dilute exhaust flow rate constant and varying the dilution air flow rate, if needed.

When using partial flow dilution systems, attention must be paid to avoiding the potential problems of loss of particulates in the transfer tube, ensuring that a representative sample is taken from the engine exhaust, and determination of the split ratio. The systems described pay attention to these critical areas.

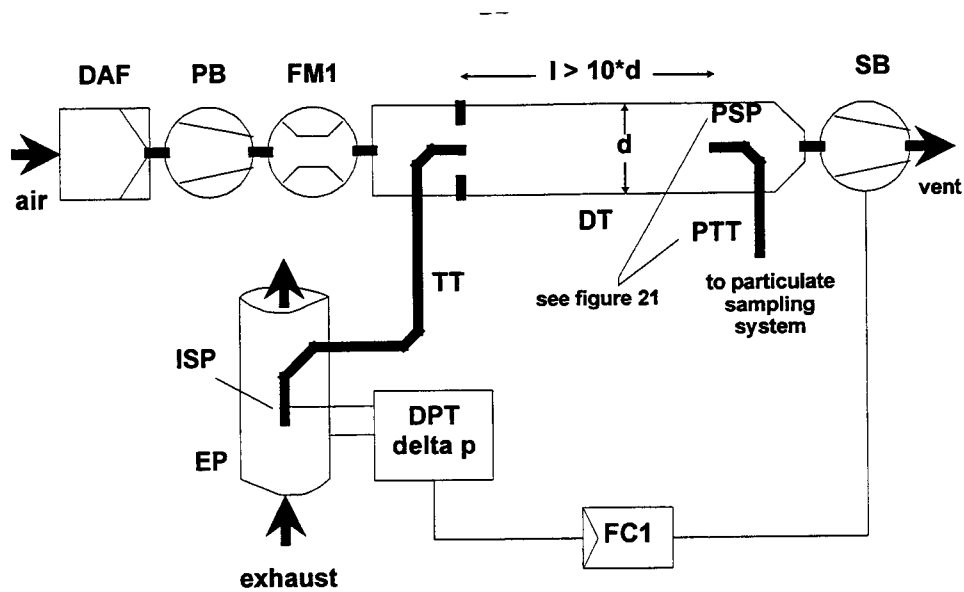


Figure 11 Partial flow dilution system with isokinetic probe and fractional sampling (SB control)

Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the transfer tube TT by the isokinetic sampling probe ISP. The differential pressure of the exhaust gas between exhaust pipe and inlet to the probe is measured with the pressure transducer DPT. This signal is transmitted to the flow controller FC1 that controls the suction blower SB to maintain a differential pressure of zero at the tip of the probe. Under these conditions, exhaust gas velocities in EP and ISP are identical, and the flow through ISP and TT is a constant fraction (split) of the exhaust gas flow. The split ratio is determined from the cross sectional areas of EP and ISP. The dilution air flow rate is measured with the flow measurement device FM1. The dilution ratio is calculated from the dilution air flow rate and the split ratio.

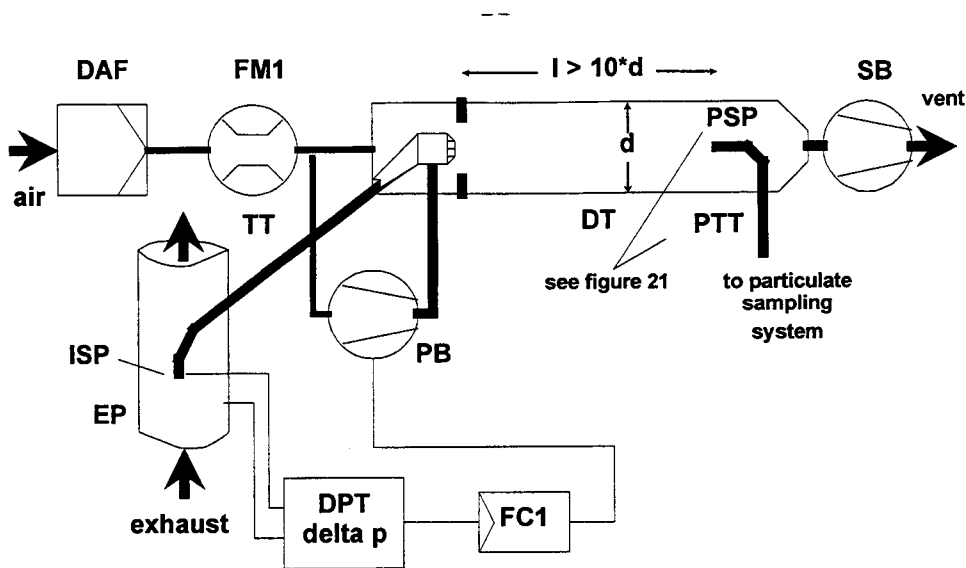


Figure 12 Partial flow dilution system with isokinetic probe and fractional sampling (PB control)

Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the transfer tube TT by the isokinetic sampling probe ISP. The differential pressure of the exhaust gas between exhaust pipe and inlet to the probe is measured with the pressure transducer DPT. This signal is transmitted to the flow controller FC1 that controls the pressure blower PB to maintain a differential pressure of zero at the tip of the probe. This is done by taking a small fraction of the dilution air whose flow rate has already been measured with the flow measurement device FM1, and feeding it to TT by means of a pneumatic orifice. Under these conditions, exhaust gas velocities in EP and ISP are identical, and the flow through ISP and TT is a constant fraction (split) of the exhaust gas flow. The split ratio is determined from the cross sectional areas of EP and ISP. The dilution air is sucked through DT by the suction blower SB, and the flow rate is measured with FM1 at the inlet to DT. The dilution ratio is calculated from the dilution air flow rate and the split ratio.

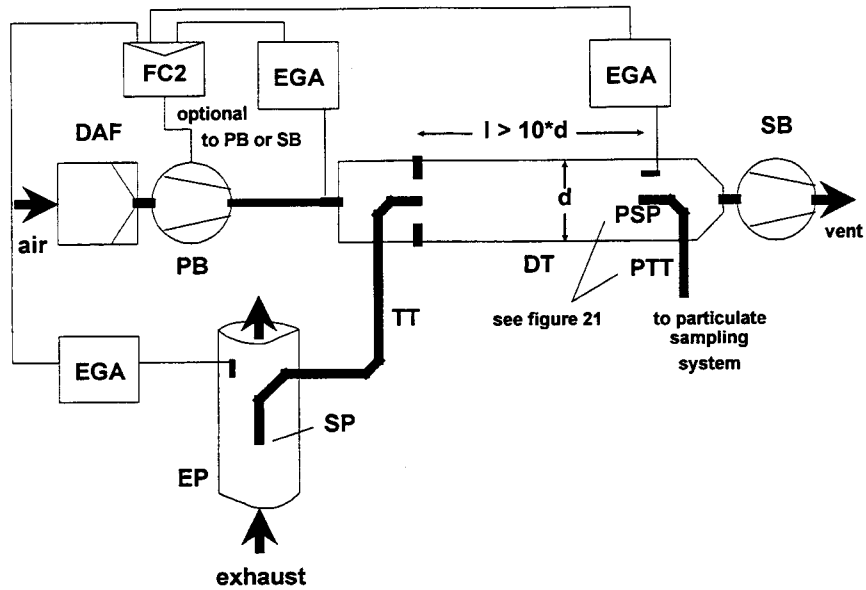


Figure 13 Partial flow dilution system with CO₂ or NO_x concentration measurement and fractional sampling

Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The concentrations of a tracer gas (CO₂ or NO_x) are measured in the raw and diluted exhaust gas as well as in the dilution air with the exhaust gas analyser(s) EGA. These signals are transmitted to the flow controller FC2 that controls either the pressure blower PB or the suction blower SB to maintain the desired exhaust split and dilution ratio in DT. The dilution ratio is calculated from the tracer gas concentrations in the raw exhaust gas, the diluted exhaust gas, and the dilution air.

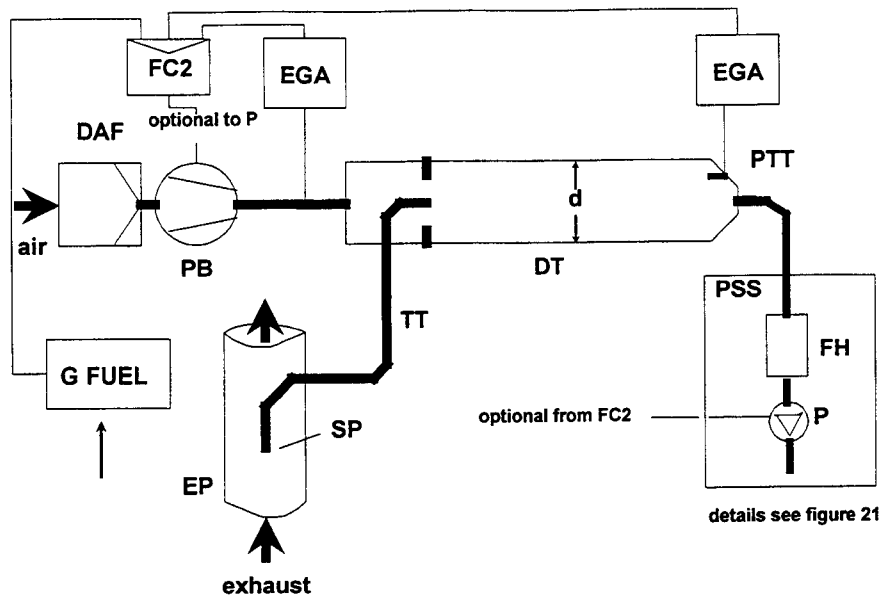


Figure 14 Partial flow dilution system with CO₂ concentration measurement, carbon balance and total sampling

Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The CO₂ concentrations are measured in the diluted exhaust gas and in the dilution air with the exhaust gas analyser(s) EGA. The CO₂ and fuel flow G_{FUEL} signals are transmitted either to the flow controller FC2, or to the flow controller FC3 of the particulate sampling system (see Figure 21). FC2 controls the pressure blower PB, FC3 the sampling pump P (see Figure 21), thereby adjusting the flows into and out of the system so as to maintain the desired exhaust split and dilution ratio in DT. The dilution ratio is calculated from the CO₂ concentrations and G_{FUEL} using the carbon balance assumption.

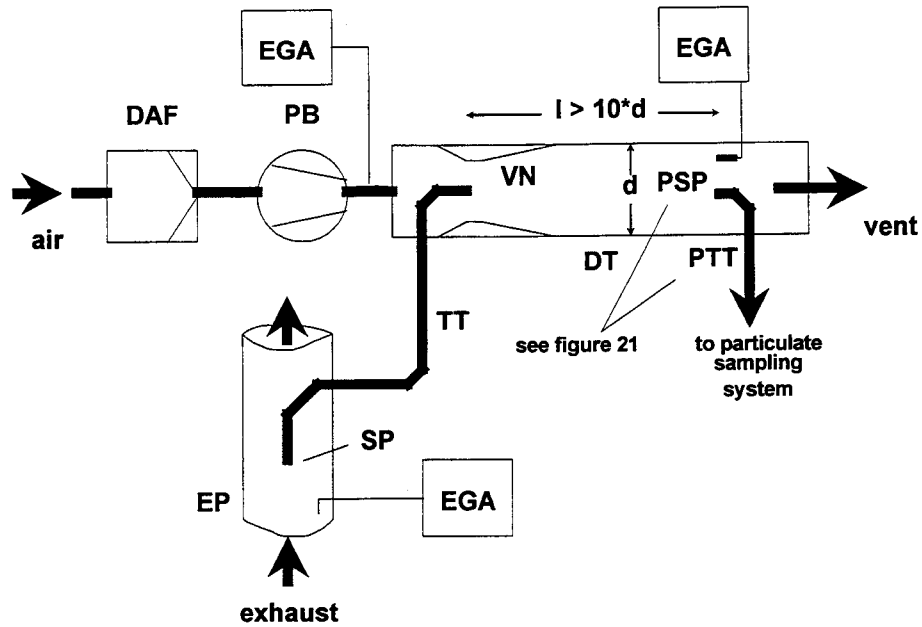


Figure 15 Partial flow dilution system with single venturi, concentration measurement and fractional sampling

Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT due to the negative pressure created by the venturi VN in DT. The gas flow rate through TT depends on the momentum exchange at the venturi zone, and is therefore affected by the absolute temperature of the gas at the exit of TT. Consequently, the exhaust split for a given tunnel flow rate is not constant, and the dilution ratio at low load is slightly lower than at high load. The tracer gas concentrations (CO_2 or NO_x) are measured in the raw exhaust gas, the diluted exhaust gas, and the dilution air with the exhaust gas analyser(s) EGA, and the dilution ratio is calculated from the values so measured.

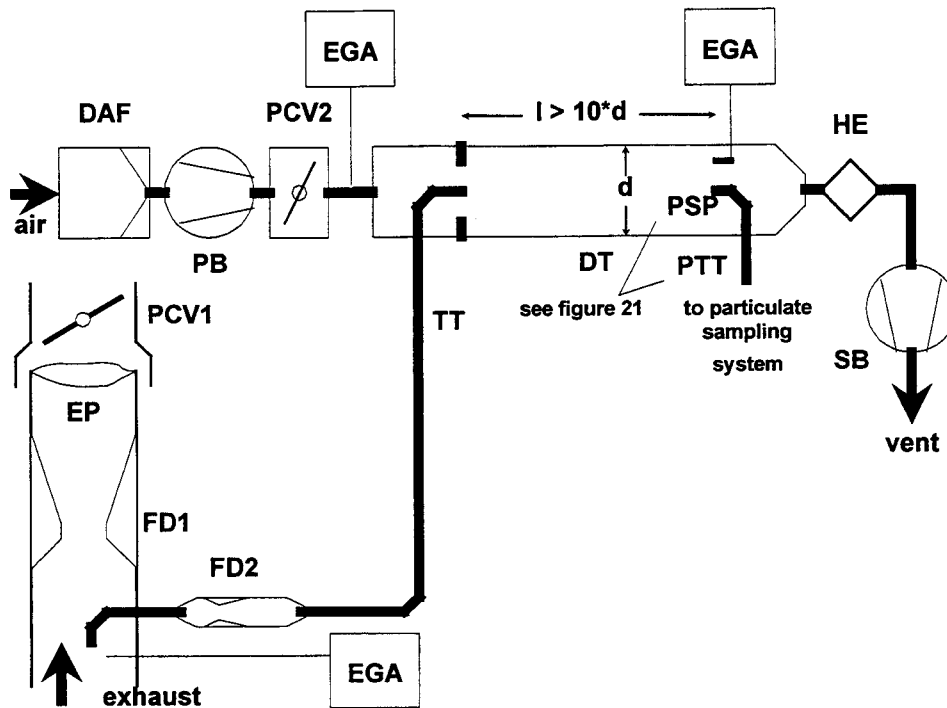


Figure 16 Partial flow dilution system with twin venturi or twin orifice, concentration measurement and fractional sampling

Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT by a flow divider that contains a set of orifices or venturis. The first one (FD1) is located in EP, the second one (FD2) in TT. Additionally, two pressure control valves (PCV1 and PCV2) are necessary to maintain a constant exhaust split by controlling the backpressure in EP and the pressure in DT. PCV1 is located downstream of SP in EP, PCV2 between the pressure blower PB and DT. The tracer gas concentrations (CO_2 or NO_x) are measured in the raw exhaust gas, the diluted exhaust gas, and the dilution air with the exhaust gas analyser(s) EGA. They are necessary for checking the exhaust split, and may be used to adjust PCV1 and PCV2 for precise split control. The dilution ratio is calculated from the tracer gas concentrations.

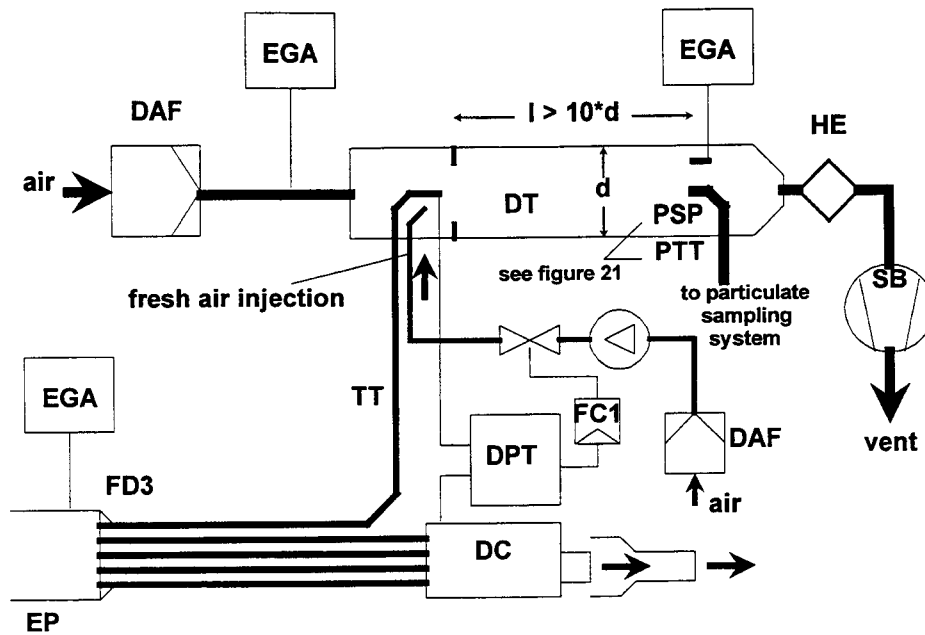


Figure 17 Partial flow dilution system with multiple tube splitting, concentration measurement and fractional sampling

Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the transfer tube TT by the flow divider FD3 that consists of a number of tubes of the same dimensions (same diameter, length and bend radius) installed in EP. The exhaust gas through one of these tubes is lead to DT, and the exhaust gas through the rest of the tubes is passed through the damping chamber DC. Thus, the exhaust split is determined by the total number of tubes. A constant split control requires a differential pressure of zero between DC and the outlet of TT, which is measured with the differential pressure transducer DPT. A differential pressure of zero is achieved by injecting fresh air into DT at the outlet of TT. The tracer gas concentrations (CO_2 or NO_x) are measured in the raw exhaust gas, the diluted exhaust gas, and the dilution air with the exhaust gas analyser(s) EGA. They are necessary for checking the exhaust split and may be used to control the injection air flow rate for precise split control. The dilution ratio is calculated from the tracer gas concentrations.

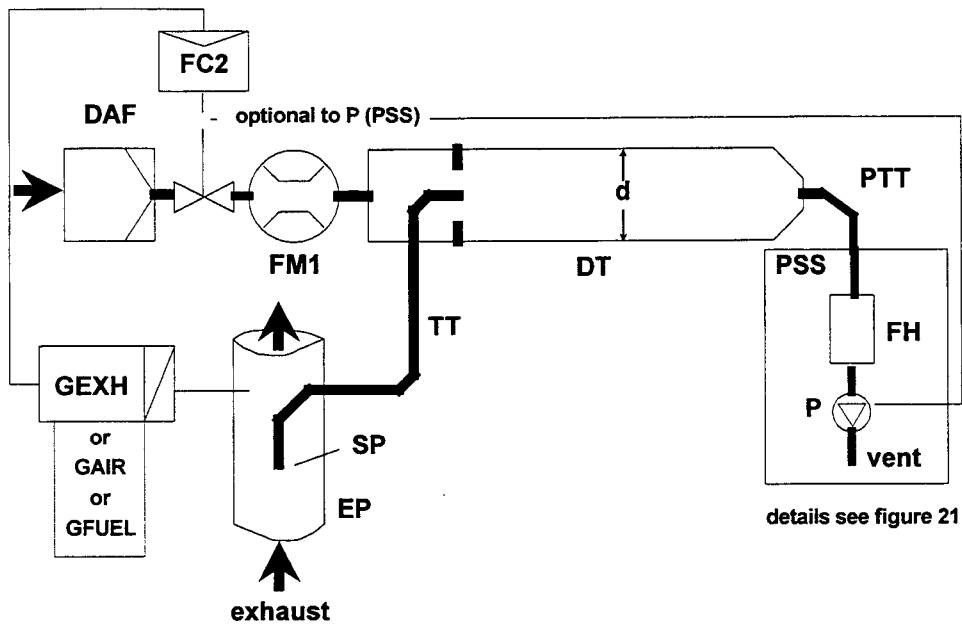


Figure 18 Partial flow dilution system with flow control and total sampling

Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The total flow through the tunnel is adjusted with the flow controller FC3 and the sampling pump P of the particulate sampling system (see Figure 18). The dilution air flow is controlled by the flow controller FC2, which may use G_{EXHW} , G_{AIRW} , or G_{FUEL} as command signals, for the desired exhaust split. The sample flow into DT is the difference of the total flow and the dilution air flow. The dilution air flow rate is measured with the flow measurement device FM1, the total flow rate with the flow measurement device FM3 of the particulate sampling system (see Figure 21). The dilution ratio is calculated from these two flow rates.

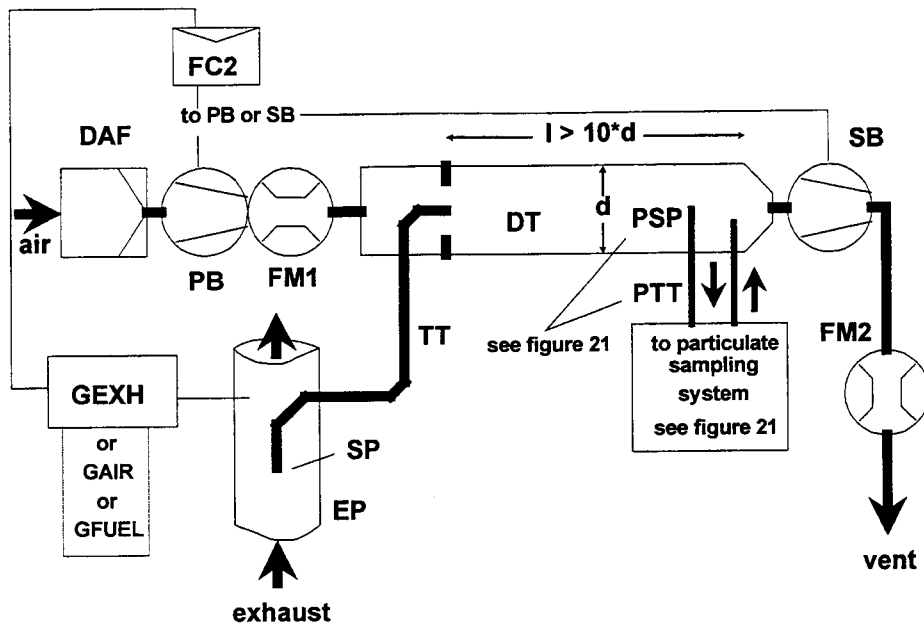


Figure 19 Partial flow dilution system with flow control and fractional sampling

Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The exhaust split and the flow into DT is controlled by the flow controller FC2 that adjusts the flows (or speeds) of the pressure blower PB and the suction blower SB, accordingly. This is possible since the sample taken with the particulate sampling system is returned into DT. G_{EXHW} , G_{AIRW} , or G_{FUEL} may be used as command signals for FC2. The dilution air flow rate is measured with the flow measurement device FM1, the total flow with the flow measurement device FM2. The dilution ratio is calculated from these two flow rates.

2.2.1. *Components of figures 11 to 19*

EP Exhaust pipe

The exhaust pipe may be insulated. To reduce the thermal inertia of the exhaust pipe a thickness to diameter ratio of 0,015 or less is recommended. The use of flexible sections shall be limited to a length to diameter ratio of 12 or less. Bends shall be minimised to reduce inertial deposition. If the system includes a test bed silencer the silencer may also be insulated.

For an isokinetic system, the exhaust pipe must be free of elbows, bends and sudden diameter changes for at least 6 pipe diameters upstream and 3 pipe diameters downstream of the tip of the probe. The gas velocity at the sampling zone must be higher than 10 m/s except at idle mode. Pressure oscillations of the exhaust gas must not exceed ± 500 Pa on the average. Any steps to reduce pressure oscillations beyond using a chassis-type exhaust system (including silencer and aftertreatment devices) must not alter engine performance nor cause the deposition of particulates.

For systems without isokinetic probe, it is recommended to have a straight pipe of 6 pipe diameters upstream and 3 pipe diameters downstream of the tip of the probe.

SP Sampling probe (Figures 10,14,15,16,18,19)

The minimum inside diameter shall be 4 mm. The minimum diameter ratio between exhaust pipe and probe shall be 4. The probe shall be an open tube facing upstream on the exhaust pipe centreline, or a multiple hole probe as described under SP1 in section 1.2.1, Figure 5.

ISP Isokinetic sampling probe (Figures 11,12)

The isokinetic sampling probe must be installed facing upstream on the exhaust pipe centreline where the flow conditions in section EP are met, and designed to provide a proportional sample of the raw exhaust gas. The minimum inside diameter shall be 12 mm.

A control system is necessary for isokinetic exhaust splitting by maintaining a differential pressure of zero between EP and ISP. Under these conditions exhaust gas velocities in EP and ISP are identical and the mass flow through ISP is a constant fraction of the exhaust gas flow. ISP has to be connected to a differential pressure transducer DPT. The control to provide a differential pressure of zero between EP and ISP is done with the flow controller FC1.

FD1, FD2 Flow divider (Figure 16)

A set of venturis or orifices is installed in the exhaust pipe EP and in the transfer tube TT, respectively, to provide a proportional sample of the raw exhaust gas. A control system consisting of two pressure control valves PCV1 and PCV2 is necessary for proportional splitting by controlling the pressures in EP and DT.

FD3 Flow divider (Figure 17)

A set of tubes (multiple tube unit) is installed in the exhaust pipe EP to provide a proportional sample of the raw exhaust gas. One of the tubes feeds exhaust gas to the dilution tunnel DT, whereas the other tubes exit exhaust gas to a damping chamber DC. The tubes must have the same dimensions (same diameter, length, bend radius), so that the exhaust split depends on the total number of tubes. A control system is necessary for proportional splitting by maintaining a differential pressure of zero between the exit of the multiple tube unit into DC and the exit of TT. Under these conditions, exhaust gas velocities in EP and FD3 are proportional, and the flow TT is a constant fraction of the exhaust gas flow. The two points have to be connected to a differential pressure transducer DPT. The control to provide a differential pressure of zero is done with the flow controller FC1.

EGA Exhaust gas analyser (Figures 13,14,15,16,17)

CO₂ or NO_x analysers may be used (with carbon balance method CO₂ only). The analysers shall be calibrated like the analysers for the measurement of the gaseous emissions. One or several analysers may be used to determine the concentration differences. The accuracy of the measuring systems has to be such that the accuracy of G_{EDFW,i} is within ± 4 %.

TT Transfer tube (Figures 11 to 19)

The transfer tube shall be:

- As short as possible, but not more than 5 m in length.
- Equal to or greater than the probe diameter, but not more than 25 mm in diameter.
- Exiting on the centreline of the dilution tunnel and pointing downstream.

If the tube is 1 meter or less in length, it shall be insulated with material with a maximum thermal conductivity of 0,05 W/m*K with a radial insulation thickness corresponding to the diameter of the probe. If the tube is longer than 1 meter, it must be insulated and heated to a minimum wall temperature of 523 K (250°C).

DPT Differential pressure transducer (Figures 11,12,17)

The differential pressure transducer shall have a range of ± 500 Pa or less.

FC1 Flow controller (Figures 11,12,17)

For *isokinetic systems (figures 11,12)*, a flow controller is necessary to maintain a differential pressure of zero between EP and ISP. The adjustment can be done by:

- (a) controlling the speed or flow of the suction blower SB and keeping the speed or flow of the pressure blower PB constant during each mode (Figure 11) or
- (b) adjusting the suction blower SB to a constant mass flow of the diluted exhaust gas and controlling the flow of the pressure blower PB, and therefore the exhaust sample flow in a region at the end of the transfer tube TT (Figure 12).

In the case of a pressure controlled system the remaining error in the control loop must not exceed ± 3 Pa. The pressure oscillations in the dilution tunnel must not exceed ± 250 Pa on the average.

For a *multi tube system (Figure 17)*, a flow controller is necessary for proportional exhaust splitting to maintain a differential pressure of zero between the exit of the multi tube unit and the exit of TT. The adjustment is done by controlling the injection air flow rate into DT at the exit of TT.

PCV1, PCV2 Pressure control valve (Figure 16)

Two pressure control valves are necessary for the *twin venturi/twin orifice system* for proportional flow splitting by controlling the backpressure of EP and the pressure in DT. The valves shall be located downstream of SP in EP and between PB and DT.

DC Damping chamber (Figure 17)

A damping chamber shall be installed at the exit of the multiple tube unit to minimise the pressure oscillations in the exhaust pipe EP.

VN Venturi (Figure 15)

A venturi is installed in the dilution tunnel DT to create a negative pressure in the region of the exit of the transfer tube TT. The gas flow rate through TT is determined by the momentum exchange at the venturi zone, and is basically proportional to the flow rate of the pressure blower PB leading to a constant dilution ratio. Since the momentum exchange is affected by the temperature at the exit of TT and the pressure difference between EP and DT, the actual dilution ratio is slightly lower at low load than at high load.

FC2 Flow controller (Figures 13,14,18,19; optional)

A flow controller may be used to control the flow of the pressure blower PB and/or the suction blower SB. It may be connected to the exhaust, intake air, or fuel flow signals and/or to the CO₂ or NO_x differential signals. When using a pressurised air supply (Figure 18), FC2 directly controls the air flow.

FM1 Flow measurement device (Figures 11,12,18,19)

Gas meter or other flow instrumentation to measure the dilution air flow. FM1 is optional if the pressure blower PB is calibrated to measure the flow.

FM2 Flow measurement device (Figure 19)

Gas meter or other flow instrumentation to measure the diluted exhaust gas flow. FM2 is optional if the suction blower SB is calibrated to measure the flow.

PB Pressure blower (Figures 11,12,13,14,15,16,19)

To control the dilution air flow rate, PB may be connected to the flow controllers FC1 or FC2. PB is not required when using a butterfly valve. PB may be used to measure the dilution air flow, if calibrated.

SB Suction blower (figures 11,12,13,16,17,19)

For fractional sampling systems only. SB may be used to measure the diluted exhaust gas flow, if calibrated.

DAF Dilution air filter (Figures 11 to 19)

It is recommended that the dilution air be filtered and charcoal scrubbed to eliminate background hydrocarbons. At the engine manufacturers request the dilution air shall be sampled according to good engineering practice to determine the background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.

DT Dilution tunnel (Figures 11 to 19)

The dilution tunnel:

- shall be of a sufficient length to cause complete mixing of the exhaust and dilution air under turbulent flow conditions;
- shall be constructed of stainless steel with:
 - thickness/diameter ratio of 0,025 or less for dilution tunnels with inside diameters greater than 75 mm;
 - a nominal thickness of no less than 1,5 mm for dilution tunnels with inside diameters of equal to or less than 75 mm;

-
- shall be at least 75 mm in diameter for the fractional sampling type;
 - is recommended to be at least 25 mm in diameter for the total sampling type;
 - may be heated to no greater than 325 K (52°C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52°C) prior to the introduction of the exhaust in the dilution tunnel;
 - may be insulated.

The engine exhaust shall be thoroughly mixed with the dilution air. For fractional sampling systems, the mixing quality shall be checked after introduction into service by means of a CO₂ -profile of the tunnel with the engine running (at least four equally spaced measuring points). If necessary, a mixing orifice may be used.

Note: If the ambient temperature in the vicinity of the dilution tunnel (DT) is below 293K (20°C), precautions should be taken to avoid particle losses onto the cool walls of the dilution tunnel. Therefore, heating and/or insulating the tunnel within the limits given above is recommended.

At high engine loads, the tunnel may be cooled by a non-aggressive means such as a circulating fan, as long as the temperature of the cooling medium is not below 293K (20°C).

HE Heat exchanger (Figures 16,17)

The heat exchanger shall be of sufficient capacity to maintain the temperature at the inlet to the suction blower SB within $\pm 11\text{K}$ of the average operating temperature observed during the test.

2.3 Full Flow Dilution System

A dilution system is described in Figure 20 based upon the dilution of the total exhaust using the CVS (Constant Volume Sampling) concept. The total volume of the mixture of exhaust and dilution air must be measured. Either a PDP or a CFV system may be used.

For subsequent collection of the particulates, a sample of the dilute exhaust gas is passed to the particulate sampling system (section 2.4, figures 21 and 22). If this is done directly, it is referred to as *single dilution*. If the sample is diluted once more in the secondary dilution tunnel, it is referred to as *double dilution*. This is useful, if the filter face temperature requirement cannot be met with single dilution. Although partly a dilution system, the double dilution system is described as a modification of a particulate sampling system in section 2.4, Figure 22, since it shares most of the parts with a typical particulate sampling system.

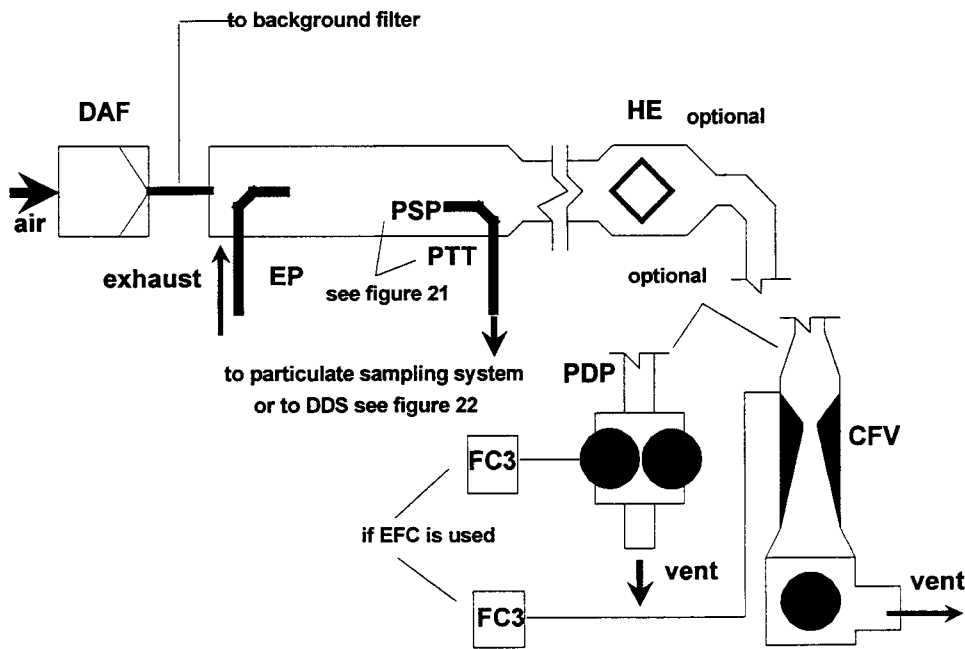


Figure 20 Full flow dilution system

The total amount of raw exhaust gas is mixed in the dilution tunnel DT with the dilution air. The diluted exhaust gas flow rate is measured either with a Positive Displacement Pump PDP or with a Critical Flow Venturi CFV. A heat exchanger HE or electronic flow compensation EFC may be used for proportional particulate sampling and for flow determination. Since particulate mass determination is based on the total diluted exhaust gas flow, the dilution ratio is not required to be calculated.

2.3.1. *Components of Figure 20*

EP Exhaust pipe

The exhaust pipe length from the exit of the engine exhaust manifold, turbocharger outlet or aftertreatment device to the dilution tunnel shall not exceed 10 m. If the exhaust pipe downstream of the engine exhaust manifold, turbocharger outlet or aftertreatment device exceeds 4 m in length, then all tubing in excess of 4 m shall be insulated, except for an in-line smokemeter, if used. The radial thickness of the insulation must be at least 25 mm. The thermal conductivity of the insulating material must have a value no greater than 0,1 W/mK measured at 673 K. To reduce the thermal inertia of the exhaust pipe a thickness to diameter ratio of 0,015 or less is recommended. The use of flexible sections shall be limited to a length to diameter ratio of 12 or less.

PDP Positive Displacement Pump

The PDP meters total diluted exhaust flow from the number of the pump revolutions and the pump displacement. The exhaust system backpressure must not be artificially lowered by the PDP or dilution air inlet system. Static exhaust backpressure measured with the PDP system operating shall remain within $\pm 1,5$ kPa of the static pressure measured without connection to the PDP at identical engine speed and load. The gas mixture temperature immediately ahead of the PDP shall be within ± 6 K of the average operating temperature observed during the test, when no flow compensation is used. Flow compensation may only be used if the temperature at the inlet to the PDP does not exceed 323K (50°C)

CFV Critical Flow Venturi

CFV measures total diluted exhaust flow by maintaining the flow at choked conditions (critical flow). Static exhaust backpressure measured with the CFV system operating shall remain within $\pm 1,5$ kPa of the static pressure measured without connection to the CFV at identical engine speed and load. The gas mixture temperature immediately ahead of the CFV shall be within ± 11 K of the average operating temperature observed during the test, when no flow compensation is used.

HE Heat exchanger (optional, if EFC is used)

The heat exchanger shall be of sufficient capacity to maintain the temperature within the limits required above.

EFC Electronic flow compensation (optional, if HE is used)

If the temperature at the inlet to either the PDP or CFV is not kept within the limits stated above, a flow compensation system is required for continuous measurement of the flow rate and control of the proportional sampling in the particulate system. To that purpose, the continuously measured flow rate signals are used to correct the sample flow rate through the particulate filters of the particulate sampling system (see section 2.4, figures 21, 22), accordingly.

DT Dilution tunnel

The dilution tunnel:

- shall be small enough in diameter to cause turbulent flow (Reynolds Number greater than 4000) and of sufficient length to cause complete mixing of the exhaust and dilution air; a mixing orifice may be used;
- shall be at least 460 mm in diameter with a single dilution system;
- shall be at least 210 mm in diameter with a double dilution system;
- may be insulated.

The engine exhaust shall be directed downstream at the point where it is introduced into the dilution tunnel, and thoroughly mixed.

When using *single dilution*, a sample from the dilution tunnel is transferred to the particulate sampling system (section 2.4, Figure 21). The flow capacity of the PDP or CFV must be sufficient to maintain the diluted exhaust at a temperature of less than or equal to 325 K (52°C) immediately before the primary particulate filter.

When using *double dilution*, a sample from the dilution tunnel is transferred to the secondary dilution tunnel where it is further diluted, and then passed through the sampling filters (section 2.4, Figure 22). The flow capacity of the PDP or CFV must be sufficient to maintain the diluted exhaust stream in the DT at a temperature of less than or equal to 464 K (191°C) at the sampling zone. The secondary dilution system must provide sufficient secondary dilution air to maintain the doubly-diluted exhaust stream at a temperature of less than or equal to 325 K (52°C) immediately before the primary particulate filter.

DAF Dilution air filter

It is recommended that the dilution air be filtered and charcoal scrubbed to eliminate background hydrocarbons. At the engine manufacturers request the dilution air shall be sampled according to good engineering practice to determine the background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.

PSP Particulate sampling probe

The probe is the leading section of PTT and:

- shall be installed facing upstream at a point where the dilution air and exhaust gas are well mixed, i.e. on the dilution tunnel (DT) centreline approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel;
- shall be of 12 mm minimum inside diameter;
- may be heated to no greater than 325 K (52°C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52°C) prior to the introduction of the exhaust in the dilution tunnel;
- may be insulated.

2.4. Particulate Sampling System

The particulate sampling system is required for collecting the particulates on the particulate filter. In the case of *total sampling partial flow dilution*, which consists of passing the entire diluted exhaust sample through the filters, dilution (section 2.2, figures 14,18) and sampling system usually form an integral unit. In the case of *fractional sampling partial flow dilution* or *full flow dilution*, which consists of passing through the filters only a portion of the diluted exhaust, the dilution (section 2.2, figures 11,12,13,15,16,17,19; section 2.3, Figure 20) and sampling systems usually form different units.

In this Directive, the double dilution system (Figure 22) of a full flow dilution system is considered as a specific modification of a typical particulate sampling system as shown in Figure 21. The double dilution system includes all important parts of the particulate sampling system, like filter holders and sampling pump, and additionally some dilution features, like a dilution air supply and a secondary dilution tunnel.

In order to avoid any impact on the control loops, it is recommended that the sample pump be running throughout the complete test procedure. For the single filter method, a bypass system shall be used for passing the sample through the sampling filters at the desired times. Interference of the switching procedure on the control loops must be minimised.

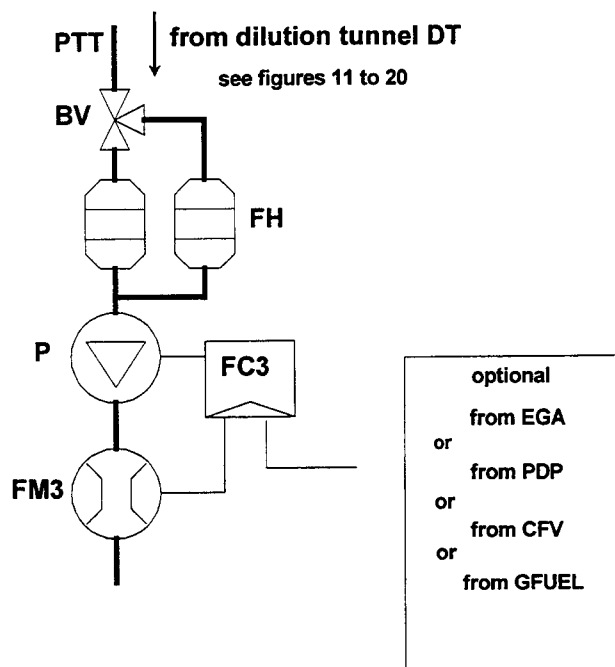


Figure 21 Particulate sampling system

A sample of the diluted exhaust gas is taken from the dilution tunnel DT of a partial flow or full flow dilution system through the particulate sampling probe PSP and the particulate transfer tube PTT by means of the sampling pump P. The sample is passed through the filter holder(s) FH that contain the particulate sampling filters. The sample flow rate is controlled by the flow controller FC3. If electronic flow compensation EFC (see Figure 20) is used, the diluted exhaust gas flow is used as command signal for FC3.

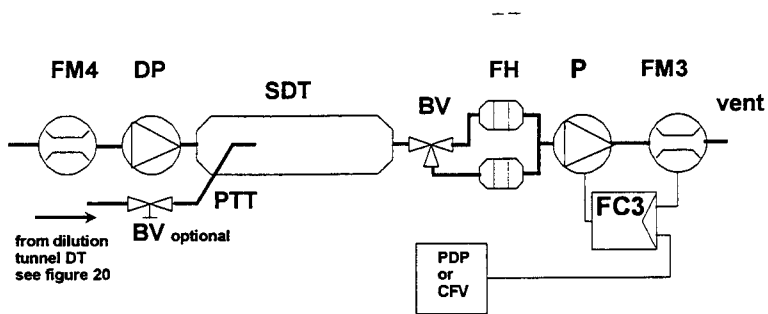


Figure 22 Double dilution system (full flow system only)

A sample of the diluted exhaust gas is transferred from the dilution tunnel DT of a full flow dilution system through the particulate sampling probe PSP and the particulate transfer tube PTT to the secondary dilution tunnel SDT, where it is diluted once more. The sample is then passed through the filter holder(s) FH that contain the particulate sampling filters. The dilution air flow rate is usually constant whereas the sample flow rate is controlled by the flow controller FC3. If electronic flow compensation EFC (see Figure 20) is used, the total diluted exhaust gas flow is used as command signal for FC3.

2.4.1. *Components of figures 21 and 22*

PTT Particulate transfer tube (Figures 21,22)

The particulate transfer tube must not exceed 1020 mm in length, and must be minimised in length whenever possible. Where applicable (i.e. for partial flow dilution fractional sampling systems and for full flow dilution systems), the length of the sampling probes (SP, ISP, PSP, respectively, see sections 2.2 and 2.3) shall be included.

The dimensions are valid for:

- the *partial flow dilution fractional sampling* type and the *full flow single dilution* system from the tip of the probe (SP, ISP, PSP, respectively) to the filter holder;
- the *partial flow dilution total sampling* type from the end of the dilution tunnel to the filter holder;
- the *full flow double dilution* system from the tip of the probe (PSP) to the secondary dilution tunnel.

The transfer tube:

- may be heated to no greater than 325K (52°C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52°C) prior to the introduction of the exhaust in the dilution tunnel;
- may be insulated.

SDT Secondary dilution tunnel (Figure 22)

The secondary dilution tunnel should have a minimum diameter of 75 mm, and should be of sufficient length so as to provide a residence time of at least 0,25 seconds for the doubly-diluted sample. The primary filter holder FH shall be located within 300 mm of the exit of the SDT.

The secondary dilution tunnel:

- may be heated to no greater than 325 K (52°C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52°C) prior to the introduction of the exhaust in the dilution tunnel;
- may be insulated.

FH Filter holder(s) (Figures 21,22)

For primary and back-up filters one filter housing or separate filter housings may be used. The requirements of Annex III, Appendix 4, section 4.1.3 shall be met.

The filter holder(s):

- may be heated to no greater than 325 K (52°C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52°C) prior to the introduction of the exhaust in the dilution tunnel;
- may be insulated.

P Sampling pump (Figures 21,22)

The particulate sampling pump shall be located sufficiently distant from the tunnel so that the inlet gas temperature is maintained constant (± 3 K), if flow correction by FC3 is not used.

DP Dilution air pump (Figure 22)

The dilution air pump shall be located so that the secondary dilution air is supplied at a temperature of 298 K ± 5 K (25°C ± 5 °C), if the dilution air is not preheated.

FC3 Flow controller (Figures 21,22)

A flow controller shall be used to compensate the particulate sample flow rate for temperature and backpressure variations in the sample path, if no other means are available. The flow controller is required if electronic flow compensation EFC (see Figure 20) is used.

FM3 Flow measurement device (Figures 21,22)

The gas meter or flow instrumentation for the particulate sample flow shall be located sufficiently distant from the sampling pump P so that the inlet gas temperature remains constant (± 3 K), if flow correction by FC3 is not used.

FM4 Flow measurement device (Figure 22)

The gas meter or flow instrumentation for the dilution air flow shall be located so that the inlet gas temperature remains at 298 K ± 5 K (25°C ± 5 °C).

BV Ball valve (optional)

The ball valve shall have an inside diameter not less than the inside diameter of the particulate transfer tube PTT, and a switching time of less than 0,5 seconds.

Note: If the ambient temperature in the vicinity of PSP, PTT, SDT, and FH is below 293K (20°C), precautions should be taken to avoid particle losses onto the cool wall of these parts. Therefore, heating and/or insulating these parts within the limits given in the respective descriptions is recommended. It is also recommended that the filter face temperature during sampling be not below 293K (20°C).

At high engine loads, the above parts may be cooled by a non-aggressive means such as a circulating fan, as long as the temperature of the cooling medium is not below 293K (20°C).

3. DETERMINATION OF SMOKE

3.1. Introduction

Sections 3.2 and 3.3 and figures 23 and 24 contain detailed descriptions of the recommended opacimeter systems. Since various configurations can produce equivalent results, exact conformance with figures 23 and 24 is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgement.

The principle of measurement is that light is transmitted through a specific length of the smoke to be measured and that proportion of the incident light which reaches a receiver is used to assess the light obscuration properties of the medium. The smoke measurement depends upon the design of the apparatus, and may be done in the exhaust pipe (full flow in-line opacimeter), at the end of the exhaust pipe (full flow end-of-line opacimeter) or by taking a sample from the exhaust pipe (partial flow opacimeter). For the determination of the light absorption coefficient from the opacity signal, the optical path length of the instrument shall be supplied by the instrument manufacturer.

3.2. Full Flow Opacimeter

Two general types of full flow opacimeters may be used (Figure 23). With the in-line opacimeter, the opacity of the full exhaust plume within the exhaust pipe is measured. With this type of opacimeter, the effective optical path length is a function of the opacimeter design. With the end-of-line opacimeter, the opacity of the full exhaust plume is measured as it exits the exhaust pipe. With this type of opacimeter, the effective optical path length is a function of the exhaust pipe design and the distance between the end of the exhaust pipe and the opacimeter.

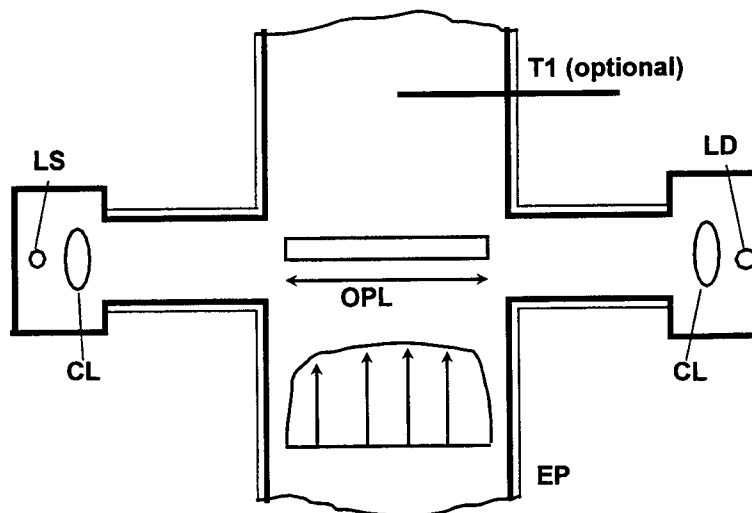


Figure 23 Full flow opacimeter

3.2.1. **Components of Figure 23**

EP Exhaust Pipe

With an in-line opacimeter, there shall be no change in the exhaust pipe diameter within 3 exhaust pipe diameters before or after the measuring zone. If the diameter of the measuring zone is greater than the diameter of the exhaust pipe, a pipe gradually convergent before the measuring zone is recommended.

With an end-of-line opacimeter, the terminal 0,6 m of the exhaust pipe shall be of circular cross section and be free from elbows and bends. The end of the exhaust pipe shall be cut off squarely. The opacimeter shall be mounted centrally to the plume within 25 ± 5 mm of the end of the exhaust pipe.

OPL Optical Path Length

The length of the smoke obscured optical path between the opacimeter light source and the receiver, corrected as necessary for non-uniformity due to density gradients and fringe effect. The optical path length shall be submitted by the instrument manufacturer taking into account any measures against sooting (e.g. purge air). If the optical path length is not available, it shall be determined in accordance with ISO IDS 11614, section 11.6.5. For the correct determination of the optical path length, a minimum exhaust gas velocity of 20 m/s is required.

LS Light source

The light source shall be an incandescent lamp with a colour temperature in the range of 2800 to 3250 K or a green light emitting diode (LED) with a spectral peak between 550 and 570 nm. The light source shall be protected against sooting by means that do not influence the optical path length beyond the manufacturers specifications.

LD Light detector

The detector shall be a photocell or a photodiode (with a filter, if necessary). In the case of an incandescent light source, the receiver shall have a peak spectral response similar to the photopic curve of the human eye (maximum response) in the range of 550 to 570 nm, to less than 4% of that maximum response below 430 nm and above 680 nm. The light detector shall be protected against sooting by means that do not influence the optical path length beyond the manufacturers specifications.

CL Collimating lens

The light output shall be collimated to a beam with a maximum diameter of 30 mm. The rays of the light beam shall be parallel within a tolerance of 3° of the optical axis.

T1 Temperature sensor (optional)

The exhaust gas temperature may be monitored over the test.

3.3. **Partial Flow Opacimeter**

With the partial flow opacimeter (Figure 24), a representative exhaust sample is taken from the exhaust pipe and passed through a transfer line to the measuring chamber. With this type of opacimeter, the effective optical path length is a function of the opacimeter design. The response times referred to in the following section apply to the minimum flow rate of the opacimeter, as specified by the instrument manufacturer.

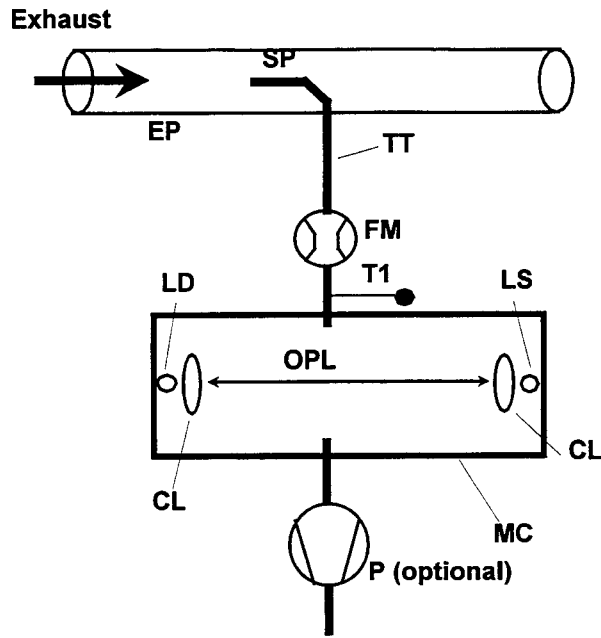


Figure 24 Partial flow opacimeter

3.3.1. *Components of Figure 24*

EP Exhaust Pipe

The exhaust pipe shall be a straight pipe of at least 6 pipe diameters upstream and 3 pipe diameters downstream of the tip of the probe.

SP Sampling probe

The sampling probe shall be an open tube facing upstream on or about the exhaust pipe centreline. The clearance with the wall of the tailpipe shall be at least 5 mm. The probe diameter shall ensure a representative sampling and a sufficient flow through the opacimeter.

TT Transfer tube

The transfer tube shall:

- Be as short as possible and ensure an exhaust gas temperature of 373 ± 30 K ($100^{\circ}\text{C} \pm 30^{\circ}\text{C}$) at the entrance to the measuring chamber.
- Have a wall temperature sufficiently above the dew point of the exhaust gas to prevent condensation.
- Be equal to the diameter of the sampling probe over the entire length.
- Have a response time of less than 0,05 s at minimum instrument flow, as determined according to Annex III, Appendix 4, section 5.2.4.
- Have no significant effect on the smoke peak.

FM Flow measurement device

Flow instrumentation to detect the correct flow into the measuring chamber. The minimum and maximum flow rates shall be specified by the instrument manufacturer, and shall be such that the response time requirement of TT and the optical path length specifications are met. The flow measurement device may be close to the sampling pump, P, if used.

MC Measuring chamber

The measuring chamber shall have a non-reflective internal surface, or equivalent optical environment. The impingement of stray light on the detector due to internal reflections of diffusion effects shall be reduced to a minimum.

The pressure of the gas in the measuring chamber shall not differ from the atmospheric pressure by more than 0,75 kPa. Where this is not possible by design, the opacimeter reading shall be converted to atmospheric pressure.

The wall temperature of the measuring chamber shall be set to within ± 5 K between 343 K (70°C) and 373 K (100°C), but in any case sufficiently above the dew point of the exhaust gas to prevent condensation. The measuring chamber shall be equipped with appropriate devices for measuring the temperature.

OPL Optical Path Length

The length of the smoke obscured optical path between the opacimeter light source and the receiver, corrected as necessary for non-uniformity due to density gradients and fringe effect. The optical path length shall be submitted by the instrument manufacturer taking into account any measures against sooting (e.g. purge air). If the optical path length is not available, it shall be determined in accordance with ISO IDS 11614, section 11.6.5.

LS Light source

The light source shall be an incandescent lamp with a colour temperature in the range of 2800 to 3250 K or a green light emitting diode (LED) with a spectral peak between 550 and 570 nm. The light source shall be protected against sooting by means that do not influence the optical path length beyond the manufacturers specifications.

LD Light detector

The detector shall be a photocell or a photodiode (with a filter, if necessary). In the case of an incandescent light source, the receiver shall have a peak spectral response similar to the photopic curve of the human eye (maximum response) in the range of 550 to 570 nm, to less than 4% of that maximum response below 430 nm and above 680 nm. The light detector shall be protected against sooting by means that do not influence the optical path length beyond the manufacturers specifications.

CL Collimating lens

The light output shall be collimated to a beam with a maximum diameter of 30 mm. The rays of the light beam shall be parallel within a tolerance of 3° of the optical axis.

T1 Temperature sensor

To monitor the exhaust gas temperature at the entrance to the measuring chamber.

P Sampling pump (optional)

A sampling pump downstream of the measuring chamber may be used to transfer the sample gas through the measuring chamber.

EC TYPE-APPROVAL CERTIFICATE

Communication concerning the:

- type-approval ⁽¹⁾
- extension of type-approval⁽¹⁾ of a type of a vehicle/separate technical unit (engine type/engine family)/component⁽¹⁾ with regard to Directive 88/77/EC as last amended by Directive

EC type-approval No.: Extension No.:

SECTION I

0 General

- 0.1 Make of vehicle/separate technical unit/component ⁽¹⁾:.....
- 0.2 Manufacturer's designation of vehicle/separate technical unit/component ⁽¹⁾:.....
- 0.3 Manufacturer's type coding as marked on the vehicle/separate technical unit/component ⁽¹⁾:.....
- 0.4 Category of vehicle:
- 0.5 Category of engine: diesel/NG fuelled/LPG fuelled ⁽¹⁾:
- 0.6 Name and address of manufacturer:
- 0.7 Name and address of manufacturer's authorised representative (if any):

SECTION II

- 1. Brief description (where appropriate): See Annex I
- 2. Technical department responsible for carrying out the tests:
- 3. Date of test report:
- 4. Number of test report:
- 5. Ground(s) for extending type approval (where appropriate):
- 6. Remarks (if any): See Annex I
- 7. Place:
- 8. Date:
- 9. Signature:
- 10. A list of documents making up the type-approval file lodged with the administrative department that has granted type approval, which may be obtained on request, is attached.

¹ Delete as appropriate

ANNEX VI - APPENDIX

to EC type-approval certificate No. ... concerning the type approval of a vehicle/separate technical unit/component ⁽¹⁾

- 1 **Brief description**
- 1.1 Particulars to be completed in relation to the type-approval of a vehicle with an engine installed:
- 1.1.1 Make of engine (name of undertaking):.....
- 1.1.2 Type and commercial description (mention any variants):
- 1.1.3 Manufacturer's code as marked on the engine:
- 1.1.4 Category of vehicle (if applicable):
- 1.1.5 Category of engine: diesel/NG fuelled/LPG fuelled ⁽¹⁾:
- 1.1.6 Name and address of manufacturer:
- 1.1.7 Name and address of manufacturer's authorised representative (if any):
- 1.2 If the engine referred to in 1.1 has been type-approved as a separate technical unit:
- 1.2.1 Type-approval number of the engine/engine family ⁽¹⁾:.....
- 1.3 Particulars to be completed in relation to the type-approval of an engine/engine family ⁽¹⁾ as a separate technical unit (conditions to be respected in the installation of the engine on a vehicle):
- 1.3.1 Maximum and/or minimum intake depression:kPa
- 1.3.2 Maximum allowable back pressure:kPa
- 1.3.3 Exhaust system volume:cm³
- 1.3.4 Power absorbed by auxiliaries needed for operating the engine:
- 1.3.4.1 Idle:kW; Low speed:kW; High speed:kW
Speed A:kW; Speed B:kW; Speed C:kW; Reference speed:kW
- 1.3.5 Restrictions of use (if any):
- 1.4 Emissions levels of the engine/parent engine ⁽¹⁾:
- 1.4.1 ESC-test (if applicable):
- CO:g/kWh
- THC:g/kWh
- NOx:g/kWh
- PT:g/kWh
- 1.4.2 ELR-test (if applicable):
- Smoke value:m⁻¹
- 1.4.3 ETC-test (if applicable):
- CO:g/kWh
- THC:g/kWh ⁽¹⁾
- NMHC:g/kWh ⁽¹⁾
- CH₄:g/kWh ⁽¹⁾
- NOx:g/kWh ⁽¹⁾
- PT: g/kWh ⁽¹⁾

¹ Delete as appropriate.

EXAMPLE OF CALCULATION PROCEDURE

1 ESC TEST

1.1 Gaseous Emissions

The measurement data for the calculation of the individual mode results are shown below. In this example, CO and NO_x are measured on a dry basis, HC on a wet basis. The HC concentration is given in propane equivalent (C3) and has to be multiplied by 3 to result in the C1 equivalent. The calculation procedure is identical for the other modes.

| P (kW) | T _a (K) | H _a (g/kg) | G _{EXH} (kg) | G _{AIRW} (kg) | G _{FUEL} (kg) | HC (ppm) | CO (ppm) | NO _x (ppm) |
|-----------|-----------------------|--------------------------|--------------------------|---------------------------|---------------------------|-------------|-------------|--------------------------|
| 82,9 | 294,8 | 7,81 | 563,38 | 545,29 | 18,09 | 6,3 | 41,2 | 495 |

Calculation of the dry to wet correction factor $K_{W,r}$ (Annex III, Appendix 1, section 4.2):

$$F_{FH} = \frac{1,969}{\left(1 + \frac{18,09}{545,29}\right)} \quad \text{and} \quad K_{w2} = \frac{1,608 * 7,81}{1000 + (1,608 * 7,81)} = 0,0124$$

$$K_{w,r} = \left(1 - 1,9058 * \frac{18,09}{541,06}\right) - 0,0124 = 0,9239$$

Calculation of the wet concentrations:

$$\begin{aligned} \text{CO} &= 41,2 * 0,9239 = 38,1 \text{ ppm} \\ \text{NO}_x &= 495 * 0,9239 = 457 \text{ ppm} \end{aligned}$$

Calculation of the NO_x humidity correction factor $K_{H,D}$ (Annex III, Appendix 1, section 4.3):

$$\begin{aligned} A &= 0,309 * 18,09/541,06 - 0,0266 = -0,0163 \\ B &= -0,209 * 18,09/541,06 + 0,00954 = 0,0026 \end{aligned}$$

$$K_{H,D} = \frac{1}{1 - 0,0163 * (7,81 - 10,71) + 0,0026 * (294,8 - 298)} = 0,9625$$

Calculation of the emission mass flow rates (Annex III, Appendix 1, section 4.4):

$$\begin{aligned} \text{NO}_x &= 0,001587 * 457 * 0,9625 * 563,38 = 393,27 \text{ g/h} \\ \text{CO} &= 0,000966 * 38,1 * 563,38 = 20,735 \text{ g/h} \\ \text{HC} &= 0,000479 * 6,3 * 3 * 563,38 = 5,100 \text{ g/h} \end{aligned}$$

Calculation of the specific emissions (Annex III, Appendix 1, section 4.5):

The following example calculation is given for CO; the calculation procedure is identical for the other components.

The emission mass flow rates of the individual modes are multiplied by the respective weighting factors, as indicated in Annex III, Appendix 1, section 2.7.1, and summed up to result in the mean emission mass flow rate over the cycle:

$$\begin{aligned} \text{CO} &= (6,7 * 0,15) + (24,6 * 0,08) + (20,5 * 0,10) + (20,7 * 0,10) + (20,6 * 0,05) + (15,0 * 0,05) \\ &\quad + (19,7 * 0,05) + (74,5 * 0,09) + (31,5 * 0,10) + (81,9 * 0,08) + (34,8 * 0,05) + (30,8 * \\ &\quad 0,05) \\ &\quad + (27,3 * 0,05) \\ &= 30,91 \text{ g/h} \end{aligned}$$

The engine power of the individual modes is multiplied by the respective weighting factors, as indicated in Annex III, Appendix 1, section 2.7.1, and summed up to result in the mean cycle power:

$$\begin{aligned} \text{P(n)} &= (0,1 * 0,15) + (96,8 * 0,08) + (55,2 * 0,10) + (82,9 * 0,10) + (46,8 * 0,05) + (70,1 * 0,05) \\ &\quad + (23,0 * 0,05) + (114,3 * 0,09) + (27,0 * 0,10) + (122,0 * 0,08) + (28,6 * 0,05) \\ &\quad + (87,4 * 0,05) + (57,9 * 0,05) \\ &= 60,006 \text{ kW} \end{aligned}$$

$$\overline{CO} = \frac{30,91}{60,006} = 0,515 \text{ g/kWh}$$

Calculation of the specific NO_x emission of the random point (Annex III, Appendix 1, section 4.6.1):

Assume the following values have been determined on the random point:

$$\begin{aligned}
 n_Z &= 1600 \text{ min}^{-1} \\
 M_Z &= 495 \text{ Nm} \\
 NO_{x \text{ mass},Z} &= 487,9 \text{ g/h (calculated according to the previous formulae)} \\
 P(n)_Z &= 83 \text{ kW} \\
 NO_{x,Z} &= 487,9/83 = 5,878 \text{ g/kWh}
 \end{aligned}$$

Determination of the emission value from the test cycle (Annex III, Appendix 1, section 4.6.2):

Assume the values of the four enveloping modes on the ESC to be as follows:

| n_{RT} | n_{SU} | E_R | E_S | E_T | E_U | M_R | M_S | M_T | M_U |
|----------|----------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1368 | 1785 | 5,943 | 5,565 | 5,889 | 4,973 | 515 | 460 | 681 | 610 |

$$\begin{aligned}
 E_{TU} &= 5,889 + (4,973 - 5,889) * (1600 - 1368) / (1785 - 1368) = 5,377 \text{ g/kWh} \\
 E_{RS} &= 5,943 + (5,565 - 5,943) * (1600 - 1368) / (1785 - 1368) = 5,732 \text{ g/kWh} \\
 M_{TU} &= 681 + (601 - 681) * (1600 - 1368) / (1785 - 1368) = 641,3 \text{ Nm} \\
 M_{RS} &= 515 + (460 - 515) * (1600 - 1368) / (1785 - 1368) = 484,3 \text{ Nm} \\
 E_Z &= 5,732 + (5,377 - 5,732) * (495 - 484,3) / (641,3 - 484,3) = 5,708 \text{ g/kWh}
 \end{aligned}$$

Comparison of the NO_x emission values (Annex III, Appendix 1, section 4.6.3):

$$NO_{x \text{ diff}} = 100 * (5,878 - 5,708) / 5,708 = 2,98 \%$$

Particulate measurement is based on the principle of sampling the particulates over the complete cycle, but determining the sample and flow rates (M_{SAM} and G_{EDF}) during the individual modes. The calculation of G_{EDF} depends on the system used. In the following examples, a system with CO_2 measurement and carbon balance method and a system with flow measurement are used. When using a full flow dilution system, G_{EDF} is directly measured by the CVS equipment.

Calculation of G_{EDF} (Annex III, Appendix 1, sections 5.2.3 and 5.2.4):

Assume the following measurement data of mode 4. The calculation procedure is identical for the other modes.

| G_{EXH} (kg/h) | G_{FUEL} (kg/h) | G_{DILW} (kg/h) | G_{TOTW} (kg/h) | CO_{2D} (%) | CO_{2A} (%) |
|---------------------|----------------------|----------------------|----------------------|------------------|------------------|
| 334,02 | 10,76 | 5,4435 | 6,0 | 0,657 | 0,040 |

a) carbon balance method

$$G_{EDFW} = \frac{206,5 * 10,76}{0,657 - 0,040} = 3601,2 \text{ kg/h}$$

b) flow measurement method

$$q = \frac{6,0}{(6,0 - 5,4435)} = 10,78$$

$$G_{EDFW} = 334,02 * 10,78 = 3600,7 \text{ kg/h}$$

Calculation of the mass flow rate (Annex III, Appendix 1, section 5.4):

The G_{EDFW} flow rates of the individual modes are multiplied by the respective weighting factors, as indicated in Annex III, Appendix 1, section 2.7.1, and summed up to result in the mean G_{EDF} over the cycle. The total sample rate M_{SAM} is summed up from the sample rates of the individual modes.

$$\begin{aligned} \overline{G_{EDFW}} &= (3567 * 0,15) + (3592 * 0,08) + (3611 * 0,10) + (3600 * 0,10) + (3618 * 0,05) \\ &\quad + (3600 * 0,05) + (3640 * 0,05) + (3614 * 0,09) + (3620 * 0,10) + (3601 * 0,08) \\ &\quad + (3639 * 0,05) + (3582 * 0,05) + (3635 * 0,05) \\ &= 3604,6 \text{ kg/h} \end{aligned}$$

$$\begin{aligned}
M_{SAM} &= 0,226 + 0,122 + 0,151 + 0,152 + 0,076 + 0,076 + 0,076 + 0,136 + 0,151 + 0,121 \\
&+ 0,076 + 0,076 + 0,075 \\
&= 1,515 \text{ kg}
\end{aligned}$$

Assume the particulate mass on the filters to be 2,5 mg, then

$$PT_{mass} = \frac{2,5}{1,515} * \frac{3604,6}{1000} = 5,948 \text{ g/h}$$

Background correction (optional)

Assume one background measurement with the following values. The calculation of the dilution factor DF is identical to section 3.1 of this Annex and not shown here.

$$M_d = 0,1 \text{ mg}; \quad M_{DIL} = 1,5 \text{ kg}$$

$$\begin{aligned}
\text{Sum of DF} &= [(1-1/119,15) * 0,15] + [(1-1/8,89) * 0,08] + [(1-1/14,75) * 0,10] + [(1-1/10,10) \\
&* 0,10] + [(1-1/18,02) * 0,05] + [(1-1/12,33) * 0,05] + [(1-1/32,18) * 0,05] + \\
&[(1-1/6,94) * 0,09] + [(1-1/25,19) * 0,10] + [(1-1/6,12) * 0,08] + [(1-1/20,87) * 0,05] \\
&+ [(1-1/8,77) * 0,05] + [(1-1/12,59) * 0,05] \\
&= 0,923
\end{aligned}$$

$$PT_{mass} = \frac{2,5}{1,515} - \left(\frac{0,1}{1,5} * 0,923 \right) * \frac{3604,6}{1000} = 5,726 \text{ g/h}$$

Calculation of the specific emission (Annex III, Appendix 1, section 5.5):

$$\begin{aligned}
 P(n) &= (0,1 * 0,15) + (96,8 * 0,08) + (55,2 * 0,10) + (82,9 * 0,10) + (46,8 * 0,05) + (70,1 * 0,05) \\
 &\quad + (23,0 * 0,05) + (114,3 * 0,09) + (27,0 * 0,10) + (122,0 * 0,08) + (28,6 * 0,05) \\
 &\quad + (87,4 * 0,05) + (57,9 * 0,05) \\
 &= 60,006 \text{ kW}
 \end{aligned}$$

$$\overline{PT} = \frac{5,948}{60,006} = 0,099 \text{ g/kWh, if background corrected } \overline{PT} = \frac{5,726}{60,006} = 0,095 \text{ g/kWh}$$

Calculation of the specific weighting factor (Annex III, Appendix 1, section 5.6):

Assume the values calculated for mode 4 above, then

$$WF_{E,i} = \frac{0,152 * 3604,6}{1,515 * 3600,7} = 0,1004$$

This value is within the required value of $0,10 \pm 0,003$.

2 ELR TEST

Since Bessel filtering is a completely new averaging procedure in European exhaust legislation, an explanation of the Bessel filter, an example of the design of a Bessel algorithm, and an example of the calculation of the final smoke value is given below. The constants of the Bessel algorithm only depend on the design of the opacimeter and the sampling rate of the data acquisition system. It is recommended that the opacimeter manufacturer provide the final Bessel filter constants for different sampling rates and that the customer use these constants for designing the Bessel algorithm and for calculating the smoke values.

2.1 General Remarks on the Bessel Filter

Due to high frequency distortions, the raw opacity signal usually shows a highly scattered trace. To remove these high frequency distortions a Bessel filter is required for the ELR-Test. The Bessel filter itself is a recursive, second-order low-pass filter which guarantees the fastest signal rise without overshoot.

Assuming a real time raw exhaust plume in the exhaust tube, each opacimeter shows a delayed and differently measured opacity trace. The delay and the magnitude of the measured opacity trace is primarily dependent on the geometry of the measuring chamber of the opacimeter, including the exhaust sample lines, and on the time needed for processing the signal in the electronics of the opacimeter. The values that characterise these two effects are called the physical and the electrical response time which represent an individual filter for each type of opacimeter. The goal of applying a Bessel filter is to guarantee a uniform overall filter characteristic of the whole opacimeter system, consisting of:

- physical response time of the opacimeter (t_p)
- electrical response time of the opacimeter (t_e)
- filter response time of the applied Bessel filter (t_f)

The resulting overall response time of the system t_{Aver} is given by:

$$t_{Aver} = \sqrt{t_F^2 + t_p^2 + t_e^2},$$

and must be equal for all kinds of opacimeters in order to give the same smoke value. Therefore, a Bessel filter has to be created in such a way, that the filter response time (t_f) together with the physical (t_p) and electrical response time (t_e) of the individual opacimeter must result in the required overall response time (t_{Aver}). Since t_p and t_e are given values for each individual opacimeter, and t_{Aver} is defined to be 1,0 s in this Directive, t_f can be calculated as follows:

$$t_F = \sqrt{t_{Aver}^2 - t_p^2 - t_e^2}$$

By definition, the filter response time t_f is the rise time of a filtered output signal between 10 % and 90 % on a step input signal. Therefore the cut-off frequency of the Bessel filter has to be iterated in such a way, that the response time of the Bessel filter fits into the required rise time.

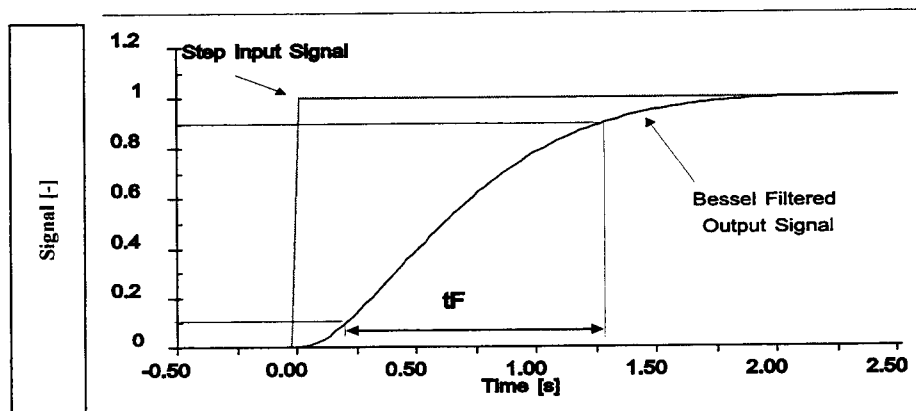
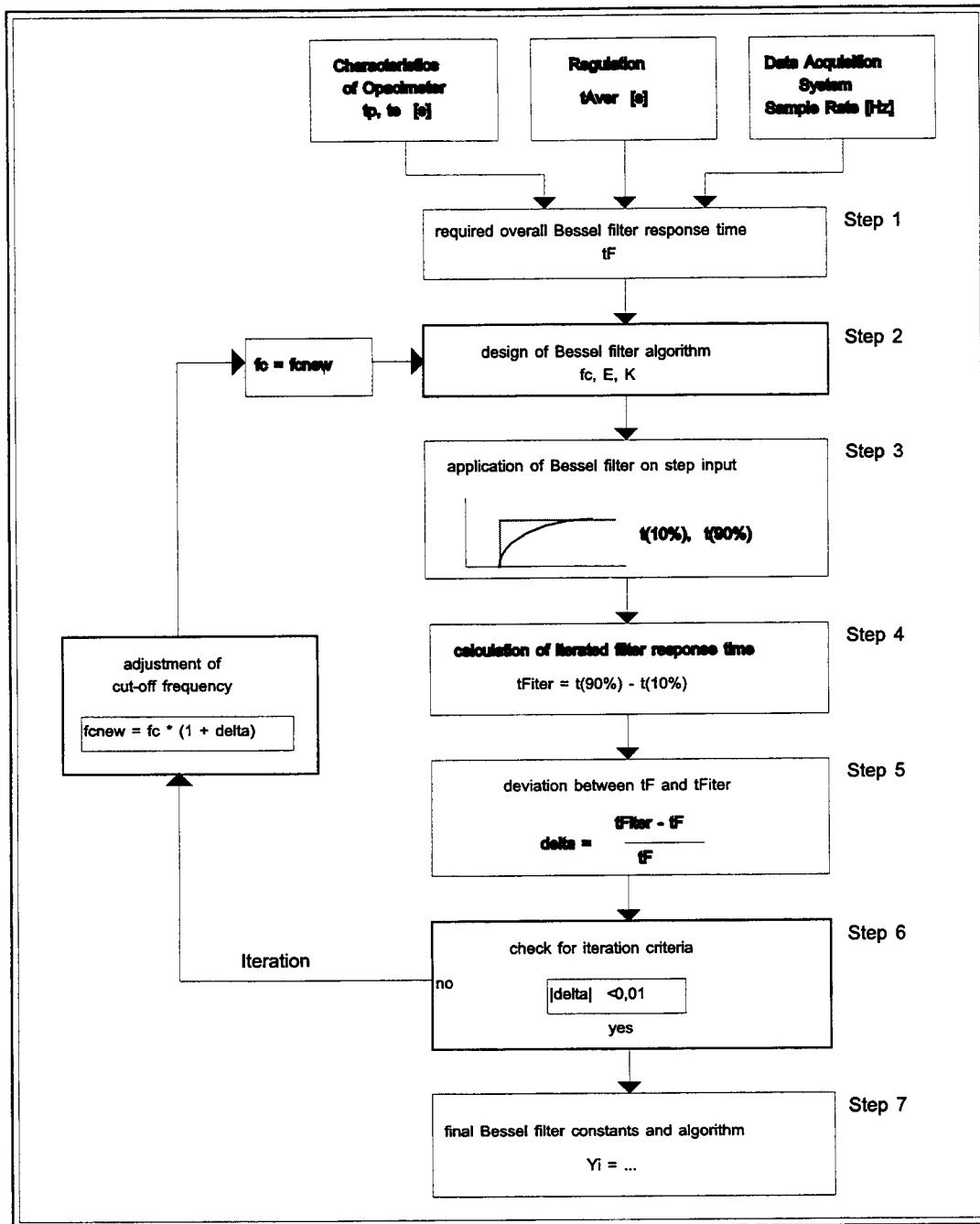


Figure (a) Traces of a Step Input Signal and the Filtered Output Signal

In figure (a), the traces of a step input signal and Bessel filtered output signal as well as the response time of the Bessel filter (t_f) are shown.

Designing the final Bessel filter algorithm is a multi step process which requires several iteration cycles. The scheme of the iteration procedure is presented below.



2.2 Calculation of the Bessel Algorithm

In this example a Bessel algorithm is designed in several steps according to the above iteration procedure which is based upon Annex III, Appendix 1, section 6.1.

For the opacimeter and the data acquisition system, the following characteristics are assumed:

- physical response time t_p 0,15 s
- electrical response time t_e 0,05 s
- overall response time t_{Aver} 1,00 s (by definition in this Directive)
- sampling rate 150 Hz

Step 1 Required Bessel filter response time t_F :

$$t_F = \sqrt{1^2 - (0,15^2 + 0,05^2)} = 0,987421 \text{ s}$$

Step 2 Estimation of cut-off frequency and calculation of Bessel constants E, K for first iteration:

$$\begin{aligned} f_c &= 3,1415 / (10 * 0,987421) &&= 0,318152 \text{ Hz} \\ \Delta t &= 1 / 150 &&= 0,006667 \text{ s} \\ \Omega &= 1 / [\tan (3,1415 * 0,006667 * 0,318152)] &&= 150,076644 \end{aligned}$$

$$E = \frac{1}{1 + 150,076644 * \sqrt{3 * 0,618034} + 0,618034 * 150,076644^2} = 7,07948 \text{ E-5}$$

$$K = 2 * 7,07948 \text{ E-5} * (0,618034 * 150,076644 - 1) - 1 = 0,970783$$

This gives the Bessel algorithm:

$$Y_i = Y_{i-1} + 7,07948 \text{ E-5} * (S_i + 2 * S_{i-1} + S_{i-2} - 4 * Y_{i-2}) + 0,970783 * (Y_{i-1} - Y_{i-2})$$

where S_i represents the values of the step input signal (either '0' or '1') and Y_i represents the filtered values of the output signal.

Step 3 Application of Bessel filter on step input:

The Bessel filter response time t_F is defined as the rise time of the filtered output signal between 10% and 90% on a step input signal. For determining the times of 10% (t_{10}) and 90% (t_{90}) of the output signal, a Bessel filter has to be applied to a step input using the above values of f_c , E and K.

The index numbers, the time and the values of a step input signal and the resulting values of the filtered output signal for the first and the second iteration are shown in table B. The points adjacent to t_{10} and t_{90} are marked in bold numbers.

In table B, first iteration, the 10% value occurs between index number 30 and 31 and the 90% value occurs between index number 191 and 192. For the calculation of $t_{F,iter}$ the exact t_{10} and t_{90} values are determined by linear interpolation between the adjacent measuring points, as follows:

$$t_{10} = t_{\text{lower}} + \Delta t * (0,1 - \text{out}_{\text{lower}}) / (\text{out}_{\text{upper}} - \text{out}_{\text{lower}})$$

$$t_{90} = t_{\text{lower}} + \Delta t * (0,9 - \text{out}_{\text{lower}}) / (\text{out}_{\text{upper}} - \text{out}_{\text{lower}})$$

where $\text{out}_{\text{upper}}$ and $\text{out}_{\text{lower}}$, respectively, are the adjacent points of the Bessel filtered output signal, and t_{lower} is the time of the adjacent time point, as indicated in table B.

$$t_{10} = 0,200000 + 0,006667 * (0,1 - 0,099208) / (0,104794 - 0,099208) = 0,200945 \text{ s}$$

$$t_{90} = 1,273333 + 0,006667 * (0,9 - 0,899147) / (0,901168 - 0,899147) = 1,276147 \text{ s}$$

Step 4 Filter response time of first iteration cycle:

$$t_{F,\text{iter}} = 1,276147 - 0,200945 = 1,075202 \text{ s}$$

Step 5 Deviation between required and obtained filter response time of first iteration cycle:

$$\Delta = (1,075202 - 0,987421) / 0,987421 = 0,081641$$

Step 6 Checking the iteration criteria:

$|\Delta| \leq 0,01$ is required. Since $0,081641 > 0,01$, the iteration criteria is not met and a further iteration cycle has to be started. For this iteration cycle, a new cut-off frequency is calculated from f_c and Δ as follows:

$$f_{c,\text{new}} = 0,318152 * (1 + 0,081641) = 0,344126 \text{ Hz}$$

This new cut-off frequency is used in the second iteration cycle, starting at step 2 again. The iteration has to be repeated until the iteration criteria is met. The resulting values of the first and second iteration are summarised in table A.

| Parameter | 1. Iteration | 2. Iteration |
|-------------------------|--------------|--------------|
| f_c (Hz) | 0,318152 | 0,344126 |
| E (-) | 7,07948 E-5 | 8,272777 E-5 |
| K (-) | 0,970783 | 0,968410 |
| t_{10} (s) | 0,200945 | 0,185523 |
| t_{90} (s) | 1,276147 | 1,179562 |
| $t_{F,\text{iter}}$ (s) | 1,075202 | 0,994039 |
| Δ (-) | 0,081641 | 0,006657 |
| $f_{c,\text{new}}$ (Hz) | 0,344126 | 0,346417 |

Table A Values of the first and second iteration

Step 7 Final Bessel algorithm:

As soon as the iteration criteria has been met, the final Bessel filter constants and the final Bessel algorithm are calculated according to step 2. In this example, the iteration criteria has been met after the second iteration ($\Delta = 0,006657 \leq 0,01$). The final algorithm is then used for determining the averaged smoke values (see next section 2.3).

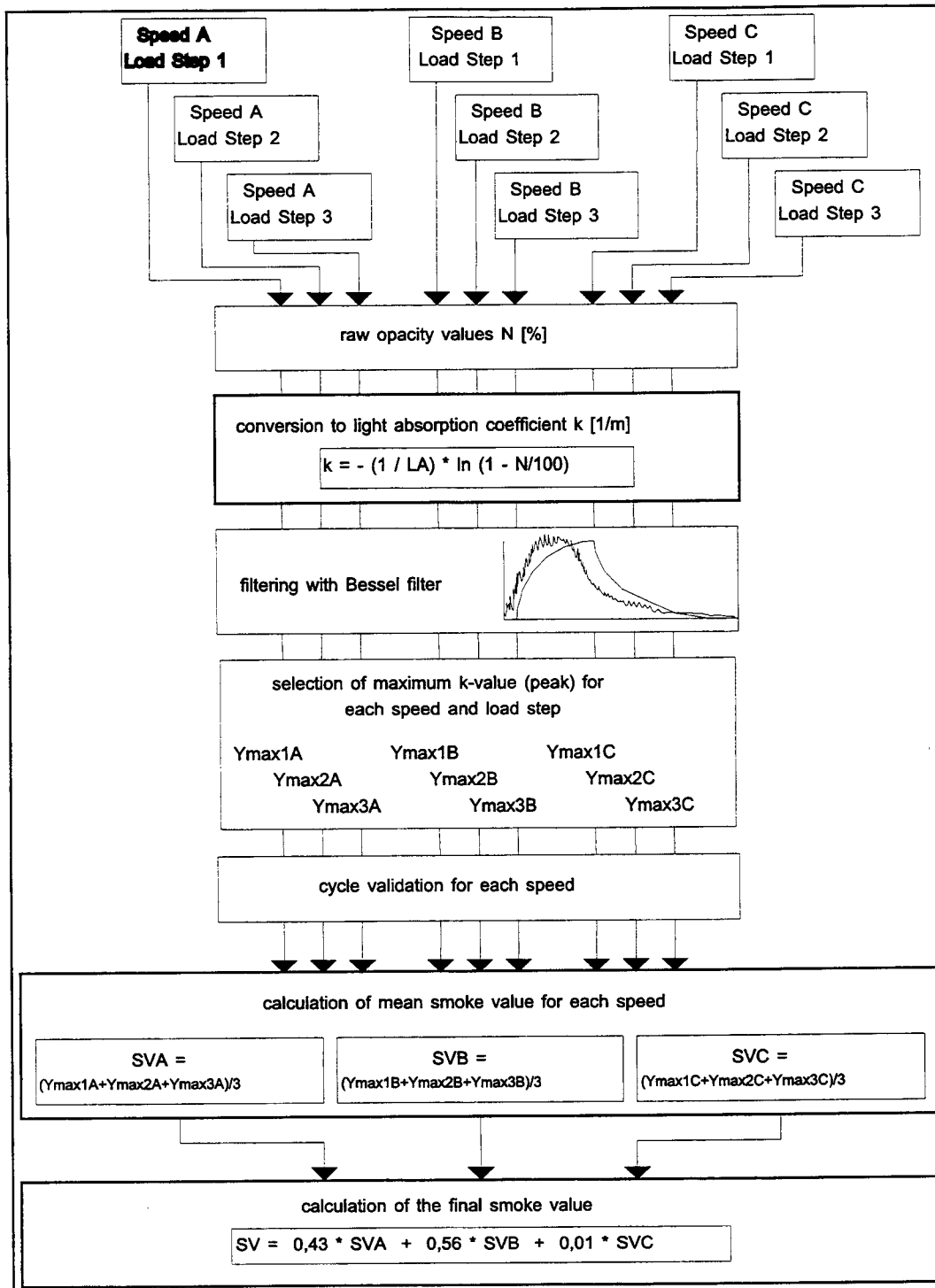
$$Y_i = Y_{i-1} + 8,272777 \text{ E-5} * (S_i + 2 * S_{i-1} + S_{i-2} - 4 * Y_{i-2}) + 0,968410 * (Y_{i-1} - Y_{i-2})$$

| Index i [-] | Time [s] | Step Input Signal S _i [-] | Filtered Output Signal Y _i [-] | |
|----------------|-------------|---|---|-----------------|
| | | | 1. Iteration | 2. Iteration |
| -2 | -0,013333 | 0 | 0,000000 | 0,000000 |
| -1 | -0,006667 | 0 | 0,000000 | 0,000000 |
| 0 | 0,000000 | 1 | 0,000071 | 0,000083 |
| 1 | 0,006667 | 1 | 0,000352 | 0,000411 |
| 2 | 0,013333 | 1 | 0,000908 | 0,001060 |
| 3 | 0,020000 | 1 | 0,001731 | 0,002019 |
| 4 | 0,026667 | 1 | 0,002813 | 0,003278 |
| 5 | 0,033333 | 1 | 0,004145 | 0,004828 |
| ~ | ~ | ~ | ~ | ~ |
| 24 | 0,160000 | 1 | 0,067877 | 0,077876 |
| 25 | 0,166667 | 1 | 0,072816 | 0,083476 |
| 26 | 0,173333 | 1 | 0,077874 | 0,089205 |
| 27 | 0,180000 | 1 | 0,083047 | 0,095056 |
| 28 | 0,186667 | 1 | 0,088331 | 0,101024 |
| 29 | 0,193333 | 1 | 0,093719 | 0,107102 |
| 30 | 0,200000 | 1 | 0,099208 | 0,113286 |
| 31 | 0,206667 | 1 | 0,104794 | 0,119570 |
| 32 | 0,213333 | 1 | 0,110471 | 0,125949 |
| 33 | 0,220000 | 1 | 0,116236 | 0,132418 |
| 34 | 0,226667 | 1 | 0,122085 | 0,138972 |
| 35 | 0,233333 | 1 | 0,128013 | 0,145605 |
| 36 | 0,240000 | 1 | 0,134016 | 0,152314 |
| 37 | 0,246667 | 1 | 0,140091 | 0,159094 |
| ~ | ~ | ~ | ~ | ~ |
| 175 | 1,166667 | 1 | 0,862416 | 0,895701 |
| 176 | 1,173333 | 1 | 0,864968 | 0,897941 |
| 177 | 1,180000 | 1 | 0,867484 | 0,900145 |
| 178 | 1,186667 | 1 | 0,869964 | 0,902312 |
| 179 | 1,193333 | 1 | 0,872410 | 0,904445 |
| 180 | 1,200000 | 1 | 0,874821 | 0,906542 |
| 181 | 1,206667 | 1 | 0,877197 | 0,908605 |
| 182 | 1,213333 | 1 | 0,879540 | 0,910633 |
| 183 | 1,220000 | 1 | 0,881849 | 0,912628 |
| 184 | 1,226667 | 1 | 0,884125 | 0,914589 |
| 185 | 1,233333 | 1 | 0,886367 | 0,916517 |
| 186 | 1,240000 | 1 | 0,888577 | 0,918412 |
| 187 | 1,246667 | 1 | 0,890755 | 0,920276 |
| 188 | 1,253333 | 1 | 0,892900 | 0,922107 |
| 189 | 1,260000 | 1 | 0,895014 | 0,923907 |
| 190 | 1,266667 | 1 | 0,897096 | 0,925676 |
| 191 | 1,273333 | 1 | 0,899147 | 0,927414 |
| 192 | 1,280000 | 1 | 0,901168 | 0,929121 |
| 193 | 1,286667 | 1 | 0,903158 | 0,930799 |
| 194 | 1,293333 | 1 | 0,905117 | 0,932448 |
| 195 | 1,300000 | 1 | 0,907047 | 0,934067 |
| ~ | ~ | ~ | ~ | ~ |

Table B Values of step input signal and Bessel filtered output signal for the first and second iteration cycle

2.3 Calculation of the Smoke Values

In the scheme below the general procedure of determining the final smoke value is presented.



In figure b, the traces of the measured raw opacity signal, and of the unfiltered and filtered light absorption coefficients (k-value) of the first load step of an ELR-Test are shown, and the maximum value $Y_{\max i, A}$ (peak) of the filtered k trace is indicated. Correspondingly, table C contains the numerical values of index i, time (sampling rate of 150 Hz), raw opacity, unfiltered k and filtered k. Filtering was conducted using the constants of the Bessel algorithm designed in section 2.2 of this Annex. Due to the large amount of data, only those sections of the smoke trace around the beginning and the peak are tabled.

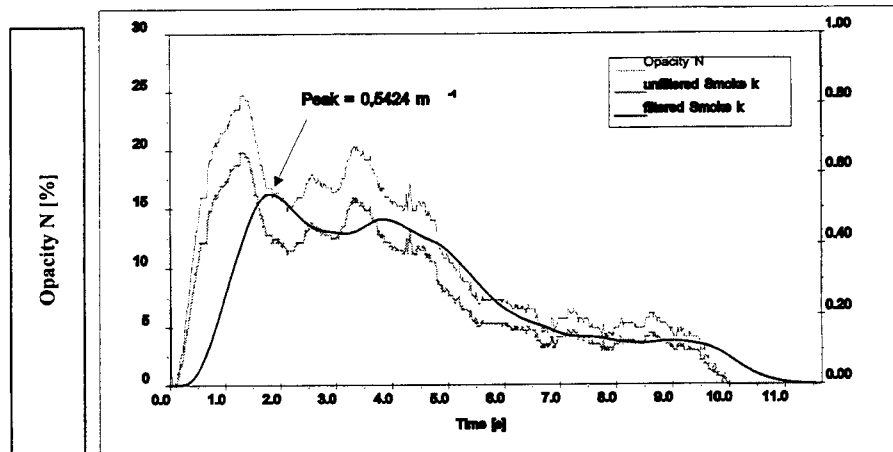


Figure b Traces of measured opacity N, of unfiltered smoke k and of filtered smoke k

The peak value ($i = 272$) is calculated assuming the following data of table C. All other individual smoke

| | |
|------------------------|-------|
| L_A (m) | ,430 |
| Index i | 272 |
| N (%) | 6,783 |
| S_{271} (m^{-1}) | 27392 |
| S_{270} (m^{-1}) | 27532 |
| Y_{271} (m^{-1}) | 42383 |
| $_{270}$ (m^{-1}) | 42337 |

Calculation of the k-value (Annex III, Appendix 1, section 6.3.1):

$$k = -\frac{1}{0,430} * \ln\left(1 - \frac{16,783}{100}\right) = 0,427252 \text{ m}^{-1}$$

This value corresponds to S_{272} in the following equation.

Calculation of Bessel averaged smoke (Annex III, Appendix 1, section 6.3.2):

In the following equation, the Bessel constants of the previous section 2.2 are used. The actual unfiltered k-value, as calculated above, corresponds to S_{272} (S_i). S_{271} (S_{i-1}) and S_{270} (S_{i-2}) are the two preceding unfiltered k-values, Y_{271} (Y_{i-1}) and Y_{270} (Y_{i-2}) are the two preceding filtered k-values.

$$\begin{aligned}
 Y_{272} &= 0,542383 + 8,272777 \text{ E-5} * (0,427252 + 2 * 0,427392 + 0,427532 - 4 * 0,542337) \\
 &\quad + 0,968410 * (0,542383 - 0,542337) \\
 &= 0,542389 \text{ m}^{-1}
 \end{aligned}$$

This value corresponds to $Y_{\max 1, A}$ in the following equation.

Calculation of the final smoke value (Annex III, Appendix 1, section 6.3.3):

From each smoke trace, the maximum filtered k-value is taken for the further calculation. Assume the following values

| Speed | $Y_{\max} \text{ (m}^{-1}\text{)}$ | | |
|-------|------------------------------------|---------|---------|
| | Cycle 1 | Cycle 2 | Cycle 3 |
| A | 0,5424 | 0,5435 | 0,5587 |
| B | 0,5596 | 0,5400 | 0,5389 |
| C | 0,4912 | 0,5207 | 0,5177 |

$$\begin{aligned}
 SV_A &= (0,5424 + 0,5435 + 0,5587) / 3 &= 0,5482 \text{ m}^{-1} \\
 SV_B &= (0,5596 + 0,5400 + 0,5389) / 3 &= 0,5462 \text{ m}^{-1} \\
 SV_C &= (0,4912 + 0,5207 + 0,5177) / 3 &= 0,5099 \text{ m}^{-1} \\
 SV &= (0,43 * 0,5482) + (0,56 * 0,5462) + (0,01 * 0,5099) &= 0,5467 \text{ m}^{-1}
 \end{aligned}$$

Cycle validation (Annex III, Appendix 1, section 3.4)

Before calculating SV, the cycle must be validated by calculating the relative standard deviations of the smoke of the three cycles for each speed.

| Speed | Mean SV (m ⁻¹) | absolute standard deviation (m ⁻¹) | relative standard deviation (%) |
|-------|----------------------------|--|---------------------------------|
| A | 0,5482 | 0,0091 | 1,7 |
| B | 0,5462 | 0,0116 | 2,1 |
| C | 0,5099 | 0,0162 | 3,2 |

In this example, the validation criteria of 15 % is met for each speed.

| Index i [-] | Time [s] | Opacity N [%] | unfiltered k-Value [m ⁻¹] | filtered k-Value [m ⁻¹] |
|----------------|-------------|------------------|---|---|
| -2 | 0,000000 | 0,000000 | 0,000000 | 0,000000 |
| -1 | 0,000000 | 0,000000 | 0,000000 | 0,000000 |
| 0 | 0,000000 | 0,000000 | 0,000000 | 0,000000 |
| 1 | 0,006667 | 0,020000 | 0,000465 | 0,000000 |
| 2 | 0,013333 | 0,020000 | 0,000465 | 0,000000 |
| 3 | 0,020000 | 0,020000 | 0,000465 | 0,000000 |
| 4 | 0,026667 | 0,020000 | 0,000465 | 0,000001 |
| 5 | 0,033333 | 0,020000 | 0,000465 | 0,000002 |
| 6 | 0,040000 | 0,020000 | 0,000465 | 0,000002 |
| 7 | 0,046667 | 0,020000 | 0,000465 | 0,000003 |
| 8 | 0,053333 | 0,020000 | 0,000465 | 0,000004 |
| 9 | 0,060000 | 0,020000 | 0,000465 | 0,000005 |
| 10 | 0,066667 | 0,020000 | 0,000465 | 0,000006 |
| 11 | 0,073333 | 0,020000 | 0,000465 | 0,000008 |
| 12 | 0,080000 | 0,020000 | 0,000465 | 0,000009 |
| 13 | 0,086667 | 0,020000 | 0,000465 | 0,000011 |
| 14 | 0,093333 | 0,020000 | 0,000465 | 0,000012 |
| 15 | 0,100000 | 0,192000 | 0,004469 | 0,000014 |
| 16 | 0,106667 | 0,212000 | 0,004935 | 0,000018 |
| 17 | 0,113333 | 0,212000 | 0,004935 | 0,000022 |
| 18 | 0,120000 | 0,212000 | 0,004935 | 0,000028 |
| 19 | 0,126667 | 0,343000 | 0,007990 | 0,000036 |
| 20 | 0,133333 | 0,566000 | 0,013200 | 0,000047 |
| 21 | 0,140000 | 0,889000 | 0,020767 | 0,000061 |
| 22 | 0,146667 | 0,929000 | 0,021706 | 0,000082 |
| 23 | 0,153333 | 0,929000 | 0,021706 | 0,000109 |
| 24 | 0,160000 | 1,263000 | 0,029559 | 0,000143 |
| 25 | 0,166667 | 1,455000 | 0,034086 | 0,000185 |
| 26 | 0,173333 | 1,697000 | 0,039804 | 0,000237 |
| 27 | 0,180000 | 2,030000 | 0,047695 | 0,000301 |
| 28 | 0,186667 | 2,081000 | 0,048906 | 0,000378 |
| 29 | 0,193333 | 2,081000 | 0,048906 | 0,000469 |
| 30 | 0,200000 | 2,424000 | 0,057067 | 0,000573 |
| 31 | 0,206667 | 2,475000 | 0,058282 | 0,000693 |
| 32 | 0,213333 | 2,475000 | 0,058282 | 0,000827 |
| 33 | 0,220000 | 2,808000 | 0,066237 | 0,000977 |
| 34 | 0,226667 | 3,010000 | 0,071075 | 0,001144 |
| 35 | 0,233333 | 3,253000 | 0,076909 | 0,001328 |
| 36 | 0,240000 | 3,606000 | 0,085410 | 0,001533 |
| 37 | 0,246667 | 3,960000 | 0,093966 | 0,001758 |
| 38 | 0,253333 | 4,455000 | 0,105983 | 0,002007 |
| 39 | 0,260000 | 4,818000 | 0,114836 | 0,002283 |
| 40 | 0,266667 | 5,020000 | 0,119776 | 0,002587 |
| ~ | ~ | ~ | ~ | ~ |

Table C Values of opacity N, unfiltered and filtered k-value at beginning of load step

| Index i [-] | Time [s] | Opacity N [%] | unfiltered k-Value [m ⁻¹] | filtered k-Value [m ⁻¹] |
|----------------|-------------|------------------|---|---|
| 259 | 1,726667 | 17,182000 | 0,438429 | 0,538856 |
| 260 | 1,733333 | 16,949000 | 0,431896 | 0,539423 |
| 261 | 1,740000 | 16,788000 | 0,427392 | 0,539936 |
| 262 | 1,746667 | 16,798000 | 0,427671 | 0,540396 |
| 263 | 1,753333 | 16,788000 | 0,427392 | 0,540805 |
| 264 | 1,760000 | 16,798000 | 0,427671 | 0,541163 |
| 265 | 1,766667 | 16,798000 | 0,427671 | 0,541473 |
| 266 | 1,773333 | 16,788000 | 0,427392 | 0,541735 |
| 267 | 1,780000 | 16,788000 | 0,427392 | 0,541951 |
| 268 | 1,786667 | 16,798000 | 0,427671 | 0,542123 |
| 269 | 1,793333 | 16,798000 | 0,427671 | 0,542251 |
| 270 | 1,800000 | 16,793000 | 0,427532 | 0,542337 |
| 271 | 1,806667 | 16,788000 | 0,427392 | 0,542383 |
| 272 | 1,813333 | 16,783000 | 0,427252 | 0,542389 |
| 273 | 1,820000 | 16,780000 | 0,427168 | 0,542357 |
| 274 | 1,826667 | 16,798000 | 0,427671 | 0,542288 |
| 275 | 1,833333 | 16,778000 | 0,427112 | 0,542183 |
| 276 | 1,840000 | 16,808000 | 0,427951 | 0,542043 |
| 277 | 1,846667 | 16,768000 | 0,426833 | 0,541870 |
| 278 | 1,853333 | 16,010000 | 0,405750 | 0,541662 |
| 279 | 1,860000 | 16,010000 | 0,405750 | 0,541418 |
| 280 | 1,866667 | 16,000000 | 0,405473 | 0,541136 |
| 281 | 1,873333 | 16,010000 | 0,405750 | 0,540819 |
| 282 | 1,880000 | 16,000000 | 0,405473 | 0,540466 |
| 283 | 1,886667 | 16,010000 | 0,405750 | 0,540080 |
| 284 | 1,893333 | 16,394000 | 0,416406 | 0,539663 |
| 285 | 1,900000 | 16,394000 | 0,416406 | 0,539216 |
| 286 | 1,906667 | 16,404000 | 0,416685 | 0,538744 |
| 287 | 1,913333 | 16,394000 | 0,416406 | 0,538245 |
| 288 | 1,920000 | 16,394000 | 0,416406 | 0,537722 |
| 289 | 1,926667 | 16,384000 | 0,416128 | 0,537175 |
| 290 | 1,933333 | 16,010000 | 0,405750 | 0,536604 |
| 291 | 1,940000 | 16,010000 | 0,405750 | 0,536009 |
| 292 | 1,946667 | 16,000000 | 0,405473 | 0,535389 |
| 293 | 1,953333 | 16,010000 | 0,405750 | 0,534745 |
| 294 | 1,960000 | 16,212000 | 0,411349 | 0,534079 |
| 295 | 1,966667 | 16,394000 | 0,416406 | 0,533394 |
| 296 | 1,973333 | 16,394000 | 0,416406 | 0,532691 |
| 297 | 1,980000 | 16,192000 | 0,410794 | 0,531971 |
| 298 | 1,986667 | 16,000000 | 0,405473 | 0,531233 |
| 299 | 1,993333 | 16,000000 | 0,405473 | 0,530477 |
| 300 | 2,000000 | 16,000000 | 0,405473 | 0,529704 |

Table C continued

Values of opacity N, unfiltered and filtered k-value around $Y_{\max 1,A}$
(□ peak value, indicated in bold number)

3 ETC TEST

3.1 Gaseous Emissions (Diesel Engine)

Assume the following test results for a PDP-CVS system

| | |
|-----------------------------------|-------|
| \dot{V}_0 (m ³ /rev) | ,1776 |
| N_p (rev) | 3073 |
| p_B (kPa) | 98,0 |
| p_1 (kPa) | 2,3 |
| T(K) | 22,5 |
| H_a (g/kg) | 12,8 |
| x_{conce} (ppm) | 53,7 |
| x_{concd} (ppm) | 0,4 |
| $conce$ (ppm) | 38,9 |
| $concd$ (ppm) | 1,0 |
| $conce$ (ppm) | 9,00 |
| $concd$ (ppm) | 3,02 |
| $O_{2,conce}$ (%) | ,723 |
| act (kWh) | 2,72 |

Calculation of the diluted exhaust gas flow (Annex III, Appendix 2, section 4.1):

$$\begin{aligned} M_{TOTW} &= 1,293 * 0,1776 * 23073 * (98,0 - 2,3) * 273 / (101,3 * 322,5) \\ &= 4237,2 \text{ kg} \end{aligned}$$

Calculation of the NO_x correction factor (Annex III, Appendix 2, section 4.2):

$$K_{H,D} = \frac{1}{1 - 0,0182 * (12,8 - 10,71)} = 1,039$$

Calculation of the background corrected concentrations (Annex III, Appendix 2, section 4.3.1.1):

Assuming a diesel fuel of the composition C₁H_{1,8}

$$F_s = 100 * \frac{1}{1 + (1,8 / 2) + (3,76 * (1 + (1,8 / 4)))} = 13,6$$

$$DF = \frac{13,6}{0,723 + (9,00 + 38,9) * 10^{-4}} = 18,69$$

$$\begin{aligned} NO_{x,conc} &= 53,7 - 0,4 * (1 - (1/18,69)) &= 53,3 \text{ ppm} \\ CO_{conc} &= 38,9 - 1,0 * (1 - (1/18,69)) &= 37,9 \text{ ppm} \\ HC_{conc} &= 9,00 - 3,02 * (1 - (1/18,69)) &= 6,14 \text{ ppm} \end{aligned}$$

Calculation of the emissions mass flow (Annex III, Appendix 2, section 4.3.1):

$$\begin{aligned} NO_{x, mass} &= 0,001587 * 53,3 * 1,039 * 4237,2 &= 372,391 \text{ g} \\ CO_{mass} &= 0,000966 * 37,9 * 4237,2 &= 155,129 \text{ g} \\ HC_{mass} &= 0,000479 * 6,14 * 4237,2 &= 12,462 \text{ g} \end{aligned}$$

Calculation of the specific emissions (Annex III, Appendix 2, section 4.4):

$$\begin{aligned} \overline{\text{NO}}_x &= 372,391 / 62,72 &= 5,94 \text{ g/kWh} \\ \overline{\text{CO}}_2 &= 155,129 / 62,72 &= 2,47 \text{ g/kWh} \\ \overline{\text{HC}}_3 &= 12,462 / 62,72 &= 0,199 \text{ g/kWh} \end{aligned}$$

3.2 Particulate Emissions (Diesel Engine)

Assume the following test results for a PDP-CVS system with double dilution

| | |
|-----------------------|-------|
| TOTW (kg) | 237,2 |
| M _{f,p} (mg) | ,030 |
| M _{f,b} (mg) | ,044 |
| TOT (kg) | ,159 |
| SEC (kg) | ,909 |
| M _d (mg) | ,341 |
| DIL (kg) | ,245 |
| DF | 8,69 |
| act (kWh) | 2,72 |

Calculation of the mass emission (Annex III, Appendix 2, section 5.1):

$$M_f = 3,030 + 0,044 = 3,074 \text{ mg}$$

$$M_{\text{SAM}} = 2,159 - 0,909 = 1,250 \text{ kg}$$

$$PT_{\text{mass}} = \frac{3,074}{1,250} * \frac{4237,2}{1000} = 10,42 \text{ g}$$

Calculation of the background corrected mass emission (Annex III, Appendix 2, section 5.1):

$$PT_{\text{mass}} = \left[\frac{3,074}{1,250} - \left(\frac{0,341}{1,245} * \left(1 - \frac{1}{18,69} \right) \right) \right] * \frac{4237,2}{1000} = 9,32 \text{ g}$$

Calculation of the specific emission (Annex III, Appendix 2, section 5.2):

$$\begin{aligned} \overline{NO_x} &= 372,391/62,72 &= 5,94 \text{ g/kWh} \\ \overline{CO} &= 155,129/62,72 &= 2,47 \text{ g/kWh} \\ \overline{HC} &= 12,462/62,72 &= 0,199 \text{ g/kWh} \end{aligned}$$

3.3 Gaseous Emissions (CNG Engine)

Assume the following test results for a PDP-CVS system with double dilution

| | |
|--------------------------|--------|
| TOTW (kg) | 4237,2 |
| H _a (g/kg) | 12,8 |
| x _{conce} (ppm) | 17,2 |
| x _{concd} (ppm) | 0,4 |
| conce(ppm) | 44,3 |
| concd(ppm) | 1,0 |
| conce(ppm) | 27,0 |
| concd(ppm) | 3,02 |
| 4 _{conce} (ppm) | 18,0 |
| 4 _{concd} (ppm) | 1,7 |
| O _{2,conce} (%) | 0,723 |
| act(kWh) | 62,72 |

Calculation of the NO_x correction factor (Annex III, Appendix 2, section 4.2):

$$K_{H_2O} = \frac{1}{1 - 0,0329 * (12,8 - 10,71)} = 1,074$$

Calculation of the NMHC concentration (Annex III, Appendix 2, section 4.3.1):

a) GC method

$$NMHC_{conce} = 27,0 - 18,0 = 9,0 \text{ ppm}$$

b) NMC method

Assuming a methane efficiency of 0,04 and an ethane efficiency of 0,98 (see Annex III, Appendix 5, section 1.8.4)

$$NMHC_{conce} = \frac{27,0 * (1 - 0,04) - 18,0}{0,98 - 0,04} = 8,4 \text{ ppm}$$

Calculation of the background corrected concentrations (Annex III, Appendix 2, section 4.3.1.1):

Assuming a G20 reference fuel (100 % methane) of the composition C₁H₄

$$F_S = \frac{100 * 1}{1 + (4 / 2) + (3,76 * (1 + (4 / 4)))} = 9,5$$

$$DF = \frac{9,5}{0,723 + (27,0 + 44,3) * 10^{-4}} = 13,01$$

For NMHC, the background concentration is the difference between $\overline{HC_{concd}}$ and $\overline{CH_{4concd}}$

$$\begin{aligned} NO_{x\ conc} &= 17,2 - 0,4 * (1 - (1/13,01)) &= 16,8 \text{ ppm} \\ CO_{conc} &= 44,3 - 1,0 * (1 - (1/13,01)) &= 43,4 \text{ ppm} \\ NMHC_{conc} &= 8,4 - 1,32 * (1 - (1/13,01)) &= 7,2 \text{ ppm} \\ CH_{4\ conc} &= 18,0 - 1,7 * (1 - (1/13,01)) &= 16,4 \text{ ppm} \end{aligned}$$

Calculation of the emissions mass flow (Annex III, Appendix 2, section 4.3.1):

$$\begin{aligned} NO_{x\ mass} &= 0,001587 * 16,8 * 1,074 * 4237,2 &= 121,330 \text{ g} \\ CO_{mass} &= 0,000966 * 43,4 * 4237,2 &= 177,642 \text{ g} \\ NMHC_{mass} &= 0,000502 * 7,2 * 4237,2 &= 15,315 \text{ g} \\ CH_{4\ mass} &= 0,000554 * 16,4 * 4237,2 &= 38,498 \text{ g} \end{aligned}$$

Calculation of the specific emissions (Annex III, Appendix 2, section 4.4):

$$\begin{aligned} \overline{NO_x} &= 121,330/62,72 &= 1,93 \text{ g/kWh} \\ \overline{CO} &= 177,642/62,72 &= 2,83 \text{ g/kWh} \\ \overline{NMHC} &= 15,315/62,72 &= 0,244 \text{ g/kWh} \\ \overline{CH_4} &= 38,498/62,72 &= 0,614 \text{ g/kWh} \end{aligned}$$

4 **λ -SHIFT FACTOR (S_λ)**
 4.1 Calculation of the λ -shift factor (S_λ)⁽¹⁾

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

where:

- S_λ = λ -shift factor;
- inert% = % by volume of inert gases in the fuel (i.e. N_2 , CO_2 , He, etc.);
- O_2^* = % by volume of original oxygen in the fuel;
- n and m = refer to average C_nH_m representing the fuel hydrocarbons, i.e:

$$n = \frac{1x \left[\frac{CH4\%}{100} \right] + 2x \left[\frac{C2\%}{100} \right] + 3x \left[\frac{C3\%}{100} \right] + 4x \left[\frac{C4\%}{100} \right] + 5x \left[\frac{C5\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}}$$

$$m = \frac{4x \left[\frac{CH4\%}{100} \right] + 4x \left[\frac{C2H4\%}{100} \right] + 6x \left[\frac{C2H6\%}{100} \right] + \dots + 8x \left[\frac{C3H8\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}}$$

where:

- CH_4 = % by volume of methane in the fuel;
- C_2 = % by volume of all C_2 hydrocarbons (e.g.: C_2H_6 , C_2H_4 , etc.) in the fuel;
- C_3 = % by volume of all C_3 hydrocarbons (e.g.: C_3H_8 , C_3H_6 , etc.) in the fuel;
- C_4 = % by volume of all C_4 hydrocarbons (e.g.: C_4H_{10} , C_4H_8 , etc.) in the fuel;
- C_5 = % by volume of all C_5 hydrocarbons (e.g.: C_5H_{12} , C_5H_{10} , etc.) in the fuel;
- diluent = % by volume of dilution gases in the fuel (i.e.: O_2^* , N_2 , CO_2 , He, etc.).

⁽¹⁾ Stoichiometric Air/Fuel ratios of automotive fuels □ SAE J1829, June 1987.
 John B. Heywood, Internal Combustion Engine Fundamentals, McGraw-Hill, 1988, Chapter 3.4 "Combustion stoichiometry"
 (pages 68 - 72).

4.2 Examples for the calculation of the λ -shift factor S_{λ}

Example 1: G_{25} : $CH_4 = 86\%$, $N_2 = 14\%$ (by vol)

$$n = \frac{1x \left[\frac{CH_4\%}{100} \right] + 2x \left[\frac{C_2\%}{100} \right] + \dots}{1 - \frac{\text{diluent}\%}{100}} = \frac{1x 0,86}{1 - \frac{14}{100}} = \frac{0,86}{0,86} = 1$$

$$m = \frac{4x \left[\frac{CH_4\%}{100} \right] + 4x \left[\frac{C_2H_4\%}{100} \right] + \dots}{1 - \frac{\text{diluent}\%}{100}} = \frac{4x 0,86}{0,86} = 4$$

$$S_{\lambda} = \frac{2}{\left(1 - \frac{\text{inertti}\%}{100}\right) \left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{14}{100}\right) x \left(1 + \frac{4}{4}\right)} = 1,16$$

Example 2: G_{xy} : $CH_4 = 87\%$, $C_2H_6 = 13\%$ (by vol)

$$n = \frac{1x \left[\frac{CH_4\%}{100} \right] + 2x \left[\frac{C_2\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}} = \frac{1x0,87 + 2x0,13}{1 - \frac{0}{100}} = \frac{1,13}{1} = 1,13$$

$$m = \frac{4x \left[\frac{CH_4\%}{100} \right] + 6x \left[\frac{C_2H_6\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}} = \frac{4x0,87 + 6x0,13}{1} = 4,26$$

$$S\lambda = \frac{2}{\left(1 - \frac{\text{inert \%}}{100}\right) \left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{0}{100}\right) x \left(1,13 + \frac{4,26}{4}\right)} = 0,911$$

Example 3: USA: $CH_4 = 89\%$, $C_2H_6 = 4,5\%$, $C_3H_8 = 2,3\%$, $C_6H_{14} = 0,2\%$, $O_2 = 0,6\%$, $N_2 = 4\%$

$$n = \frac{1x \left[\frac{CH_4\%}{100} \right] + 2x \left[\frac{C_2\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}} = \frac{1x0,89 + 2x0,045 + 3x0,023 + 4x0,002}{1 - \frac{(0,64 + 4)}{100}} = 1,11$$

$$m = \frac{4x \left[\frac{CH_4\%}{100} \right] + 4x \left[\frac{C_2H_4\%}{100} \right] + 6x \left[\frac{C_2H_6\%}{100} \right] + \dots + 8x \left[\frac{C_3H_8\%}{100} \right]}{1 - \frac{\text{diluent \%}}{100}} = \frac{4x0,89 + 4x0,045 + 8x0,023 + 14x0,002}{1 - \frac{0,6 + 4}{100}} = 4,24$$

$$S\lambda = \frac{2}{\left(1 - \frac{\text{inert \%}}{100}\right) \left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{4}{100}\right) x \left(1,11 + \frac{4,24}{4}\right) - \frac{0,6}{100}} = 0,96$$

Interinstitutional
File No 97/0350 (COD)

5734/1/99 REV 1 ADD I

LIMITE

ENT 21
ENV 23
CODEC 52

**COUNCIL COMMON POSITION NE /99
OF 22 APRIL 1999
WITH A VIEW TO ADOPTING DIRECTIVE 99/ /EC
OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
ON THE APPROXIMATION OF THE LAWS OF THE MEMBER STATES
RELATING TO MEASURES TO BE TAKEN AGAINST
THE EMISSION OF GASEOUS AND PARTICULATE POLLUTANTS
FROM COMPRESSION IGNITION ENGINES FOR USE IN VEHICLES
AND THE EMISSION OF GASEOUS POLLUTANTS FROM POSITIVE IGNITION ENGINES
FUELLED WITH NATURAL GAS OR LIQUEFIED PETROLEUM GAS FOR USE IN VEHICLES
AND AMENDING COUNCIL DIRECTIVE 88/77/EEC**

STATEMENT OF THE COUNCIL'S REASONS

I. INTRODUCTION

1. On 23 March 1998 the Commission submitted a proposal, based on Article 95 of the EC Treaty, relating to measures to be taken against the emission of gaseous and particulate pollutants from compression ignition engines for use in vehicles and the emission of gaseous pollutants from positive ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles and amending Council Directive 88/77/EEC.
2. The European Parliament delivered its Opinion on 21 October 1998 and proposed 24 amendments to the Commission proposal. In the light of that Opinion the Commission submitted an amended proposal on 16 March 1999 accepting 10 of the European Parliament's amendments, 2 of which were accepted in full, 5 in principle subject to redrafting and 4 in part.
3. The Economic and Social Committee delivered its Opinion on 9 September 1998.
4. On 22 April 1999, the Council adopted a common position on the Commission proposal in accordance with Article 251 of the Treaty.

II. OBJECTIVE

5. The objective of the Commission's proposal is to apply more stringent emission limits applicable to engines fitted in heavy-duty vehicles from the year 2000 and so amend Directive 88/77/EEC on diesel engine emissions. It is one part of the proposals resulting from the Auto-Oil I programme which also include passenger car emissions, fuel quality, light commercial vehicle emissions and inspection and maintenance.

III. ANALYSIS OF THE COMMON POSITION

6. Preliminary comment

The Council has felt that it was appropriate to introduce, as requested by the European Parliament, a second stage of more stringent emission limit values by 2005 as well as to adopt provisions aiming at introducing before this date complementary measures on durability, on-board-diagnostics (OBD) and in-use conformity testing.

Furthermore, the Council has decided to introduce a further stage applicable from October 2008 that aims for a further reduction of the NO_x limit by 43% over the limit set for 2005. However, recognising that the necessary NO_x reduction technology is not yet available, the Council has decided that the Commission shall report on the state of play of such technology by the end of 2002 accompanied, if necessary by appropriate proposals.

As the Council has judged that the apportionment of test cycles applicable for 2000 would no longer be valid for the stringent emission limits envisaged for 2005, it has decided that for 2005, all diesel engines must be tested on all cycles (ESC, ELR and ETC cycles) for the purpose of type-approval.

The Council has extended the scope of the Directive to provide for the European type-approval of gas-fuelled engines - liquified petroleum gas (LPG) or natural gas (NG). This is achieved through the application of the same emission limits as apply to diesel engines but with the addition of specific emission limits for non-methane hydrocarbons (instead of total hydrocarbons) and methane for gas fuelled engines. Gas engines are tested on the ETC cycle only and due to their inherently low particulate emission, gas engines are not subject to particulate measurement for the purposes of type-approval.

The Council has agreed to introduce specific values for extra-low emission vehicles (EEV) for use primarily in urban fleets.

As has been the case in the other so-called Auto-Oil Directives, taxation provisions have been introduced and thus the Council has decided that Member States can apply tax incentives to encourage the earlier introduction of vehicles complying with future emission limits. However, incentives for vehicles complying with the more stringent standards will only be permitted from 1 October 2000 and incentives shall cease from the date of mandatory application of the legislative requirements.

7. **Enacting terms**

(a) **Article 1(2)**

A definition of Enhanced Environmentally Friendly vehicle has been introduced in Article 1.

(b) **Article 2 (6) and (7)** (new)

Two paragraphs have been added in Article 2 for consequential reasons, adapting provisions for type-approval and certificates of conformity provisions for vehicles not complying with emission values set for the new stage 2008.

(c) **Article 3 (1) subparagraphs (a) and (b), Article 3(2)**

The wording of this article has been changed slightly as a consequence of the introduction of the second set of emission values for 2005 and the addition of limit values for EEV.

(d) **Articles 4 - 6** (new)

Articles 4-6 contain provisions concerning the application of EC type approval in respect of OBD systems from 2005 (new types of vehicles) and 2006 (all types of vehicles), durability requirements and in-use conformity testing respectively. These Articles also serve to recall that the Commission is to propose provisions to this effect.

(d) **Article 7** (Article 4 of Commission proposal)

Article 7 follows very closely the line taken in the Commission proposal. However, the Council thought it best to add new paragraphs asking the Commission to submit proposals before the end of 2000 on the introduction of supplementary measures relating to OBD, durability requirements and in-use conformity testing from October 2005 and on the future prospects for a world harmonised test cycle for heavy duty vehicles. As technology to provide compliance with the stringent NOx limit in 2008 is not available at present, the Council has decided that the Commission shall report on the state of play of NOx reduction technology by the end of 2002 and, if necessary, put forward appropriate proposals (see preliminary comment in paragraph 6 above).

(e) **Annex I**

A number of amendments have been made to Annex I:

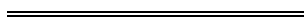
In Annex I, section 2, two new definitions have been introduced: 2.27 "EEV", and 2.28 "Defeat device". The latter has been introduced as the Council found it best explicitly to make sure that unfriendly engine management strategies in relation to test proceeding under practical operations are excluded.

Section 6.2 has been amended as the Council judged that with the introduction of stringent limit values for 2005, the test cycles apportionment would have to be changed accordingly and thus the Council has decided that for 2005 all diesel engines will be tested on all cycles for the purpose of type-approval. Conventional gas fuelled engines will not be subject to particulate measurement for the purposes of type approval for the 2000 requirement. For the 2005 and 2008 stages these engines will continue to be tested only on the ETC cycle.

In table 1 and 2 of Section 6.2.1, row B has been divided into B1 (limit values for 2005) and B2 (limit values for 2008) and a new row C (limit values for EEV) has been added (see preliminary comments in paragraph 6 above). The Council has confirmed the limit values proposed by the Commission for the initial stage 2000. In this regard the Council has agreed to grant a derogation to small high speed diesel engines as far as particulate emissions are concerned. However, the Council has expanded the definition of these engines to engines with a cylinder swept volume of 750 cc instead of 700 cc. Furthermore, the Council has confirmed that this exception shall end from the application of the second stage in 2005.

The Council has decided to add a mandatory set of stringent limit values applicable from October 2005, introducing particularly stringent limits for particulates allowing for a reduction of a further 80% over the limits set for 2000. The Council has agreed to add a further stage applicable from October 2008, aiming for a further reduction in the NOx limit by 43% over the limit set for 2005.

Finally, the Council has decided to include specific target values for EEV to be used by Member States for application on a permissive basis for the encouragement of ultra-low emission vehicles operating in specific areas.





COMMISSION OF THE EUROPEAN COMMUNITIES

Brussels, 16.07.1999
SEC(1999) 423 final

97/0350 (COD)

COMMUNICATION FROM THE COMMISSION
TO THE EUROPEAN PARLIAMENT

pursuant to the second subparagraph of Article 251 (2) of the EC-Treaty

Common position of the Council on the proposal for a European Parliament and Council Directive amending Directive 88/77/EEC on the measures to be taken against the emission of gaseous and particulate pollutants from diesel engines for use in vehicles

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT

Subject : Common position of the Council on the proposal for a European Parliament and Council Directive amending Directive 88/77/EEC on the measures to be taken against the emission of gaseous and particulate pollutants from diesel engines for use in vehicles

1. Background to the proposal

- A proposal to amend Directive 88/77/EEC was adopted by the Commission on 3 December 1997 (**heavy duty vehicles**) and transmitted to the Council, the European Parliament and the Economic and Social Committee on 23 March 1998 (*Reference COM(97)627 final*).
- The European Parliament delivered its opinion in first reading on 21 October 1998 and the Economic and Social Committee delivered its opinion on 9 September 1998.
- The Commission submitted an amended proposal on measures to be incorporated relating to Enhanced Environmentally Friendly Vehicles (EEV) into the Directive referred to in the first indent above on 17 December 1998 (*Reference COM(98)776 final of 17 December 1998*).
- The Council adopted a Common Position on the proposal referred to in the first indent above on 22 April 1999.

2. Objective of the proposal

The objective of the proposal is to apply more stringent emission limits applicable to engines fitted in heavy-duty vehicles from the year 2000. The Commission's proposal amends Directive 88/77/EEC on diesel engine emissions. It is one part of the proposals resulting from the Auto-Oil I programme which also includes passenger car and light commercial vehicle emissions, fuel quality and inspection and maintenance.

3. Position of the European Parliament in its first reading and the Commission's opinion

The European Parliament adopted 24 amendments to the Commission's proposal. The amendments:

- introduce a mandatory second stage of emission limits applicable from October 2005. The emission limits would effectively require all heavy duty vehicles to be equipped with exhaust aftertreatment devices for the control of NO_x and particulate emissions. *The Commission did not agree with the European Parliament's proposal to include a mandatory stage 2005 – the Commission's proposal was to use the results of the Auto-Oil II programme to make relevant cost-effective proposals based on technical capability, coupled with a package of measures for on-board diagnostics (OBD) and durability;*
- introduce, within the mandatory second stage referred to above, additional technical requirements relating to OBD, durability and in-use conformity testing. *The Commission agrees on the need for further technical measures relating to OBD and durability and is sympathetic to the possible need for in-use conformity testing of heavy duty vehicles;*
- introduce provisions for tax incentives for vehicles that meet in advance the mandatory emission limits for 2005 and also permit tax or fiscal incentives for the re-equipment of older heavy duty vehicles. *The Commission agrees with the need for tax incentives according to agreed Community emission standards, but not in advance of its own proposals for 2005 based on Auto-Oil II;*

- support the on-going study towards a world-wide harmonised emission test cycle. *The Commission supports the world-wide harmonised emission test cycle study.*

4. The Common Position adopted by the Council

Emission limits and test cycles - stage 2000

In taking the same position as the European Parliament, the Council agrees fully with the Commission on the emission limit values applicable from 1 October 2000 for heavy duty vehicles and the introduction of two new test cycles. The emission limits agreed for application in 2000 reflect a 30% reduction in the emission limits applicable since 1996. This decision endorses the results of the Commission's Auto-Oil I programme.

The Council agrees with the Commission on the retention of the derogation for small high speed diesel engines to meet slightly less stringent particulate emission limits. However, the Council has expanded the definition of these small high speed diesel engines, specifically first introduced in Directive 96/1/EC, to engines with a cylinder swept volume of 750 cc, instead of a cylinder swept volume of 700 cc. In addition, Council has confirmed that this exception shall end from the application of a second stage in 2005.

The Council agrees with the Commission on the apportioning of the two new test cycles to different engine technologies and fuel requirements. Conventional diesel engines (including those equipped with oxidation catalysts and exhaust gas recirculation) are tested on the European Steady State Cycle (ESC) for emissions of CO, HC, NO_x and particulates plus the European Load Response Cycle (ELR) for the emission of smoke. More advanced diesel engines (including those fitted with particulate traps and/or de-NO_x catalysts) are tested on the ESC, ELR and the European Transient Cycle (ETC).

The Council agrees with the Commission on the need to extend the scope of the Directive to provide for the European type-approval of gas fuelled engines - liquefied petroleum gas (LPG) or natural gas (NG). This is achieved through the application of the same emission limits as apply to diesel engines but with the addition of specific emission limits for non-methane hydrocarbons (instead of total hydrocarbons) and methane for gas fuelled engines. Gas engines are tested on the ETC cycle only and due to their inherently low particulate emission, gas engines are not subject to particulate measurement for the purposes of type-approval.

Emission limits and test cycles - stage 2005

The Council has decided that a mandatory second stage of emission limits be applied from October 2005. The agreement sets emission limits for CO, HC and NO_x that will result in a further 30% reduction over the limits set for 2000. The Council has also decided on a more aggressive strategy for particulates that will result in a further 80% reduction over the particulate limits set for 2000. With today's technical knowledge, the particulate limit for 2005 will require the use of particulate traps on all diesel vehicles within the scope of this Directive.

In meeting the aspirations of the European Parliament, the Council has also decided on a further stage applicable from October 2008 that aims for a further reduction in the NO_x limit by 43% over the limit set for 2005. Effectively, the NO_x limit for 2008 will require the use of NO_x reduction technology on all diesel vehicles within the scope of this Directive. However, in recognising that the necessary NO_x reduction technology is still in the development stage, the Council has decided that

the Commission shall report on the state of play of such technology by the end of 2002 accompanied, if necessary, by appropriate proposals.

The Council has decided that for the stringent emission limits envisaged in 2005, the test cycle apportionment applicable for 2000 would no longer be valid. Therefore, the Council has decided that for 2005, all diesel engines will be tested on all cycles (ESC, ELR and ETC cycles) for the purposes of type-approval.

Conventional gas fuelled engines are subject to the same percentage emission reductions in 2005 and 2008 and will continue to be tested only on the ETC cycle and, as for the 2000 requirements, will not be subject to particulate measurement for the purposes of type-approval.

Enhanced Environmentally Friendly Vehicles (EEV)

The Council agrees with the Commission on the concept of emission target values that are fuel neutral which can be used for application by Member States, on a permissive basis, for the encouragement of ultra-low emission vehicles operating in specific areas and applications where there is an air quality need. Taking note of the Commission's amended proposal (COM(98) 776 final), the Council has included specific EEV target values and Articles of application in its Common Position.

Tax incentives

The Council has decided that tax incentives may be applied by Member States to encourage the earlier introduction of vehicles complying with future European emission limits. Therefore, from October 2000, tax incentives may be introduced for vehicles that comply in advance with the limit values applicable from 2005 and 2008 and the target values for EEVs. Such incentives shall cease from the date of mandatory application of the future requirements.

Other issues

To further improve the emissions performance of heavy duty vehicles while in service, the Council has decided that the mandatory stage 2005 should be supplemented by additional measures. Therefore, by the end of 2000, the Commission shall come forward with a proposal relating to the introduction of on-board diagnostic (OBD) systems, durability of emission control devices and in-use conformity testing, to be applicable to new heavy duty vehicles from October 2005.

The proposal shall take account of the dependence of advanced exhaust aftertreatment systems on the use of low sulphur diesel fuel, the need to improve the accuracy and repeatability of particulate measuring and sampling procedures for the very low levels of particulate limits being applied from 2005 and the development of a world harmonised test cycle.

5. Conclusions

In tightening the Commission's proposal with the addition of a mandatory second stage applicable from October 2005 and a further mandatory stage applicable from 2008 (but subject to Commission review), the Council's Common Position meets the aspirations of the first reading of the European Parliament which had the aim of setting future emission standards which would require the fitment of exhaust aftertreatment technology to heavy duty diesel engine vehicles.

In agreeing further mandatory stages applicable from 2005, the Council has set extremely challenging targets for the heavy duty vehicle and engine industry and the exhaust aftertreatment industry. At this time, the technology necessary to provide compliance with the 2005 limits, and certainly the 2008 limits, is not ready in terms of applicability and durability for a significant number of the vehicles or engine types covered by the scope of this Directive. Today's particulate traps, for instance, are very good at stopping emissions of particulate, even the ultra-fine particulate which seem to be of greatest concern regarding health effects; however, the problem which the aftertreatment industry has yet to fully solve is one of efficiently removing the accumulated particulate from the trap thereby ensuring adequate operational efficiency and durability. Therefore, engine manufacturers, vehicle builders and the aftertreatment industry still have a significant amount of work to do.

It is well known that the quality of the fuel, specifically the sulphur content, is an important contributing factor to the efficient and durable operation of exhaust aftertreatment devices. Last year, the Council and the European Parliament agreed on an amending Directive (Directive 98/70/EC) that sets the mandatory fuel quality specifications in the European Union from 2000 and 2005 (from 2005 the maximum sulphur content of diesel fuel will be 50 parts per million - ppm). The mandatory application of the heavy duty emission limits from October 2005 and the achievement of those emission limits in service is heavily reliant on the mandatory introduction of such cleaner diesel fuel into the European market from January 2005.

However, the Common Position allows Member States to use tax incentives to encourage the introduction of vehicles that meet the 2005 limits from October 2000, well in advance of the date for the mandatory introduction of low sulphur fuel in 2005. Therefore, it is important that Member States, as soon as possible, introduce diesel fuel that complies with the mandatory 2005 standards to facilitate international transport with such vehicles. It is therefore implicit that if a Member State provides for tax incentives for the earlier introduction of 2005 compliant vehicles, then similar incentives should also provide for the parallel introduction of diesel fuel complying with the mandatory 2005 standards. The Commission would like to highlight the fact that the time for the development of sufficiently durable and efficient particulate and NO_x reduction technology capable of complying with the 2005 limits, as applied in advance of 2005 through tax incentives, is extremely short.

The Commission supports the aspirations of the Common Position in setting stringent 2005 standards for particulate emissions that will require the use of a particulate trap (or other control device) on diesel engines. It is a precautionary control approach against the emissions of ultra-fine particulate while awaiting the confirmed view of the medical experts regarding the impact of ultra-fine particulate on human health. While the emission control technology has yet to be fully developed for a significant number of the vehicles and engines covered by the scope of this Directive, sufficient lead time has been given to the industry before the mandatory application of the relevant emission limits in 2005.

The technology to achieve the extremely stringent NO_x limit in 2008 is less advanced in terms of its development so the review, due at the end of 2002, will provide for the necessary means of checking whether the NO_x limit in 2008 is a practical aim. If necessary, an appropriate proposal from the Commission could either amend the NO_x limit and/or the application date.

The Council also agrees on the introduction of supplementary measures relating to OBD, durability requirements and in-use conformity testing from October 2005 and on the future prospects for a world harmonised test cycle for heavy duty vehicles. The Commission agrees that the additional technical measures on OBD, durability and in-use conformity testing will provide for the necessary in-use emissions performance of heavy duty vehicles.

In general, the Commission welcomes the Common Position and invites the two institutions to reach an agreement on measures applied to heavy duty vehicles as soon as possible.

