II

(Acts whose publication is not obligatory)

COUNCIL

COUNCIL DIRECTIVE

of 1 October 1991

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 pollutants from diesel engines for use in vehicles

(91/542/EEC)

THE COUNCIL OF THE EUROPEAN COMMUNITIES,

Having regard to the Treaty establishing the European Economic Community, and in particular Article 100a thereof,

Having regard to the proposal from the Commission (1),

In cooperation with the European Parliament (2),

Having regard to the opinion of the Economic and Social Committee (3),

Whereas it is important to adopt measures with the aim of progressively establishing the internal market over a period expiring on 31 December 1992; whereas the internal market shall comprise an area without internal frontiers in which the free movement of goods, persons, services and capital is ensured;

Whereas the first programme of action of the European Communities on the protection of the environment, 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 third programme of action provides for additional efforts to be made to reduce considerably the present level of emissions of pollutants from motor vehicles;

Whereas Directive 88/77/EEC (4) lays 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 representative for European driving conditions for the vehicles concerned; whereas in accordance with Article 6 of that Directive these limit values should be further reduced in the light of technical progress and a limit value for particulate emissions fixed;

Whereas, in laying down the new standards and test procedures, it is necessary to take account of future traffic growth in the European Community; whereas an increase in vehicle registrations, particularly lorries, is to be expected in anticipation of the internal market;

Whereas the work undertaken by the Commission in that sphere has shown that the Community motor industry has had available for some time or is currently perfecting technologies which allow a considerable reduction of the limit values in question and the particulate standards; whereas, because of this and the likely increase in the number of motor vehicles in Europe as a result of the internal market, it is imperative to reduce emission limit values radically in the interests of environmental protection and public health;

Whereas it is appropriate to introduce these more stringent standards in two stages, the first coinciding with the implementation dates of the new stringent European emission standards for passenger cars; whereas the second stage aims at the establishment of a longer-term orientation for the European motor industry in fixing limit values which are based on the expected performance of technologies which

(1) OJ No C 187, 27. 7. 1990, p. 6.
(2) OJ No C 48, 25. 2. 1991, p. 162; and OJ No C 240, 16. 9. 1991, p. 106.
(3) OJ No C 41, 18. 2. 1991, p. 51.
(4) OJ No L 36, 9. 2. 1988, p. 33.

are still under development, granting to industry a sufficient lead time for perfecting such technologies; whereas the enforcement of the second stage requires as a prerequisite the meeting of certain framework conditions in relation to the availability of low-sulphur diesel fuel and of a corresponding reference fuel for emissions testing, to the progress achieved on emission control technologies, and to the availability of an improved method for the control of production conformity which the Commission adopts in application of the procedure for adaptation to technical progress set out in Article 4 of Directive 88/77/EEC; whereas the Commission will present, before the end of 1993, a comprehensive report on these matters to the Council enabling the latter to decide, if necessary, before 30 September 1994, the limit value for the particulate emissions to be retained for the second stage;

Whereas an addition to the European 13-mode test cycle for checking the limit values of gaseous pollutants should be considered to take account of dynamic processes such as acceleration; whereas the Commission will submit a report on this subject in due course;

Whereas, under the spot-check procedure in production testing, the production limit value for pollutants need only be maintained on average; whereas an improved sampling procedure would be highly desirable; whereas the Commission will submit appropriate proposals;

Whereas, so that the limit values laid down can be complied with effectively, a special annual mandatory exhaust test must be introduced for all the vehicles in question; whereas the Commission will submit appropriate proposals;

Whereas in order to allow the European environment to benefit to the maximum from these provisions and at the same time ensure the unity of the market, it is necessary to impose the new, very stringent standards;

Whereas it would be desirable for the Member States to take the initiative to encourage, by means of tax incentives, compliance with European emission standards ahead of time, it being understood that such incentives were applicable to all models marketed in a Member State;

Whereas the process of tightening up the standards would also be speeded up if Member States introduced schemes to encourage the purchasers of new cars to scrap their old vehicles or, as far as possible, surrender them for recycling;

Whereas the the Community should study and develop alternative systems of propulsion, alternative fuels and corresponding transport concepts and provide financial support for research and development in these fields,

HAS ADOPTED THIS DIRECTIVE:

Article 1

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

1. The title is replaced by the following:

'Council Directive

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 diesel engines for use in vehicles'

2. Annexes I, II, III, V and VIII are amended in accordance with the Annex to this Directive.

Article 2

1. From 1 January 1992 no Member State may, on grounds relating to the gaseous and particulate pollutants emitted from an engine:

— refuse to grant EEC type-approval, or to issue the document provided for in the last indent of Article 10 (1) of Council Directive 70/156/EEC [1], or to grant national type-approval for a type of vehicle propelled by a diesel engine, or

— prohibit the registration, sale, entry into service or use of such new vehicles, or

— refuse to grant EEC type-approval, or to grant national type-approval for a type of diesel engine, or

— prohibit the sale or use of new diesel engines,

if the requirements of the Annexes to Directive 88/77/EEC are satisfied.

2. Member States may no longer grant EEC 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, of types of diesel engines and types of vehicle propelled by a diesel engine:

— from 1 July 1992 where the emissions of gaseous and particulate pollutants from the engine do not comply with the limit values set out in line A,

— from 1 October 1995 where the emission of gaseous and particulate pollutants from the engine do not comply with the limit values set out in line B

of the table in section 6.2.1. of Annex I to Directive 88/77/EEC.

3. Until 30 September 1993, paragraph 2 shall not apply to types of vehicle propelled by a diesel engine if the latter is

[1] OJ No L 42, 23. 2. 1970, p. 1.

described in the Annex to a type-approval certificate granted before 1 July 1992 in accordance with Directive 88/77/EEC.

4. With the exception of vehicles and diesel engines intended for export to third countries, Member States shall prohibit the registration, sale, entry into service and use of new vehicles propelled by a diesel engine and the sale and use of new diesel engines:

- from 1 October 1993, where the emissions of gaseous and particulate pollutants from the engine do not comply with the limit values set out in line A,
- from 1 October 1996, where the emissions of gaseous and particulate pollutants from the engine do not comply with the limit values set out in line B

of the table in section 8.3.1.1. of Annex I to Directive 88/77/EEC.

Article 3

Member States may make provision for tax incentives for the vehicles covered by this Directive. Such incentives shall meet the provisions of the Treaty as well as the following conditions:

- they shall apply to all domestic car production and to vehicles imported for marketing in a Member State and fitted with equipment allowing the European standards to be met in 1996 to be satisfied ahead of time,
- they shall cease upon the date set in Article 2 (4) for the compulsory entry into force of the emission values for new vehicles,
- they shall be of a value, for each type of vehicle, substantially lower than the actual cost of the equipment fitted to meet the values set and of its fitting on the vehicle.

The Commission shall be informed of any plans to introduce or amend the tax incentives referred to in the first subparagraph in sufficient time to allow it to submit comments.

Article 4

Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive not later than 1 January 1992. They shall forthwith inform the Commission thereof.

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

Article 5

1. Before the end of 1991, the Council, acting by a qualified majority on the basis of a Commission proposal, shall decide on measures to ensure the availability in the Member States of improved diesel fuel with a maximum permitted sulphur content of 0,05 %.

2. Before the end of 1993 the Commission shall give an account, in a report to the Council, of the progress made regarding:

- the availability of techniques for controlling air-polluting emissions from diesel engines, particularly those of less than 85 kW,
- a new statistical method for the monitoring of production conformity to be adopted in accordance with Article 4 of Directive 88/77/EEC.

If necessary it shall submit to the Council a proposal for revising upwards the limit values for particulate emissions. The Council shall take a decision on the basis of the proposal not later than 30 September 1994.

3. Before the end of 1996, in the light of the technical progress achieved, the Commission shall submit to the Council a revision of the limit values for polluting emissions combined if necessary with a revision of the test procedure. The new limit values shall not be applicable before 1 October 1999 as regards new type-approvals.

Article 6

The Council, acting by a qualified majority on a proposal from the Commission, which shall take account of the results of current work on the greenhouse effect, shall decide on the measures to be taken to limit CO_2 emissions from motor vehicles.

Article 7

This Directive is addressed to the Member States.

Done at Luxembourg, 1 October 1991.

For the Council

The President

J. G. M. ALDERS

ANNEX

Amendments to the Annexes of Directive 88/77/EEC

ANNEX I

SCOPE, DEFINITIONS AND ABBREVIATIONS, APPLICATION FOR EEC TYPE-APPROVAL, REQUIREMENTS AND TESTS AND CONFORMITY OF PRODUCTION

1. *Section 1 is hereby replaced by the following:*

'1 SCOPE

This Directive applies to the emission of gaseous and particulate pollutants from all motor vehicles, as defined in Article 1, equipped with diesel engines and to diesel engines as specified in Article 1, with the exception of those vehicles of category N_1, N_2 and M_2 for which type-approval has been granted under Directive 70/220/EEC (1), as last amended by Directive 91/441/EEC (2).

(1) OJ No L 76, 6. 4. 1970, p. 1.
(2) OJ No L 242, 30. 8. 1991, p. 1.'

Section 2.1 is hereby replaced by the following:

'2.1 *"Approval of an engine"* means the approval of an engine type with regard to the level of emission of gaseous and particulate pollutants.'

Section 2.4 is hereby supplemented as follows:

'2.4 *"Particulate pollutants"* means any material collected on a specified filter medium after diluting diesel exhaust to gases with clean filtered air so that the temperature does not exceed 325 K (52 °C).'

Section 2.9 is hereby replaced by the following:

'2.9 **Abbreviations and units**

All volumes and volumetric flow-rates must be calculated at 273 K (0 °C) and 101,3 kPa.

P	kW	net power output non-corrected
CO	g/kWh	carbon monoxide emission
HC	g/kWh	hydrocarbon emissions
NO_x	g/kWh	emission of oxides of nitrogen
PT	g/kWh	particulate emission
$\overline{CO}$, $\overline{HC}$, $\overline{NO_x}$, $\overline{PT}$		weighted average of respective emissions
conc	ppm	concentration (ppm by volume)
mass	g/h	pollutant mass flow
WF		weighting factor
WF_E		effective weighting factor
G_{EXH}	kg/h	exhaust gas mass flow-rate on a wet basis
V'_{EXH}	m^3/h	exhaust gas volume flow-rate on a dry basis
V''_{EXH}	m^3/h	exhaust gas volume flow-rate on a wet basis
G_{AIR}	kg/h	intake air mass flow-rate
V''_{AIR}	m^3/h	intake air volume flow-rate on a wet basis
G_{FUEL}	kg/h	fuel mass flow-rate
G_{DIL}	kg/h	dilution air mass flow-rate
V''_{DIL}	m^3/h	dilution air volume flow-rate on a wet basis

M_{SAM}	kg	mass of sample through particulate sampling filters
V_{SAM}	m^3	volume of sample through particulate sampling filters on a wet basis
G_{EDF}	kg/h	equivalent diluted mass flow-rate
V''_{EDF}	m^3/h	equivalent diluted volume flow-rate on a wet basis
i		subscript denoting an individual mode
P_f	mg	particulate sample mass
G_{TOT}	kg/h	diluted exhaust gas mass flow-rate
V''_{TOT}	m^3/h	diluted exhaust-gas volume flow-rate on a wet basis
q		dilution ratio
r		ratio of cross sectional areas of sampling probe and exhaust pipe
A_p	m^2	cross sectional area of the isokinetic sampling probe
A_T	m^2	cross sectional area of the exhaust pipe
HFID		heated flame ionization detector
NDUVR		non-dispersive ultraviolet resonance absorption
NDIR		non-dispersive infra-red
CLA		chemiluminescent analyser
HCLA		heated chemiluminescent analyser
S	kW	dynamometer setting, as indicated in Annex III, section 4.6.4
P_{min}	kW	minimum net engine power as indicated in line (e) in the table of section 7.2 in Appendix 1 to Annex II
L		per cent load as indicated in section 4.1 of this Annex
P_{aux}	kW	maximum permissible power absorbed by the engine-driven equipment as specified in section 5 of Annex II, Appendix 1, minus the total power absorbed by the engine-driven equipment during the test as specified in section 6.2.2 of Annex II, Appendix 1.'

Section 3.1.1 is hereby replaced by the following:

'3.1.1 The application for approval of an engine type with regard to the level of the emission of gaseous and particulate pollutants is submitted by the engine manufacturer or by a duly accredited representative.'

Section 3.2.1 is hereby replaced by the following:

'3.2.1 The application for approval of a vehicle type with regard to emission of gaseous and particulate pollutants by its engine is submitted by the vehicle manufacturer or a duly accredited representative.'

Section 6.1 is hereby replaced by the following:

'6.1 **General**

The components liable to affect the emission of gaseous and particulate pollutants must be so designed, constructed and assembled as to enable the engine, in normal use, despite the vibration to which it may be subjected, to comply with the requirements of this Directive.'

Section 6.2 is hereby replaced by the following:

'6.2 **Requirements for the emission of gaseous and particulate pollutants**

The emission of gaseous and particulate pollutants by the engine submitted for testing must be measured by the method described in Annex III. Annex V describes the recommended analytical systems for the gaseous pollutants and the recommended particulate sampling systems. Other systems or analysers may be approved by the technical service if it is found that they yield equivalent results. For a single laboratory, equivalency is defined as the test results to fall within ± 5 % of the test results of one of the reference systems described herein. For particulate emissions only the full-flow-dilution system is recognized as the reference system. For introduction of a new system into the Directive, the determination of equivalency must be based upon the calculation of repeatability and reproducibility by an interlaboratory test, as described in ISO 5725.'

Section 6.2.1 is hereby replaced by the following:

'6.2.1 The mass of the carbon monoxide, the mass of the hydrocarbons, the mass of the oxides of nitrogen, and the mass of the particulates must not exceed the amounts shown in the table below:

	Mass of carbon monoxide (CO) g/kWh	Mass of hydrocarbons (HC) g/kWh	Mass of nitrogen oxides (NO_x) g/kWh	Mass of particulates (PT) g/kWh
A (1. 7. 1992)	4,5	1,1	8,0	0,36 (*)
B (1. 10. 1995)	4,0	1,1	7,0	0,15

(*) In the case of engines of 85 kW or less, a coefficient of 1,7 is applied to the limit value for particulate emissions.'

Section 8.3.1.1 is hereby replaced by the following:

'8.3.1.1 An engine is taken from the series and subjected to the test described in Annex III. The mass of the carbon monoxide, the mass of the hydrocarbons, the mass of the oxides of nitrogen and the mass of particulates must not exceed the amounts shown in the table below:

	Mass of carbon monoxide (CO) g/kWh	Mass of hydrocarbons (HC) g/kWh	Mass of nitrogen oxides (NO_x) g/kWh	Mass of particulates (PT) g/kWh
A (1. 7. 1992)	4,9	1,23	9,0	0,4 (*)
B (1. 10. 1995)	4,0	1,1	7,0	0,15

(*) In the case of engines of 85 kW or less, a coefficient of 1,7 is applied to the limit value for particulate emissions.'

The fourth sentence of section 8.3.1.2 is hereby replaced by the following:

'The arithmetical mean ($_x$) of the results obtained with the sample is then determined for each pollutant.'

The last sentence is hereby replaced by the following:

'L is the limit value laid down in 8.3.1.1 for each pollutant considered, and k is a statistical factor depending on n and given in the following table:'

ANNEX II

The title of Annex II is hereby replaced by the following:

'ANNEX II

INFORMATION DOCUMENT No . . .

in accordance with Annex I to Council Directive 70/156/EEC relating to EEC type-approval and referring to measures to be taken against the emission of gaseous and particulate pollutants from diesel engines for use in vehicles

(Directive 88/77/EEC as last amended by Directive 91/542/EEC)'

Appendix 1, section 2, is hereby replaced by the following:

'2 **Additional anti-pollution devices** (if any, and if not covered by another heading)

Description and/or diagram(s): . . .'

ANNEX III

TEST PROCEDURE

Section 1.1 is hereby replaced by the following:

'1.1 This Annex describes the method of determining emissions of gaseous and particulate pollutants from the engine tested.'

Section 2 is hereby replaced by the following:

'2 MEASUREMENT PRINCIPLE

The emissions from the exhaust of the engine include hydrocarbons, carbon monoxide, oxides of nitrogen and particulates. During a prescribed test cycle the amounts of the above pollutants are examined continuously. The test cycle consists of a number of speed and power modes which span 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. For particulates one sample over the complete test cycle is taken. All values are used to calculate the grams of each pollutant emitted per kilowatt hour, as described in this Annex.'

Section 3.1.4 is hereby replaced by the following:

'3.1.4 a non-insulated and uncooled exhaust system extending at least 0,5 metres past the point where the raw exhaust sample probes are located, and presenting an exhaust backpressure within ± 650 Pa (± 5 mm Hg) of the upper limit at the maximum rated power, as established by the engine manufacturer's sale and service literature for vehicle application;'

Section 3.2 is hereby replaced by the following:

'3.2 **Analytical and sampling equipment**

The system shall comprise one HFID analyser for the measurement of the unburned hydrocarbons (HC), and NDIR analysers for the measurement of carbon monoxide (CO) and carbon dioxide (CO_2, for calculating the dilution ratio, if applicable), a CLA, HCLA or equivalent analyser for the measurement of the oxides of nitrogen (NO_x), and a dilution and filtering system for the measurement of the particulates (PT). Due to the heavy hydrocarbons present in the diesel exhaust, the HFID system must be heated and maintained at a temperature of 453 to 473 K (180 °C to 200 °C).

The accuracy of the analysers must be ± 2,5 % of full-scale deflection or better. The scale of measurement of the analysers must be selected appropriately in relation to the values measured.'

Section 3.3.1 is hereby replaced by the following:

'3.3.1 The system must be free of gas leaks. The design and materials used must be such that the system does not influence the pollutant concentration in the exhaust gas. The following gases may be used:

Analyser	Span gas	Zero gas
CO	CO in N_2	nitrogen or dry purified air
HC	C_3H_8 in air	dry purified air
NO_x	NO in N_2 (1)	nitrogen or dry purified air
CO_2	CO_2 in N_2	nitrogen or dry purified air

(1) The amount of NO_2 contained in this gas must not exceed 5 % of the NO content.'

The last sentence of section 4.2 is replaced by the following:

'Calculation of the HC and PT emissions will include G_{EXH} and V''_{EXH} according to the measuring method used.'

Section 4.3.1.4 is hereby replaced by the following:

'4.3.1.4 Using purified dry air (or nitrogen), the CO, CO_2 (if used) and NO_x analysers are set at zero; dry air is purified for the HC analyser. Using appropriate calibration gases, the analysers shall be reset.'

The new sections 4.3.1.6, 4.3.1.7 and 4.3.1.8 are hereby added after section 4.3.1.5:

'4.3.1.6 Gas meters or flow instrumentation used to determine flow through the particulate filters and to calculate the dilution ratio are calibrated with a standard air flow measurement device upstream of the instrument. This device must conform to the regulations of the National Bureau of Standards of the respective country. The points on the calibration curve relative to the device measurements must be within ± 1,0 % of the maximum operating range or ± 2,0 % of the point, whichever is smaller.

4.3.1.7 When using a partial-flow-dilution system with isokinetic probe, the dilution ratio is checked with the engine running using either the CO_2 or NO_x concentrations in the raw and diluted exhaust.

4.3.1.8 When using a full-flow-dilution system, the total flow is verified by means of a propane check. The gravimetric mass of propane injected into the system is subtracted from the mass measured with the full-flow-dilution system and then divided by the gravimetric mass. Any discrepancy greater than ± 3 % must be corrected.'

The following new section 4.3.4.5 is hereby added after section 4.3.4.4:

'4.3.4.5 The range of the exhaust gas velocity and the pressure oscillations is checked and adjusted according to the requirements of Annex V, if applicable.'

Sections 4.6, 4.6.1 and 4.6.2 are hereby replaced by the following:

'4.6 **Test run**

At least two hours before the test, each filter is placed in a closed but unsealed Petri dish and placed in a weighing chamber for stabilization. At the end of the stabilization period each filter is weighed, and the tare weight recorded. The filter is then stored in the Petri dish which must remain in the weighing chamber until needed for testing, or a sealed filter holder. If the filter is not used within one hour of its removal from the weighing chamber, it must be reweighed before use. During each mode of the test cycle the specified speed must be held to within ± 50 rpm and the specified torque held to within ± 2 % of the maximum torque at the test speed. The fuel temperature at the injection pump inlet must be 306 to 316 K (33 to 43 °C). The governor and fuel system must be adjusted as established by the manufacturer's sales and service literature. The following steps are taken for each test:

4.6.1 Instrumentation and sample probes are installed as required. When using a full-flow-dilution system for exhaust gas dilution, the tailpipe is connected to the system, and the settings of inlet restriction and exhaust backpressure readjusted accordingly. The total flow must be set so as to keep the temperature of the diluted exhaust at or below 325 K (52 °C) immediately before the particulate filters at the mode with the maximum heat flow as determined from exhaust flow and/or temperature;

4.6.2 the cooling system and the full-flow-dilution system, or partial-flow-dilution system, respectively, are started.'

Section 4.6.4 is hereby replaced by the following:

'4.6.4 the torque curve at full load must be determined by experimentation to calculate the torque values for the specified test modes; the maximum permissible power absorbed by engine-driven equipment, declared by the manufacturer to be applicable to the engine type, is taken into account. The dynamometer setting for each engine speed and load are calculated using the formula:

$$S = P_{min} \times \frac{L}{100} + P_{aux}.'.$$

Section 4.6.5 is hereby replaced by the following:

'4.6.5 the emission analysers are set at zero and spanned; the particulate sampling system is started. When using a partial-flow-dilution system, the dilution ratio must be set so as to keep the temperature of the diluted exhaust at or below 325 K (52 °C) immediately before the particulate filters at the mode with the maximum heat flow as determined from exhaust flow and/or temperature;'

Section 4.6.6 is hereby replaced by the following:

'4.6.6 the test sequence is started (see section 4.1). The engine is operated for six minutes in each mode, completing engine speed and load changes in the first minute. The responses of the analysers are recorded on a strip chart recorder for the full six minutes with exhaust gas flowing through the analysers at least during the last three minutes. For particulate sampling, one pair of filters (primary and back-up filters, see Annex V) is used for the complete test procedure. With a partial-flow-dilution system, the product of dilution ratio and exhaust gas flow for each mode must be within ± 7 % of the average of all modes. With the full-flow-dilution system, the total mass flow rate must be kept within ± 7 % of the average of all modes. The sample mass drawn through the particulate filters (M_{SAM}) must be adjusted at each mode to take account of the modal weighting factor and the exhaust or fuel mass flow-rate (see 4.8.3.3). A sampling time of at least 20 seconds is used. Sampling must be conducted as late as possible within each mode. The engine speed and load, intake air temperature and exhaust flow are recorded during the last five minutes of each mode, with the speed and load requirements being met during the time of particulate sampling, but in any case during the last minute of each mode;'

Section 4.7 is hereby replaced by the following:

'4.7 **Evaluation of results**

4.7.1 At the completion of testing the total sample mass through the filters (M_{SAM}) is recorded. The filters are returned to the weighing chamber and conditioned for at least two hours, but not more than 36 hours, and then weighed. The gross weight of the filters is recorded. The particulate mass (P_f) is the sum of the particulate masses collected on the primary and back-up filters.

4.7.2 For the evaluation of the gaseous emissions chart recording, the last 60 seconds of each mode must be located, and the average chart reading for HC, CO and NO_x over this period determined. The concentration of HC, CO and NO_x during each mode is determined from the average chart readings and the corresponding calibration data. However a different type of registration can be used if it ensures an equivalent data acquisition.'

Section 4.8.1 is hereby replaced by the following:

'4.8.1 The final reported test results of the gaseous emissions are derived through the following steps:'

4.8.2 *The first part of section 4.8.2 is hereby replaced by the following:*

'The gaseous emissions are calculated in the following way:

$$\overline{NO_x} = \frac{\Sigma\, NO_{x\,mass} \cdot WF_i}{\Sigma\, (P_i - P_{aux}) \cdot WF_i}$$

$$\overline{CO} = \frac{\Sigma\, CO_{mass} \cdot WF_i}{\Sigma\, (P_i - P_{aux}) \cdot WF_i}$$

$$\overline{HC} = \frac{\Sigma\, HC_{mass} \cdot WF_i}{\Sigma\, (P_i - P_{aux}) \cdot WF_i}$$"

(remainder unchanged)'

The following new sections 4.8.3, 4.8.4 and 4.8.5 are hereby added after section 4.8.2:

'4.8.3 The particulate emissions are calculated in the following way. The general equations of this paragraph apply to both full-flow-dilution and partial-flow-dilution systems:

$$\overline{PT} = \frac{PT_{mass}}{\Sigma\, (P_i - P_{aux}) \cdot WF_i}$$

4.8.3.1 The particulate mass flow is calculated as follows:

$$PT_{mass} = \frac{P_f \cdot \overline{G_{EDF}}}{M_{SAM} \cdot 1\,000}$$

or

$$PT_{mass} = \frac{P_f \cdot \overline{V''_{EDF}}}{V_{SAM} \cdot 1\,000}$$

4.8.3.2 $\overline{G_{EDF}}$, $\overline{V''_{EDF}}$, M_{SAM} and V_{SAM} over the test cycle are determined by summation of the average values of the individual modes:

$$\overline{G_{EDF}} = \Sigma\, G_{EDF,i} \cdot WF_i$$

$$\overline{V''_{EDF}} = \Sigma\, V''_{EDF,i} \cdot WF_i$$

$$M_{SAM} = \Sigma\, M_{SAM,i}$$

$$V_{SAM} = \Sigma\, V_{SAM,i}$$

4.8.3.3 The effective weighting factor WF_E for each mode is calculated in the following way:

$$WF_{E,i} = \frac{M_{SAM,i} \cdot \overline{G_{EDF}}}{M_{SAM} \cdot G_{EDF,i}}$$

or

$$WF_{E,i} = \frac{V_{SAM,i} \cdot \overline{V''_{EDF}}}{V_{SAM} \cdot V''_{EDF,i}}$$

The value of the effective weighting factors must be within ± 0,003 of the weighting factors listed in Annex III, section 4.8.2.

4.8.4 The final reported test results of the particulate emission are derived through the following steps, when using the full-flow-dilution system (Annex V, System 4):

4.8.4.1 The diluted exhaust gas volume flow-rate V''_{TOT} over all modes is determined. $V''_{TOT,i}$ corresponds to $V''_{EDF,i}$ in the general equations in 4.8.3.2.

4.8.4.2 When using a single-dilution system, M_{SAM} is the mass through the sampling filters (GF 1 in Annex V, System 4).

4.8.4.3 When using a double-dilution system, M_{SAM} is the mass through the sampling filters (GF 1 in Annex V, System 4) minus the mass of the secondary dilution air (GF 2 in Annex V, System 4).

4.8.5 The final reported test results of the particulate emission are derived through the following steps, when using the partial-flow-dilution system (Annex V, System 5). Since various types of dilution rate control may be used, different calculation methods for G_{EDF} or V''_{EDF} apply. All calculations are based upon the average values of the individual modes during the sampling period.

4.8.5.1 Fractional sampling type with isokinetic probe.

$$G_{EDF,i} = G_{EXH,i} \cdot q_i$$

or

$$V''_{EDF,i} = V''_{EXH,i} \cdot q_i$$

$$q_i = \frac{G_{DIL,i} + (G_{EXH,i} \cdot r)}{(G_{EXH,i} \cdot r)}$$

or

$$q_i = \frac{V''_{DIL,i} + (V''_{EXH,i} \cdot r)}{(V''_{EXH,i} \cdot r)}$$

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

$$r = \frac{A_P}{A_T}$$

4.8.5.2 Fractional sampling type with CO_2 or NO_x measurement

$$G_{EDF,i} = G_{EXH,i} \cdot q_i$$

or

$$V''_{EDF,i} = V''_{EXH,i} \cdot q_i$$

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

where $Conc_E$ = concentration of the raw exhaust
$Conc_D$ = concentration of the diluted exhaust
$Conc_A$ = concentration of the diluted air

Concentrations measured on a dry basis are converted to a wet basis according to Annex VI.

4.8.5.3 Total sampling type with CO_2-measurement and carbon balance method

$$G_{EDF,i} = \frac{206 \cdot G_{Fuel,i}}{CO_{2D,i} - CO_{2A,i}}$$

where CO_{2D} = CO_2 concentration of the diluted exhaust gases,
CO_{2A} = CO_2 concentration of the diluted 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 CO_2) and derived through the following steps:

$$G_{EDF,i} = G_{EXH,i} \cdot q_i$$

$$q_i = \frac{206 \cdot G_{Fuel,i}}{G_{EXH,i} \cdot (CO_{2D,i} - CO_{2A,i})}$$

4.8.5.4 Total sampling type with mass flow control

$$G_{EDF,i} = G_{EXH,i} \cdot q_i$$

$$q_i = \frac{G_{TOT,i}}{(G_{TOT,i} - G_{DIL,i})},$$

ANNEX IV

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

The following footnote 8 should be added and the reference in the table to 'sulphur content' amended accordingly to 'sulphur content (8)':

'(8) At the request of the vehicle manufacturer, diesel fuel with a 0,05 % mass maximum sulphur content may be used to represent future market fuel quality, both for type-approval and for conformity of production testing.'

ANNEX V

The heading is hereby amended as follows:

'ANALYTICAL AND SAMPLING SYSTEMS'

The first part is hereby replaced by the following:

'1 DETERMINATION OF THE GASEOUS EMISSIONS

Three analytical systems for the determination of the gaseous emissions are described based on the use of:

— HFID analyser for the measurement of hydrocarbons,

— NDIR analyser for the measurement of carbon monoxide,

— CLA, HCLA or equivalent analyser with or without heated sampling line for measurement of nitrogen oxides.'

The following new section 2 is hereby added after Figure 3:

'2 DETERMINATION OF THE PARTICULATE EMISSIONS

The determination of the particulate emissions requires a dilution system capable of maintaining the temperature of the diluted exhaust gas at or below 325 K (52 °C), a particulate sampling system, specified particulate sampling filters, and a microgram balance which shall be placed in an air conditioned weighing chamber. Two principally different dilution and sampling systems (full-flow-dilution system and partial-flow-dilution system) are described. The specification of filters, the balance and the weighing chamber apply to both systems.

2.1 **Particulate sampling filters**

2.1.1 Fluorocarbon-coated glass fibre filters or fluorocarbon-based (membrane) filters are required.

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

2.1.3 The diluted exhaust gases are sampled by a pair of filters placed in series (one primary and one back-up filter) during the test sequence. The back-up filter must be located no more than 100 mm downstream of, and must not be in contact with, the primary filter.

2.1.4 The recommended minimum loading on a primary 47 mm filter (37 mm stain diameter) is 0,5 milligrams, on a primary 70 mm filter (60 mm stain diameter) 1,3 milligrams.

Equivalent minimum loadings of 0,5 mg/1 075 mm^2 (i. e. mass/stain area) are recommended for other filters.

2.2 **Weighing chamber and microgram balance specifications**

2.2.1 The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed must be maintained to within ± 6 K of a set point between 293 K and 303 K (20 ° and 30 °C) during all filter conditioning and weighing. The relative humidity must be maintained to within ± 10 % relative humidity of a set point between 35 % and 55 %.

2.2.2 The chamber (or room) environment must be free of any ambient contaminates (such as dust) that could settle on the particulate filters during their stabilization. At least two unused reference filters must be weighed within four hours of, but preferably at the same time as, the sample filter weighings. If the average weight of the reference filter changes between sample filter weighings by more than ± 6,0 % of the recommended minimum filter loading, then all sample filters are discarded and the emissions tests repeated.

In case of a weight change between − 3,0 % and − 6,0 % the manufacturer has the option of either repeating the test or adding the average amount of weight loss to the net weight of the sample. In case of a weight change between + 3,0 % and + 6,0 % the manufacturer has the option of either repeating the test or accepting the measured sample filter weight values. If the average weight changes by not more than ± 3,0 %, the measured sample filter weights are used. The reference filters must be the same size and material as the sample filters, and be changed at least once a month.

2.2.3 The microgram balance used to determine the weights of all filters must have a precision (standard deviation) of 2 % and a readability of 1 % of the recommended minimum filter loading.

2.3 **Additional specifications**

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 minimize deposition or alteration of the particulates. All parts must be made of electrically conductive material, that does not react with exhaust gas components, and must be electrically grounded, to prevent electrostatic effects.

System 4 (full-flow-dilution system)

A particulate sampling system is described based upon the dilution of the total exhaust using the CVS (Constant Volume Sampling) concept. Figure 4 is a schematic drawing of this system. The total volume of the mixture of exhaust and dilution air must be measured, and a sample must be collected for analysis.

The mass of particulate emissions is subsequently determined from the mass sample collected on a pair of filters, the sample flow and the total flow of dilution air and exhaust gas over the test period. Either a PDP or a CFV and a single-dilution or a double-dilution system may be used. Gaseous emissions must not be determined with a CVS system. The components must meet the following requirements:

EP *Exhaust pipe*

The exhaust pipe length from the exit of the engine exhaust manifold or turbocharger outlet to the dilution tunnel is required to be not more than 10 m. If the system exceeds 4 m in length, then all tubing in excess of 4 m must be insulated. 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 (300 °C).

PDP *Positive Displacement Pump*

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 pressure measured with the operating CVS system must remain within ± 1,5 kPa of the static pressure measured without connection to the CVS at identical engine speed and load. The gas mixture temperature immediately ahead of the PDP must be within ± 6 K of the average operating temperature observed during the test, when no flow computation is used.

CFV *Critical Flow Venturi*

CFV measures total diluted flow by maintaining the flow at choked conditions (critical flow). The static pressure variations in the raw exhaust conform to the specifications detailed for the PDP. The gas mixture temperature immediately ahead of the CFV must be within ± 11 K of the average operating temperature observed during the test, when no flow computation is used.

HE *Heat exchanger* (optional, if EFC is used)

The heat exchanger must be of sufficient capacity to maintain the temperature within the limits required above.

EFC *Electronic flow computation* (optional, if HE is used)

If the temperature at the inlet to either PDP or CFV is not kept constant, a flow computation system is required for continuous measurement of the flow rate.

PDT *Primary dilution tunnel*

The primary dilution tunnel must be:

— small enough in diameter to cause turbulent flow (Reynolds Number greater than 4 000) and of sufficient length to cause complete mixing of the exhaust and dilution air,

— at least 460 mm in diameter with a single-dilution system or at least 200 mm in diameter with a double-dilution system.

The engine exhaust must be directed downstream at the point where it is introduced into the primary dilution tunnel, and thoroughly mixed.

SDS *Single-dilution system*

The single-dilution method collects a sample from the primary tunnel, and then passes this sample through the sampling filters. The flow capacity of the PDP or CFV must be sufficient to maintain the diluted exhaust at a temperature of no more than 325 K (52 °C) immediately before the primary particulate filter.

DDS *Double-dilution system*

The double-dilution method collects a sample from the primary tunnel, and then transfers this sample to a secondary dilution tunnel where the sample is further diluted. The doubly-diluted sample is then passed through the sampling filters. The flow capacity of the PDP or CFV must be sufficient to maintain the diluted exhaust stream in the PDP 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.

PSP *Particulate sample probe* (for SDS only)

The particulate sample probe must:

— be installed facing upstream at a point where the dilution air and exhaust gas are well mixed (i.e., on the dilution tunnel centre line, approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel),

— have an inside diameter of at least 12 mm.

The distance from the probe tip to the filter holder must not exceed 1 020 mm. The sample probe must not be heated.

PTT *Particulate transfer tube* (for DDS only)

The particulate transfer tube must be:

- installed facing upstream at a point where the dilution air and exhaust gas are well mixed (i. e., on the dilution tunnel centreline, approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel),
- 12 mm minimum inside diameter,
- not more than 910 mm from inlet plane to exit plane.

The particulate sample must exit on the centre line of the secondary dilution tunnel and point downstream. The transfer tube must not be heated.

SDT *Secondary dilution tunnel* (for DDS only)

The secondary dilution tunnel must have a minimum diameter of 75 mm, and 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 must be located within 300 mm of the exit of the secondary dilution tunnel.

DAF *Dilution air filter*

The dilution air may be filtered at the dilution air inlet, must have a temperature of 298 K (25 °C) ± 5 K, and may be sampled to determine background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.

FH *Filter holder(s)*

For primary and back-up filters one filter housing or separate filter housings may be used. The requirements of Annex V, section 2.1.3 must be be met. The filter holders must not be heated.

SP *Sample pump*

The particulate sample pump must be located sufficiently distant from the tunnel so that the inlet gas temperature is maintained constant (± 3 K), if flow computation is not used. The sample pump(s) must be running throughout the complete test procedure. A by-pass system is used for passing the sample through the sampling filters.

DP *Dilution air pump* (for DDS only)

The dilution air pump must be located so that the secondary dilution air is supplied with a temperature of 298 K (25 °C) ± 5 K.

GF 1 *Gas flowmeter* (particulate sample flow)

The gas meter or flow instrumentation must be located sufficiently distant from the tunnel so that the inlet gas temperature remains constant (± 3 K), if flow computation is not used.

GF 2 *Gas flowmeter* (dilution air, for DDS only)

The gas meter or flow instrumentation must be located so that the inlet gas temperature remains at 298 K (25 °C) ± 5 K.

System 5 (Partial-flow-dilution system)

A particulate sampling system is described based upon the dilution of part of the exhaust gas. Figure 5 is a schematic drawing of this system. The mass of particulate emissions is determined from a mass sample collected on a pair of filters and from the dilution ratio, sample flow and exhaust gas flow or fuel flow over the test period. The calculation of the dilution ratio depends upon the type of system used. Only a fraction of the diluted exhaust (fractional sampling type) or all of the diluted exhaust (total sampling type) may be sampled. All types described herein are equivalent as long as they comply with the requirements of Annex III, sections 4.6.6 and 4.8.3.3. The components must meet the following requirements:

EP *Exhaust pipe*

For types without isokinetic probe, it is necessary to have a straight pipe of a length of 6 pipe diameters upstream and 3 pipe diameters downstream of the tip of the probe.

For a type with isokinetic probe, the exhaust pipe must be free of elbows, bends and sudden diameter changes for at least 15 pipe diameters upstream and 4 pipe diameters downstream of the tip of the probe. The exhaust gas velocity at the sampling zone must be higher than 10 m/s and lower than 200 m/s. Pressure oscillations of the exhaust gas must not exceed ± 500 Pa on average. Any steps to reduce pressure oscillations beyond using a chassis-type exhaust system (including muffler) must not alter engine performance nor cause the deposition of particulate.

PR *Sampling probe*

The probe must be installed facing upstream on the exhaust pipe centre line at a point where the above flow conditions are met. The minimum diameter ratio between exhaust pipe diameter and probe diameter must be 4.

ISP *Isokinetic sampling probe* (optional, if EGA or mass flow control is used)

The isokinetic sampling probe must be designed to provide a proportional sample of the raw exhaust gas. To that purpose, ISP replaces PR as described above and has to be connected to a differential pressure transducer and a speed controller, to obtain isokinetic flow at the probe tip. The inside diameter must be at least 12 mm.

EGA *Exhaust gas analyser* (optional, if ISP or mass flow control is used)

CO_2 or NO_x analysers may be used (with carbon balance method CO_2 only). The analysers must be calibrated in the same way as the analysers for the measurement of the gaseous pollutants. One or more analysers may be used for the determination of the concentration differences.

TT *Transfer tube*

The particulate sample transfer tube must be:

— heated or insulated so that the gas temperature in the transfer tube be not below 423 K (150 °C). If the gas temperature is below 423 K (150 °C) it must not be below the exhaust gas temperature,

— equal to or greater in diameter than the probe diameter, but not more than 25 mm in diameter,

— not more than 1 000 mm from inlet plane to exit plane.

The particulate sample must exit on the centre line of the dilution tunnel and point downstream.

SC *Speed controller* (for ISP only)

A pressure 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. The adjustment is done by controlling the speed of the suction blower (SB) and keeping the speed of the pressure blower (PB) constant during each mode. The remaining error in the pressure control loop must not exceed ± 0,5 % of the measuring range of the pressure transducer (DPT). The pressure oscillations in the dilution tunnel must not exceed ± 250 Pa on average.

DPT *Differential pressure transducer* (for ISP only)

The differential pressure transducer must have a range of the order of ± 500 Pa.

FC 1 *Flow controller* (dilution air)

A flow controller is necessary to control the dilution air mass flow. It may be connected to the exhaust flow or fuel flow and/or CO_2 differential signal. When using a pressurized air supply, FC 1 directly controls the air flow.

GF 1 *Gas flowmeter* (dilution air)

The gas meter or flow instrumentation must be located so that the inlet gas temperature remains at 298 (25 °C) ± 5 K.

SB *Suction blower* (for fractional sampling type only)

PB *Pressure blower*

To control the dilution air mass flow-rate, PB must be connected to FC 1. Exhaust flow or fuel flow and/or CO_2 differential signals may be used as command signals. PB is not required, when using a pressurized air supply.

DAF *Dilution air filter*

The dilution air may be filtered at the dilution air inlet, must have a temperature of 298 K (25 °C) ± 5 K, and may be sampled to determine background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.

DT *Dilution tunnel*

The dilution tunnel must be:

— small enough in diameter to cause turbulent flow (Reynolds Number greater than 4 000) and of sufficient length to cause complete mixing of the exhaust and dilution air,

— at least 25 mm in diameter for the total sampling type,

— at least 75 mm in diameter for the fractional sampling type.

The engine exhaust must be directed downstream at the point where it is introduced into the dilution tunnel, and thouroughly mixed with the dilution air by means of a mixing orifice. For fractional systems, the mixing quality must be checked after introduction into service by means of a CO_2-profile of the tunnel with the engine running (at least six equally spaced measuring points).

PSS *Particulate sampling system*

The particulate sampling system must be configured so as to collect a sample from the dilution tunnel and to pass this sample through the sampling filters (fractional sampling type), or to pass all of the diluted exhaust through the sampling filters (total sampling type). In order to avoid any impact on the control loops, it is recommended that the sample pump be running throughout the complete test procedure. A by-pass system with a ball valve between the sample probe and the filter holder must 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 corrected within less than three seconds.

PSP *Particulate sample probe* (for fractional sampling type only)

The particulate sample probe must:

— be installed facing upstream at a point where the dilution air and exhaust gas are well mixed (i. e., on the dilution tunnel centre line, approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel),

— have an inside diameter of at least 12 mm.

PTT *Particulate transfer tube*

The particulate transfer tube must not be heated and must not exceed 1 020 mm in length:

— for the fractional sampling type from the probe tip to the filter holder,

— for the total sampling type from the end of the dilution tunnel to the filter holder.

FH *Filter holder(s)*

For primary and back-up filters one filter housing or separate filter housings may be used. The requirements of Annex V, section 2.1.3 must be met. The filter holders must not be heated.

SP *Sample pump*

The particulate sample pump must be located sufficiently distant from the tunnel so that the inlet gas temperature is maintained constant (± 3 K), if flow computation is not used.

FC 2 *Flow controller* (particulate sample flow, optional)

A flow controller may be used, in order to improve accuracy of the particulate sample flow-rate.

GF 2 *Gas flowmeter* (particulate sample flow)

The gas meter or flow instrumentation must be located sufficiently distant from the tunnel so that the inlet gas temperature remains constant (± 3 K), if flow computation is not used.

BV *Ball valve*

The ball valve must have a diameter no less than the sampling tube and a switching time of less than 0,5 seconds.'

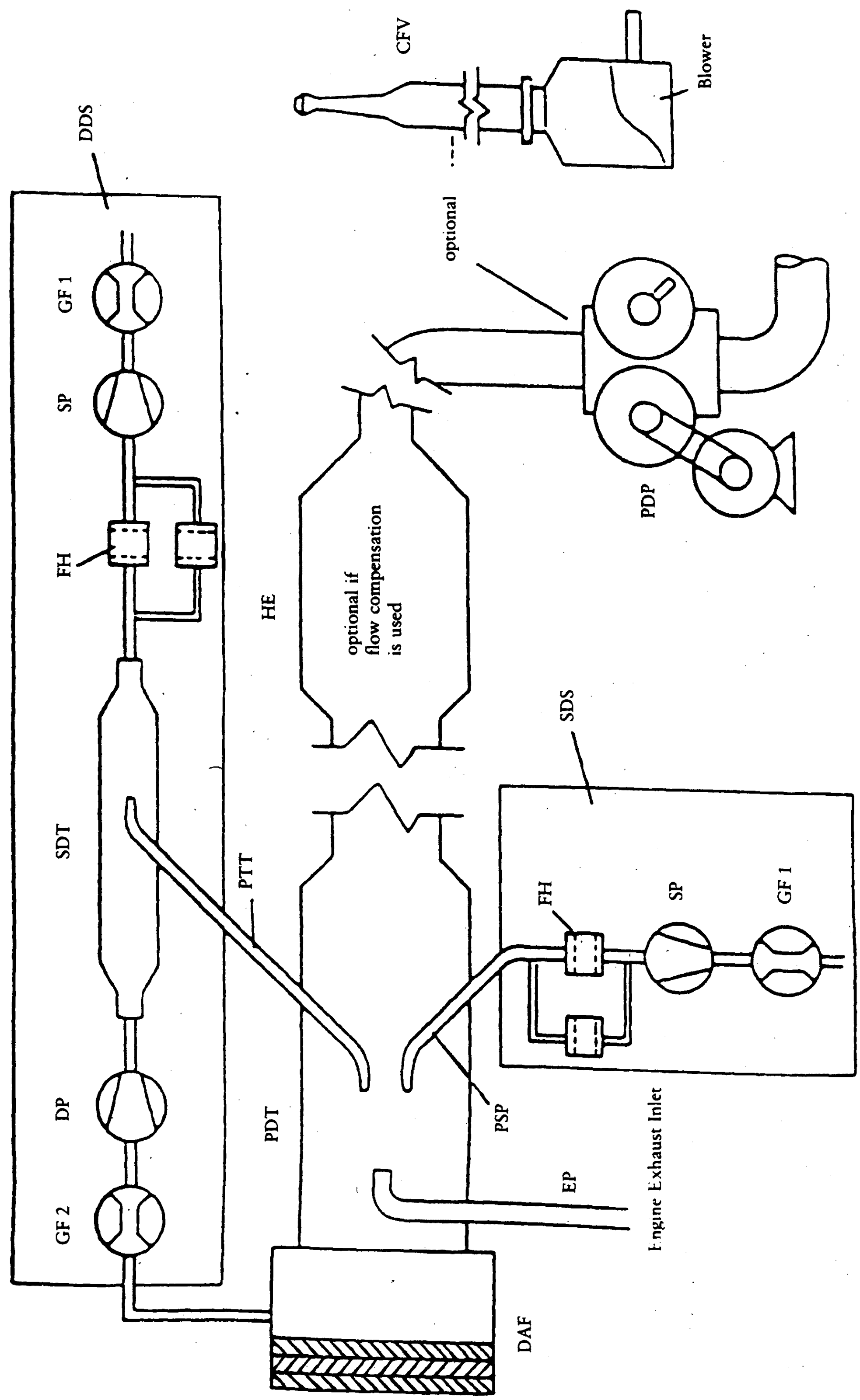
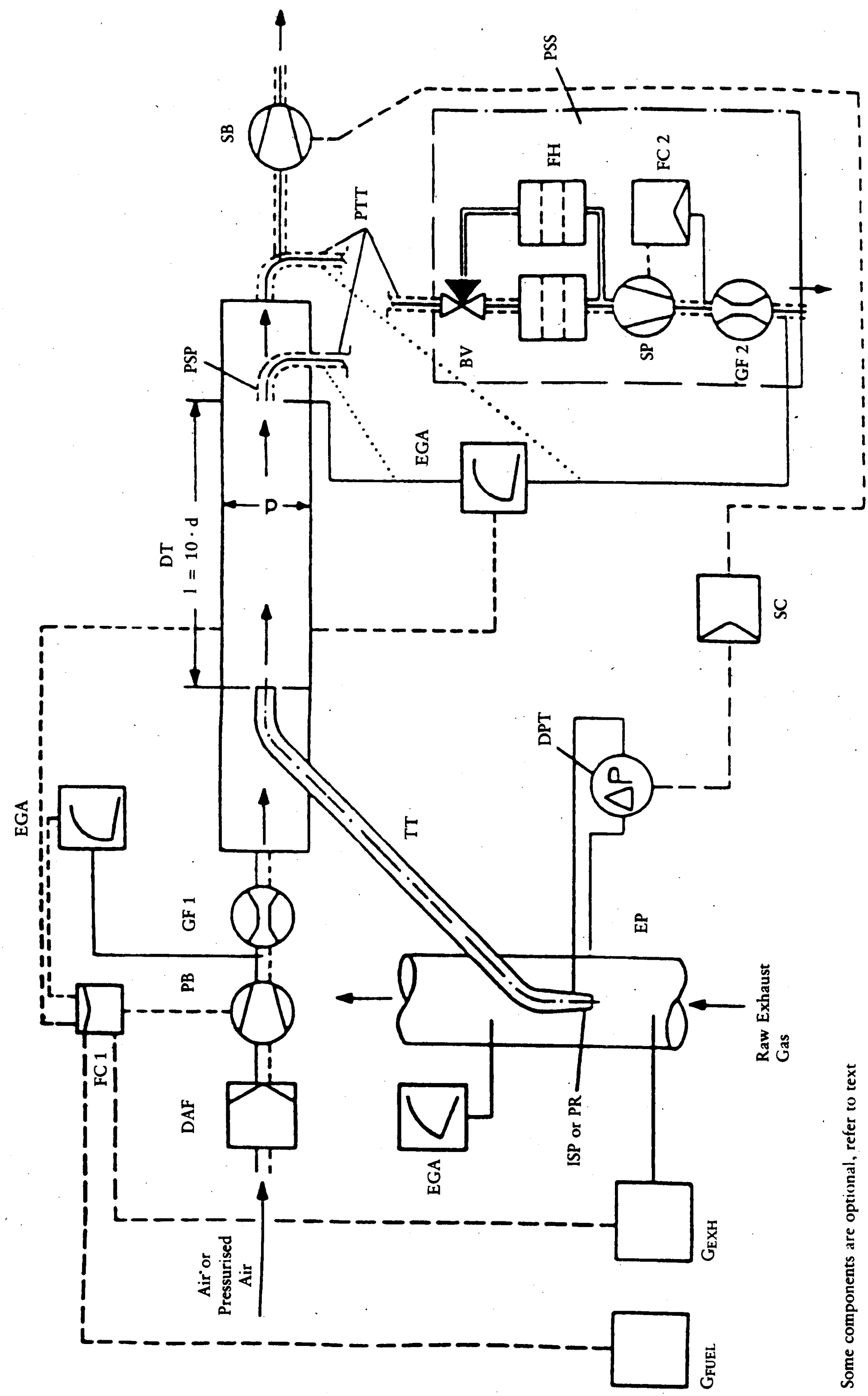


Figure 4

Full-flow-dilution system



Some components are optional, refer to text

Figure 5

Partial-flow-dilution system

ANNEX VIII

(MODEL)

EEC TYPE-APPROVAL CERTIFICATE

In the Appendix, section 1.4 is hereby replaced by the following:

'1.4. *Emission levels*

$\overline{CO}$ .... g/kWh		determined by a full/partial flow system (1).'
$\overline{HC}$ .... g/kWh		
$\overline{NO}$ .... g/kWh		
$\overline{PT}$ .... g/kWh		