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
(88/77/EEC)

91/452/EEC

(OJ No L 36, 9. 2. 1988, p. 33.)

Amended by:

	Official Journal No	page	date
Council Directive of 1 October 1991	L 295	1	25. 10. 1991
Agreement on the European Economic Area (2 94 A 0103(52))	L 1	263	3. 1. 1994
Protocol adjusting the Agreement on the European Economic Area (2 94 A 0103(73))	L 1	572	3. 1. 1994

COUNCIL DIRECTIVE
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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
(88/77/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 the technical requirements which motor vehicles must satisfy pursuant to national laws relate, *inter alia*, to the emission of gaseous pollutants from diesel engines for use in vehicles;

Whereas those requirements differ from one Member State to another; whereas these differences could restrict the free circulation of the products in question;

whereas (SIC! Whereas) it is therefore necessary that all the Member States adopt the same requirements either in addition to or in place of their existing rules, in order, in particular, to permit the implementation, for each vehicle type, of the EEC type-approval, which was the subject of Council Directive 70/156/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers [(4)], as last amended by Directive 87/403/EEC [(5)];

Whereas it is desirable to follow the technical requirements adopted by the United Nations Economic Commission for Europe in its Regulation No 49 (uniform provisions concerning the approval of diesel engines with regard to the emission of gaseous pollutants), which is annexed to

(1) OJ No C 193, 31. 7. 1986, p. 3.
(2) Position of Parliament on 18 November 1987 (OJ No C 345, 21. 12. 1987, p. 61).
(3) OJ No C 333, 29. 12. 1986, p. 17.
(4) OJ No L 42, 23. 2. 1970, p. 1.
(5) OJ No L 220, 8. 8. 1987, p. 44.

the Agreement of 20 March 1958 concerning the adoption of uniform conditions of approval and reciprocal recognition of approval for motor vehicle equipment and parts;

Whereas the Commission has undertaken to submit proposals to the Council, not later than the end of 1988, regarding a further reduction of the limit values for the three pollutants which are the subject of this Directive and the fixing of limit values for particulate emissions,

HAS ADOPTED THIS DIRECTIVE:

Article 1

88/77/EEC

For the purposes of this Directive:

— 'vehicle' means any vehicle propelled by a diesel engine, intended for use on the road, with or without bodywork, having at least four wheels and a maximum design speed exceeding 25 km/h, with the exception of vehicles of category M_1 as defined in section 0.4 of Annex I to Directive 70/156/EEC, having a total mass not exceeding 3,5 tonnes, and vehicles which run on rails, agricultural tractors and machines and public works vehicles,

— 'diesel-engine type' means a diesel engine for which type-approval of a separate technical unit within the meaning of Article 9a of Directive 70/156/EEC may be granted.

Article 2

1. From 1 July 1988, no Member State may, on grounds relating to the gaseous 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 Directive 70/156/EEC, 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 this Directive are satisfied.

2. From 1 July 1988, Member States may, on grounds relating to gaseous pollutants emitted from an engine:

— refuse to grant national type-approval for a type of vehicle propelled by a diesel engine, or

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

if the requirements of the Annexes to this Directive are not satisfied.

3. Until 30 September 1990, paragraph 2 shall not apply to types of vehicles propelled by a diesel engine, and to diesel-engine types if the diesel engine is described in the Annex to a type approval certificate granted before that date in accordance with Directive 72/306/EEC.

4. From 1 October 1990 Member States may, on grounds relating to gaseous pollutants emitted from an engine: 88/77/EEC

— prohibit the registration, sale, entry into service and use of new vehicles, propelled by a diesel engine,

or

— prohibit the sale and use of new diesel engines

if the requirements of the Annexes to this Directive are not satisfied.

Article 3

1. The Member State which has granted type-approval of a type of diesel engine shall take the necessary measures to ensure that it is informed of any modification of a part or characteristic referred to in section 2.3 of Annex I. The competent authorities of that Member State shall decide whether fresh tests should be carried out on the modified engine and a fresh report drawn up. Where the tests reveal failure to comply with this Directive, the modification shall not be approved.

2. The Member State which has granted type-approval of a vehicle type in respect of its diesel engine shall take the necessary measures to ensure that it is informed of any modification of such vehicle type as regards the engine installed. The competent authorities of that Member State shall decide whether after such a modification, measures in application of Directive 70/156/EEC, especially of Article 4 or of Article 6 thereof, must be taken.

Article 4

The modifications necessary for adapting the requirements of the Annexes so as to take account of technical progress shall be adopted in accordance with the procedure laid down in Article 13 of Directive 70/156/EEC.

Article 5

1. Member States shall bring into force the laws, regulations, and administrative provisions necessary to comply with the Directive by 1 July 1988. They shall forthwith inform the Commission thereof.

2. As soon as this Directive has been notified, Member States shall also ensure that the Commission is informed, in sufficient time for it to submit its comments of any draft major laws, regulations or administrative provisions which they intend to adopt in the field covered by this Directive.

Article 6

Not later than the end of 1988, the Council will consider, on the basis of a proposal from the Commission, a further reduction of the limit values for the three pollutants concerned by this Directive and the fixing of limit values for particulate emissions.

Article 7

This Directive is addressed to the Member States.

88/77/EEC

ANNEX I | 88/77/EEC

SCOPE, DEFINITIONS AND ABBREVATIONS, APPLICATION FOR EEC TYPE-APPROVAL SPECIFICATIONS AND TESTS AND CONFORMITY OF PRODUCTION

91/542/EEC

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].

88/77/EEC

2. DEFINITIONS AND ABBREVIATIONS

For the purposes of this Directive:

91/542/EEC

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.

88/77/EEC

2.2. '*diesel engine*' means an engine which works on the compression-ignition principle;

2.3. '*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;

91/542/EEC

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 ûC).

88/77/EEC

2.5. '*net power*' means the power in EEC kW obtained on the test bench at the end of the crankshaft, or its equivalent, measured in accordance with the EEC method of measuring power as set out in Directive 80/1269/EEC [3];

[1] OJ No L 76, 6. 4. 1970, p. 1.
[2] OJ No L 242, 30. 8. 1970, p. 1.
[3] OJ No L 375, 31. 12. 1980, p. 46.

2.6.	‘*rated speed*’ means the maximum full load speed allowed by the governor as specified by the manufacturer in his sales and service literature;	88/77/EEC
2.7.	‘*per cent load*’ means the fraction of the maximum available torque at an engine speed;	
2.8.	‘*intermediate speed*’ means the speed corresponding to the maximum torque value if such speed is within the range of 60 to 75 % of rated speed; in other cases it means a speed equal to 60 % of rated speed;	
2.9.	**Abbreviations and units**	91/542/EEC

All volumes and volumetric flow-rates must be calculated at 273 K (0 ûC) 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	particular 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 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.

3. APPLICATION FOR EEC TYPE-APPROVAL — 88/77/EEC

3.1. **Application for EEC type-approval for a type of engine as a separate technical unit**

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. — 91/542/EEC

3.1.2. It shall be accompanied by the undermentioned documents in triplicate and the following particulars: — 88/77/EEC

3.1.2.1. a description of the engine type comprising the particulars referred to in Annex II to this Directive which conform to the requirements of Article 9a of Directive 70/156/EEC.

3.1.3. An engine conforming to the 'engine type' characteristics described in Annex II shall be submitted to the technical service responsible for conducting the approval tests defined in section 6. 88/77/EEC

3.2. **Application for EEC type-approval for a vehicle type in respect of its engine**

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. 91/542/EEC

3.2.2. It shall be accompanied by the undermentioned documents in triplicate and the following particulars: 88/77/EEC

3.2.2.1. a description of the vehicle type and of engine-related vehicle parts comprising the particulars referred to in Annex II, along with the documentation required in application of Article 3 of Directive 70/156/EEC,

or

3.2.2.2. 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 EEC Type-Approval Certificate (Annex VIII) for the engine 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. EEC TYPE-APPROVAL

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

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 EEC type-approval number preceded by the distinctive letter(s) of the country granting EEC type-approval [1].

5.2. These marks must be clearly legible and indelible.

[1] B = Belgium, D = Federal Republic of Germany, DK = Denmark, E = Spain, F = France, GR = Greece, I = Italy, IRL = Ireland, L = Luxembourg, NL = Netherlands, P = Portugal, UK = United Kingdom.

6. SPECIFICATIONS AND TESTS — 88/77/EEC

6.1. **General** — 91/542/EEC

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.

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.

6.2.1. The mass of the carbon monoxide, the mass of the hydrocarbons and the mass of the oxides of nitrogen obtained shall 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.

7. INSTALLATION ON THE VEHICLE | 88/77/EEC

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 VIII;

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

7.1.3. maximum power absorbed by the engine-driven equipment shall not exceed the maximum permissible power specified for the type-approved engine in Annex VIII.

8. CONFORMITY OF PRODUCTION

8.1. Every engine bearing an EEC type-approval number pursuant to this Directive shall conform to the engine-type approved.

8.2. In order to verify conformity as prescribed in section 8.1, an engine bearing an EEC type-approval number shall be taken from the series.

8.3. As a general rule, conformity of the engine with the approved type shall be verified on the basis of the description given in the type-approval certificate and its annexes and, if necessary, an engine shall be subjected to the test referred to in section 6.2.

8.3.1. For verifying the conformity of the engine in a test, the following procedure is adopted:

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: | 91/542/EEC

	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.

8.3.1.2. If the engine taken from the series does not satisfy the requirements of section 8.3.1.1., the manufacturer may ask for measurements to be performed on a sample of engines taken from the series and including the engine originally taken. The manufacturer shall determine the size (n) of the sample, in agreement with the technical service. Engines other than the engine originally taken shall be subjected to a test. The arithmetical mean (x) of the results obtained with the sample shall then be determined for each pollutant. The production of the series shall then be deemed to conform if the following condition is met: — 88/77/EEC; 91/542/EEC

$$\bar{x} + k S \le L$$ [1]

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: — 91/542/EEC

n	2	3	4	5	6	7	8	9	10
k	0,973	0,613	0,489	0,421	0,376	0,342	0,317	0,296	0,279
n	11	12	13	14	15	16	17	18	19
k	0,265	0,253	0,242	0,233	0,224	0,216	0,210	0,203	0,198

if $n \geq 20$, $k = \frac{0,860}{\sqrt{n}}$

8.3.2. The technical service responsible for verifying the conformity of production shall carry out tests on engines which have been run-in (Sic! run in) partially or completely, according to the manufacturer's specifications.

1 $S^2 = \sum \frac{(x - \bar{x})^2}{(n - 1)}$, where x is any one of the individual results obtained with the sample n.

ANNEX II 91/542/EEC

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)

88/77/EEC

Vehicle/engine type: . . . .

0. **General**

0.1. Make (name of undertaking): . . . .

0.2. Type and commercial description (mention any variants): . . . .
. . . .

0.3. Manufacturer's type coding as marked on the vehicle/separate technical unit/component: . . . .

0.4. Category of vehicle (if applicable): . . . .

0.5. Name and address of manufacturer: . . . .
. . . .

0.6. Name and address of manufacturer's authorized representative (if any): . . . .
. . . .

Attachments

1. Essential characteristics of the engine and information concerning the conduct of test.

2. Characteristics of the engine-related vehicle parts (if applicable).

3. Photographs of the engine and, if applicable, of the engine compartment.

4. List further attachments if any.

Date, File

Appendix 1

ESSENTIAL CHARACTERISTICS OF THE 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. Bore: . . . . mm

1.5. Stroke: . . . . mm

1.6. Number and layout of cylinders: . . . .

1.7. Engine capacity: . . . . cm^3

1.8. Volumetric compression ratio [3]: . . . .

1.9. Drawing(s) of combustion chamber and piston crown: . . . .

1.10. Minimum cross-sectional area of inlet and outlet ports: . . . .

1.11. *Cooling system*

1.11.1. L i q u i d

1.11.1.1. Nature of liquid: . . . .

1.11.1.2. Circulating pump(s): yes/no (2)

1.11.1.3. Characteristics or make(s) and type(s) (if applicable): . . . .

1.11.1.4. Drive ratio(s) (if applicable): . . . .

1.11.2. A i r

1.11.2.1. Blower: yes/no (2)

1.11.2.2. Characteristics or make(s) and type(s) (if applicable): . . . .

1.11.2.3. Drive ratio(s) (if applicable): . . . .

1.12. *Temperature permitted by the manufacturer*

1.12.1. Liquid cooling: Maximum temperature at outlet: .
. . . . K

1.12.2. Air cooling:

Reference point: . . . .

Maximum temperature at reference point: . . . . . .
. . . .
K

1.12.3. Maximum charge air outlet temperature of the inlet intercooler (if applicable): . . . . K

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[1] In the case of non-conventional engines and systems, particulars equivalent to those referred to here shall be supplied by the manufacturer.

[2] Stike out what does not apply.

[3] Specify the tolerance.

1.12.4.	Maximum exhaust temperature at the point in the exhaust pipe(s) adjacent to the outer flange(s) of the exhaust manifold(s): . . . . K	88/77/EEC
1.12.5.	Fuel temperature: min. . . . . K, max. . . . . K	
1.12.6.	Lubricant temperature: min. . . . . K, max. . . . . K	
1.13.	*Pressure charger: yes/no* (2)	
1.13.1.	Make:	
1.13.2.	Type:	
1.13.3.	Description of the system (e.g. max. charge pressure, wastegate, if applicable):	
1.13.4.	Intercooler: yes/no [1]	
1.14.	*Intake system* Minimum and/or maximum allowable intake depression (if applicable) at rated engine speed and at 100 % load: . . . . kPa	
1.15.	*Exhaust system* Maximum allowable exhaust back pressure at rated engine speed and at 100 % load: . . . . kPa	
2.	**Additional anti-pollution devices** (if any, and if not covered by another heading) Description and/or diagram(s) . . .	91/542/EEC
3.	**Fuel feed**	88/77/EEC
3.1.	*Feed pump* Pressure [2]: . . . . kPa or characteristic diagram (2):	
3.2.	*Injection system*	
3.2.1.	Pump	
3.2.1.1.	Make(s):	
3.2.1.2.	Type(s):	
3.2.1.3.	Delivery: . . . . mm^3 (2) per stroke or cycle at pump speed of . . . . rpm at full injection, or characteristic diagram (1) (2): . . . . Mention the method used: On engine/on pump bench (1)	
3.2.1.4.	Injection advance	
3.2.1.4.1.	Injection advance curve (2):	
3.2.1.4.2.	Timing (2):	

1 Strike out what does not apply.
2 Specify the tolerance.

3.2.2. Injection piping

3.2.2.1. Length: .... mm

3.2.2.2. Internal diameter: .... mm

3.2.3. Injector(s)

3.2.3.1. Make(s): ....

3.2.3.2. Type(s): ....

3.2.3.3. 'Opening pressure': .... kPa (1)

or characteristic diagram[1] [2](2): ....

3.2.4. Governor

3.2.4.1. Make(s): ....

3.2.4.2. Type(s): ....

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

3.2.4.4. Maximum no-load speed: .... rpm

3.2.4.5. Idling speed: .... rpm

3.3. *Cold start system*

3.3.1. Make(s):

3.3.2. Type(s):

3.3.3. Description: ....

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 (1)

5. **Engine-driven equipment**

Maximum permissible power absorbed by the engine-driven equipment as specified in and under the operating conditions of Directive 80/1269/EEC [3], Annex I, section 5.1.1, at each engine speed as defined in section 4.1 of Annex III to this Directive:

Idle: .... kW; Intermediate: .... kW; Rated: .... kW

6. **Additional information on test conditions**

6.1. *Lubricant used*

6.1.1. Make: ....

---

1 Strike out what does not apply.
2 Specify the tollerance.
3 OJ No L 375 du 31. 12. 1980, p. 46.

6.1.2. Type: . . . .

(State percentage of oil in mixture if lubricant and fuel are mixed): . . . .

6.2. *Engine-driven equipment* (as specified in section 5) (if applicable)

6.2.1. Enumeration and identifying details: . . . .

6.2.2. Power absorbed at various indicated engine speeds:

Equipment	Power absorbed (kW) at various speeds		
	Idle	Interme-diate	Rated
Total			

6.3. *Dynamometer settings (kW)*

Per cent load	Engine speed		
	Idle	Interme-diate	Rated
10	—		
25	—		
50	—		
75	—		
100	—		

7. **Engine performances**

7.1. *Engine speeds* [1]

Idle: . . . . rpm

Intermediate: . . . . rpm

Rated: . . . . rpm

[1] Specify the tollerance.

7.2. *Engine power* (measured in accordance with the provisions of Directive *80/1269/EEC)* 88/77/EEC

	Engine speed		
	Idle	Inter-mediate	Rated
Maximum power measured on test (kW (a)) Total power absorbed by engine-driven equipment as per section 6.2.2 (kW (b))			
Gross engine power (kW (c)) Maximum permissible power absorbed as per section 5 (kW (d))			
Minimum net engine power (kW (e))			
c = a+b; e = c − d			

Appendix 2

CHARACTERISTICS OF THE ENGINE-RELATED VEHICLE PARTS

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

2. Exhaust system back pressure at rated engine rpm and at 100 % load: .... kPa

3. Power absorbed by the engine-driven equipment as specified in and under the operation conditions of Directive 80/1269/EEC, Annex I, section 5.1.1, at each engine speed as defined in section 4.1 of Annex III to this Directive.

Equipment	Power absorbed (kW) at various engine speeds		
	Idle	Interme-diate	Rated
Total			

ANNEX III 88/77/EEC

TEST PROCEDURE

1. INTRODUCTION

1.1. This Annex describes the method of determining emissions of gaseous and particulate pollutants from the engine tested. 91/542/EEC

1.2. The test shall be carried out with the engine mounted on a test bench and connected to a dynamometer. 88/77/EEC

2. MEASUREMENT PRINCIPLE 91/542/EEC

The emission 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 polluants 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 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 desribed in this Annex.

3. EQUIPMENT 88/77/EEC

3.1. **Dynamometer and engine equipment**

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

3.1.1. an engine dynamometer with adequate characteristics to perform the test cycle described in section 4.1;

3.1.2. measuring instruments for speed, torque, fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and inlet manifold depression, exhaust gas temperature, air inlet temperature, atmospheric pressure, humidity and fuel temperature. The accuracy of these instruments shall satisfy the EEC method of measuring the power of the internal combustion engines of road vehicles;

3.1.3.	an engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures for the duration of the prescribed engine tests;	88/77/EEC
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;	91/542/EEC
3.1.5.	an engine air inlet system presenting an air inlet restriction within ± 300 Pa (30 mm H_2O) of the upper limit for the engine operating condition which results in maximum air flow, as established by the engine manufacturer for an air cleaner, for the engine being tested.	88/77/EEC
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 (NOx), 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 ûC to 200 ûC). 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.	91/542/EEC
3.3.	**Gases**	88/77/EEC
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:	91/542/EEC

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 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.

3.4. **Support gases** 88/77/EEC

3.4.1. The following gases must be available if necessary for operation:

3.4.2. Purified nitrogen (purity ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO2, ≤ 0,1 ppm NO);

3.4.3. Purified oxygen (purity ≥ 99,5 % vol O_2):

3.4.4. Hydrogen mixture (40 ± 2 % hydrogen, balance nitrogen or helium) (purity ≤ 1 ppm C, ≤ 400 ppm CO_2);

3.4.5. Purified synthetic air (purity ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0,1 ppm NO) oxygen content between 18 and 21 % vol.

3.5. **Calibration gases**

3.5.1. The true concentration of a calibration gas must be within ± 2 % of the stated figure.

3.5.2. The gases used for calibration may also be obtained by means of a gas divider, diluting with purified N_2 or with purified synthetic air. The accuracy of the mixing device must be such that the concentrations of the diluted calibration gases may be determined to within ± 2 %.

Annex V describes the analytical systems in current use. Other systems or analysers which have proved to give equivalent results may be used.

4. TEST PROCEDURE

4.1. **Test cycle**

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

Mode No	Engine speed	Per cent load
1	idle	—
2	intermediate	10
3	intermediate	25
4	intermediate	50
5	intermediate	75
6	intermediate	100
7	idle	—
8	rated	100
9	rated	75
10	rated	50
11	rated	25
12	rated	10
13	idle	—

4.2. **Measurement of exhaust gas flow**

For calculation of the emission it is necessary to know the exhaust gas flow (see section 4.8.1.1). For determination of exhaust flow either of the following methods may be used:

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

(b) Measurement of the air flow and the fuel flow by suitable metering systems and calculation of the exhaust flow by the following equations:

$$G_{EXH} = G_{AIR} + G_{FUEL}$$

or

$V'_{EXH} = V_{AIR} - 0{,}75\ G_{FUEL}$ (dry exhaust volume)

or

$V''_{EXH} = V_{AIR} + 0{,}77\ G_{FUEL}$ (wet exhaust volume)

The accuracy of exhaust flow determination shall be ± 2,5 % or better. The concentration of carbon monoxide and nitric oxide are measured in the dry exhaust. For this reason the CO and NO_x emissions shall be calculated using the dry exhaust gas volume V'_{EXH}. However in the case of an analytical system with heated sampling line, the NOx emissions shall be calculated using the wet exhaust gas volume V''_{EXH}, If the exhaust mass flow rate (G_{EXH}) is used in the calculation the CO and NO_X concentrations shall be related to the wet exhaust. Calculation of the HC emission shall include G_{EXH} and V'_{EXH} according to the measuring method used. 91/542/EEC

4.3. **Operating procedure for analysers and sampling system** 88/77/EEC

The operating procedure for analysers shall follow the start-up and operating instructions of the instrument manufacturer. The following minimum requirements shall be included.

4.3.1. *Calibration procedure*

The calibration procedure shall be carried out within one month preceding the emission test. 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.

4.3.1.1. A minimum of two hours shall be allowed for warming up the analysers.

4.3.1.2. 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 stabilization period all flow meters and pressure gauges should read zero. If not, the sampling line(s) shall be checked and the fault corrected.

4.3.1.3. The NDIR analyser shall be tuned, where appropriate, and the flame combustion of the HFID analyser optimized.

4.3.1.4 Using purified dry air (or nitrogen), the CO, CO_2(if used) and NOx analysers are set at zero; dry air is purified for the HC analyser. Using appropriate calibration gases, the analysers shall be reset. 91/542/EEC

4.3.1.5. The zero setting shall be rechecked and the procedure described in section 4.3.1.4 above repeated, if necessary. 88/77/EEC

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. 91/542/EEC

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 NOx concentrations in the raw and diluted exhaust. 91/542/EEC

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.'

4.3.2. *Establishment of the calibration curve* 88/77/EEC

4.3.2.1. The analyser calibration curve is established by at least five calibration points spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration must be not less than 80 % of the full scale.

4.3.2.2. The calibration curve is calculated by the least square method.

If the resulting polynominal degree is greater than 3, the number of calibration points must be at least equal to this polynominal degree plus 2.

4.3.2.3. The calibration curve must not differ by more than 2 %, from the nominal value of each calibration gas.

4.3.2.4. Trace of the calibration curve

From the trace of 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 scale,

— the sensitivity,

— the zero point,

— the date of carrying out the calibration.

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

4.3.3. *Efficiency test of the NO_x converter*

4.3.3.1. The efficiency of the converter used for the conversion of NO_x into NO is tested as follows.

88/77/EEC

4.3.3.2. Using the test set up as shown at the end of this Annex and the procedure below, the efficiency of converters can be tested by means of an ozonator.

4.3.3.3. Calibrate the CLA in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which must amount to about 80 % of the operating range and the NO_2 concentration of the gas mixture to less than 5 % of the NO concentration). The NOx analyser must be in the NO mode so that the span gas does not pass through the converter. Record the indicated concentration.

4.3.3.4. Via a T-fitting, oxygen is added continously to the gas flow until the concentration indicated is about 10 % less than the indicated calibration concentration given in section 4.3.3.3. Record the indicated concentration (c). The ozonator is kept deactivated throughout the process.

4.3.3.5. The ozonator is now activated to generate enough ozone to bring the NO concentration down to 20 % (minimum 10 %) of the calibration concentration given in 4.3.3.3. Record the indicated concentration (d).

4.3.3.6. The NO analyser is then switched to the NOx mode which means that the gas mixture (consisting of NO, NO_2, O_2 and N_2) now passes through the converter. Record the indicated concentration (a).

4.3.3.7. The ozonator is now deactivated. The mixture of gases described in section 4.3.3.4 passes through the converter into the detector. Record the indicated concentration (b).

4.3.3.8. With the ozonator deactivated, the flow of oxygen is also shut off. The NO reading of the analyser must then be no more than 5 % above the figure given in section 4.3.3.3.

4.3.3.9. The efficiency of the NOx converter is calculated as follows:

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

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

4.3.3.11. The efficiency of the converter must not be less than 90%. | 88/77/EEC

NB:

If the analyser operating range is above the highest range that the NOx generator can operate to give a reduction from 80 to 20 %, then the highest range the NOx generator will operate on will be used.

4.3.4. *Pre-test checks*

A minimum of two hours shall be allowed for warming up the infra-red NDIR analysers, but it is preferable that power be left on continuously in the analysers. The chopper motors may be turned off when not in use.

4.3.4.1. The HC analyser shall be set at zero on dry air or nitrogen and a stable zero obtained on the amplifier meter and recorder.

4.3.4.2. Span gas shall be introduced and the gain set to match the calibration curve. The same flow rate shall be used for calibration, span and exhaust sampling to avoid correction for sample cell pressure. Span gas having a concentration of the constituent that will give a 75 to 95 % full-scale deflection shall be used. Concentration shall be obtained to ± 2,5 %.

4.3.4.3. Zero shall be checked and the procedures described in sections 4.3.2.1 and 4.3.2.2 repeated, if required.

4.3.4.4. Flow rates shall be checked.

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. | 91/542/EEC

4.4. **Fuel** | 88/77/EEC

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

4.5. **Engine test conditions**

4.5.1. The absolute temperature (T) of the engine air inlet expressed in kelvins and the dry atmospheric pressure (ps) expressed in kilopascals shall be measured and the parameter F shall be determined by the formula:

$$F = \left(\frac{99}{ps}\right)^{0,65} \times \left(\frac{T}{298}\right)^{0,5}$$

4.5.2. For a test to be recognized as valid, the parameter F shall be such that: — 88/77/EEC

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

4.6. **Test run** — 91/542/EEC

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 ûC). 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 ûC) 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.

4.6.3. the engine shall be started and warmed up until all temperatures and pressures have reached equilibrium; — 88/77/EEC

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: | 91/542/EEC

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

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 ûC) immediately before the particulate filters at the mode with the maximum heat flow as determined from exhaust flow and/ or temperature;

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 (Ms_{am}) 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;

4.6.7. any additional data required for calculation shall be read and recorded (see section 4.7); | 88/77/EEC

4.6.8. the zero and span settings of the emission analysers shall be checked and reset, as required, at least at the end of the test. The test shall be considered satisfactory if the adjustment necessary after the test does not exceed the accuracy of the analysers prescribed in section 3.2.

4.7. **Evaluation of results** | 91/542/EEC

4.7.1. At the completion of testing the total sample mass through the filters (Ms_{am}) 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 NOx over this period determined. The concentration of HC, CO and NOx 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.

4.8. **Calculations** | 88/77/EEC

4.8.1. The final reported test results of the gaseous emissions are derived through the following steps: | 91/542/EEC

4.8.1.1. the exhaust gas mass flow rate G_{EXH} or V'_{EXH} and V''_{EXH} shall be determined (see section 4.2) for each mode; | 88/77/EEC

4.8.1.2. when applying G_{EXH} the measured carbon monoxide and oxides of nitrogen concentration shall be converted to a wet basis according to Annex VI. However in the case of an analytical system with heated sampling line, the NOx emissions shall not be converted according to Annex VI;

4.8.1.3. the NOx concentration shall be corrected according to Annex VII;

4.8.1.4. the pollutant mass flow for each mode shall be calculated as follows: | 88/77/EEC

(1) $NO_{x\,mass} = 0{,}001587 \times NO_{x\,conc} \times G_{EXH}$

(2) $CO_{mass} = 0{,}000966 \times CO_{conc} \times G_{EXH}$

(3) $HC_{mass} = 0{,}000478 \times HC_{conc} \times G_{EXH}$

or

(1) $NO_{x\,masse} = 0{,}00205 \times NO_{x\,conc} \times V'_{EXH}$ (dry) for unheated systems

(2) $NO_{x\,mass} = 0{,}00205 \times NO_{x\,conc} \times V''_{EXH}$ (wet) for heated systems

(3) $CO_{mass} = 0{,}00125 \times CO_{conc} \times V'_{EXH}$ (dry)

(4) $HC_{mass} = 0{,}000618 \times HC_{conc} \times V''_{EXH}$ (wet)

4.8.2. The gaseous emissions are calculated in the following way: | 91/542/EEC

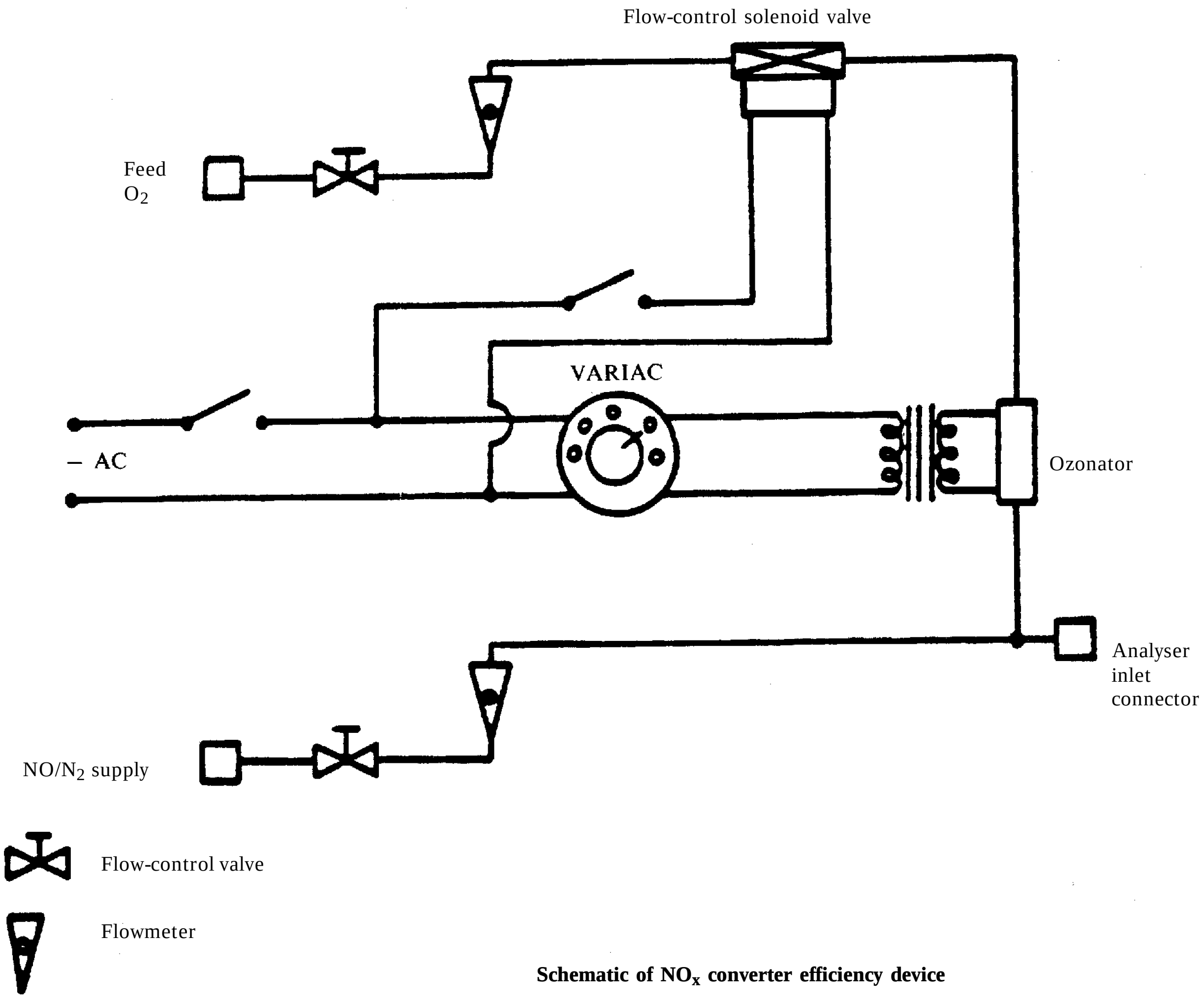
$$\overline{NO_x} = \frac{\sum NO_{x\,mass}\,WF_i}{\sum (P_i - P_{aux})\,WF_i}$$

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

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

The weighting factors used in the above calculation are according to the following table: | 88/77/EEC

Mode No	WF
1	0,25/3
2	0,08
3	0,08
4	0,08
5	0,08
6	0,25
7	0,25/3
8	0,10
9	0,02
10	0,02
11	0,02
12	0,02
13	0,25/3



Schematic of NO_x converter efficiency device

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: 91/542/CEE

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

4.8.3.1. The particulate mass flow is calculated as follows:

$$PT_{mass} = \frac{P_f\, \overline{G}_{EDF}}{M_{SAM}\, 1000}$$

$$PT_{mass} = \frac{P_f\, \overline{V''}_{EDF}}{V_{SAM}\, 1000}$$

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

$$\overline{G}_{EDF} = \sum G_{EDF,i}\, WF_i$$

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

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

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

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

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

or

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

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).

91/542/CEE

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.

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

or

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

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

or

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

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 NOx measurement

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

or

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

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

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

91/542/CEE

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

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:

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

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

4.8.5.4. Total sampling type with mass flow control

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

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

ANNEX IV

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

CEC reference fuel RF–03–A–84 (1) (3) (7)

Type: Diesel fuel

	Limits and units	ASTM Method
Cetane number (4)	min. 49	D 613
	max. 53	
Density 15ûC (kg/l)	min. 0,835	D 1298
	max. 0,845	
Distillation (2):		
— 50 % point	min. 245 ûC	D 86
— 90 % point	min. 320 ûC	
	max. 340 ûC	
— final boiling point	max. 370 ûC	
Flash point	min. 55 ûC	D 93
CFPP	min.—	EN 116 (CEN)
	max. – 5 ûC	
Viscosity 40 ûC	min. 2,5 mm^2/s	D 445
	max. 3,5 mm^2/s	
Sulphur content (8)	min. (to be reported)	D 1266/D 2622
	max. 0,3 % mass	D 2785
Copper corrosion	max. 1	D 130
Conradson carbon residue (10 % DR)	max. 0,2 % mass	D 189
Ash content	max.0,01% mass	D 482
Water content	max. 0,05 % mass	D 95/D 1744
Neutralization (strong acid) number	max. 0,20 mg KOH/g	
Oxidation stability (6)	max. 2,5 mg/l 100 ml	D 2274
Additives (5)		

(1) Equivalent 150 methods will be adopted when issued for all properties listed above.

(2) The figures quoted show the total evaporated quantities (% recovered + % loss).

(3) The values quoted in the specification are 'true values'.

In establishment of their limit values the terms of ASTM D 3244, *Defining a Basis for Petroleum Product Quality Disputes*, have been applied and in fixing a maximum 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 ASTM D 3244 should be applied.

(4) The range for cetane is not in accordance with the requirement of a minimum range of 4R. However, in cases of dispute between fuel supplier and user, the terms in ASTM D 3244 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.

(5) This fuel should be based on straight run and cracked hydrocarbon distillate components only; desulphurization is allowed. It must not contain any metallic additives or cetane improver additives.

(6) 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.

(7) 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 ûC,

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).

(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.

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ANALYTICAL AND SAMPLING SYSTEMS

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.

88/77/EEC

System 1

A schematic diagram of the analytical and sampling system using the chemiluminescent analyser for measuring NOx is shown in Figure 1.

SP	Stainless-steel sample probe, to obtain samples from the exhaust system. A closed-end multihole static probe extending at least 80 % across the exhaust pipe is recommended. The exhaust gas temperature at the probe shall be not less than 343 K (70 ûC).
HSL	Heated sampling line, temperature shall be kept at 453 to 473 K (180 to 200 ûC); the line shall be made in stainless steel or PTFE.
F_1	Heated pre-filter, if used; temperature shall be the same as HSL.
T_1	Temperature read-out of sample stream entering oven compartment.
V_1	Suitable valving for selecting sample, span gas or air gas flow to the system. The valve shall be in the oven compartment or heated to the temperature of the sampling line.
V_2, V_3	Needle valves to regulate calibration gas and zero gas.

F_2	Filter to remove particulates. A 70-mm-diameter glass-fibre-type filter disc is suitable. The filter shall be readily accessible and changed daily or more frequently, as needed.
P_1	Heated sample pump.
G_1	Pressure gauge to measure pressure in sample line.
V_4	Pressure regulator valve to control pressure in sample line and flow to detector.
HFID	Heated flame ionization detector for hydrocarbons. Temperature of oven shall be kept at 453 to 473 K (180 to 200 ûC).
FL_1	Flowmeter to measure sample by-pass flow.
R_1, R_2	Pressure regulators for air and fuel.
SL	Sample line. The line shall be made in PTFE or in stainless steel. It may be heated or unheated.
B	Bath to cool and condense water from exhaust sample. The bath shall be maintained at a temperature of 273 to 277 K (0 to 4 ûC) by ice or refrigeration.
C	Cooling coil and trap sufficient to condense and collect water vapour.
T_2	Temperature read-out of bath temperature.
V_5, V_6	Toggle valves to drain condensate trap and bath.
V_7	Three-way valve.
F_3	Filter for removing particulate contaminants from sample prior to analysis. A glass-fibre type of at least 70 mm diameter is suitable.
P_2	Sample pump.
V_8	Pressure regulator to control sample flow.

V_9, V_{10}, V_{11}, V_{12}	Three-way ball valves or solenoid valves to direct sample, zero gas or calibrating gas streams to the analysers.
V_{13}, V_{14}	Needle valves to regulate flows to the analysers.
CO	NDIR analyser for carbon monoxide.
NO_x	CLA analyser for nitric oxides.
FL_2, FL_3, FL_4	By-pass flowmeters.

System 2

A schematic diagram of the analytical and sampling system using the NDIR analyser for measuring NOx is shown in Figure 2.

SP	Stainless-steel sample probe, to obtain samples from the exhaust system. A closed-end multihole static probe extending at least 80 % across the exhaust pipe is recommended; the temperature at the probe shall be at least 343 K (70 ûC) (in accordance with Directive 72/306/EEC). The probe shall be located in the exhaust line at a distance of 1 to 5 metres from the exhaust manifold outlet flange of the outlet of the turbocharger
HSL	Heated sampling line, temperature shall be kept at 453 to 473 K (180 to 200 ûC); the line shall be made in stainless steel or PTFE.
F_1	Heated pre-filter, if used; temperature shall be the same as the HSL.
T_1	Temperature read-out of sample stream entering oven compartment.

V_1	Suitable valving for selecting sample, span gas or air zero gas flow to the system. The valve shall be in the oven compartment or heated to the temperature of the sampling line.
V_2, V_3	Needle valves to regulate calibration gas and zero gas.
F_2	Filter to remove particulates. A 70 – mm-diameter glass-fibre-type filter disc is suitable. The filter shall be readily accessible and changed daily or more frequently, as needed.
P_1	Heated sample pump.
G_1	Pressure gauge to measure pressure in sample line.
V_4	Pressure regulator valve to control pressure in sample line and flow to detector.
HFID	Heated flame ionization detector for hydrocarbons. Temperature of oven shall be kept at 453 to 473 K (180 to 200 ûC).
FL_1	Flowmeter to measure sample by-pass flow.
R_1, R_2	Pressure regulators for air and fuel.
SL	Sample line. The line shall be made in PTFE or in stainless steel. It may be heated or unheated
B	Bath to cool and condense water from exhaust sample. The bath shall be maintained at a temperature of 273 to 277 K (0 to 4 ûC) by ice or refrigeration.
C	Cooling coil and trap sufficient to condense and collect water vapour.
T_2	Temperature read-out of bath temperature.
V_5, V_6	Toggle valves to drain condensation trap and bath.
V_7	Three-way valve.

F_3	Filter for removing particulate contaminates from sample prior to analysis. A glass-fibre type of at least 70 mm diameter is suitable.
P_2	Sample pump.
V_8	Pressure regulator to control sample flow.
V_9	Ball or solenoid valve to direct sample, zero gas or calibrating gas streams to the analysers.
V_{10}, V_{11}	Three-way valves to by-pass drier.
D	Drier to remove moisture in the sample stream. If a drier is used before NOx analyser it shall have minimum effect on NOx concentration.
V_{12}	Needle valve to regulate flow to the analysers.
G_2	Gauge to indicate inlet pressure to the analysers.
CO	NDIR analyser for carbon monoxide.
NO_x	NDIR analyser for nitric oxides.
FL_2, FL_3	By-pass flowmeters.

System 3

A schematic diagram of the analytical and sampling system using HCLA or equivalent systems for measuring NOx is shown in Figure 3 to this Annex.

SP	Stainless-steel sample probe, to obtain samples from exhaust system. A closed-end multihole straight probe extending at least 80 % across the exhaust pipe is recommended. The exhaust gas temperature at the probe shall be not less than 343 K (70 ûC).
HSL_1	Heated sampling line, temperature shall be kept at 453 to 473 K (180 to 200 ûC); the line shall be made in stainless steel or PTFE.
F_1	Heated pre-filter, if used; temperature shall be the same as HSL_1.
T_1	Temperature read-out of sample stream entering oven compartment.
V_1	Suitable valving for selecting sample, span gas or air gas flow to the system. The valve shall be in the oven compartment or heated to the temperature of the samping line HSL_1.
V_2, V_3	Needle valves to regulate calibration gas and zero gas.
F_2	Filter to remove particulates. A 70-mm-diameter glass-fibre-type filter disc is suitable. The filter shall be readily accessible and changed daily or more frequently, as needed.
P_1	Heated sample pump.
G_1	Pressure gauge to measure pressure in sample line HC-analyser.
R_3	Pressure regulator valve to control pressure in sample line and flow to detector.

HFID	Heated flame ionization detector for hydrocarbons. Temperature of oven shall be kept at 453 to 473 K (180 to 200 ûC).
FL_1, FL_2, FL_3	Flowmeters to measure sample by-pass flow.
R_1, R_2	Pressure regulators for air and fuel.
HSL_2	Heated sampling line, temperature shall be kept between 368 and 473 K (95 and 200 ûC); the line shall be made in stainless steel or PTFE.
T_2	Temperature read-out of sample stream entering CL analyser.
T_3	Temperature read-out of NO_2 to NO converter.
V_9, V_{10}	Three-way valve to by-pass NO_2 to NO converter.
V_{11}	Needle valve to balance flow through NO_2 to NO converter and by-pass.
SL	Sample line. The line shall be made in PTFE or in stainless steel. It may be heated or unheated.
B	Bath to cool and condense water from exhaust sample. The bath shall be maintained at a temperature of 273 to 277 K (0 to 4 ûC) by ice or refrigeration.
C	Cooling coil and trap sufficient to condense and collect water vapour.
T_4	Temperature read-out of bath temperature.
V_5, V_6	Toggle valves to drain condensate trap and bath.
R_4, R_5	Pressure regulators to control sample flow.
V_7, V_8	Ball valve or -solenoid valves to direct sample, zero gas or calibrating gas streams to the analysers.
V_{12}, V_{13}	Needle valves to regulate flows to the analysers.

CO	NDIR analyser for carbon monoxide.
NO_x	HCLA analyser for nitric oxides.
FL_4, FL_5	By-pass f1owmeters.
V_4, V_{14}	Three-way ball or solenoid valves. The valves shall be in an oven compartment or heated to the temperature of the sampling line HSL_1.

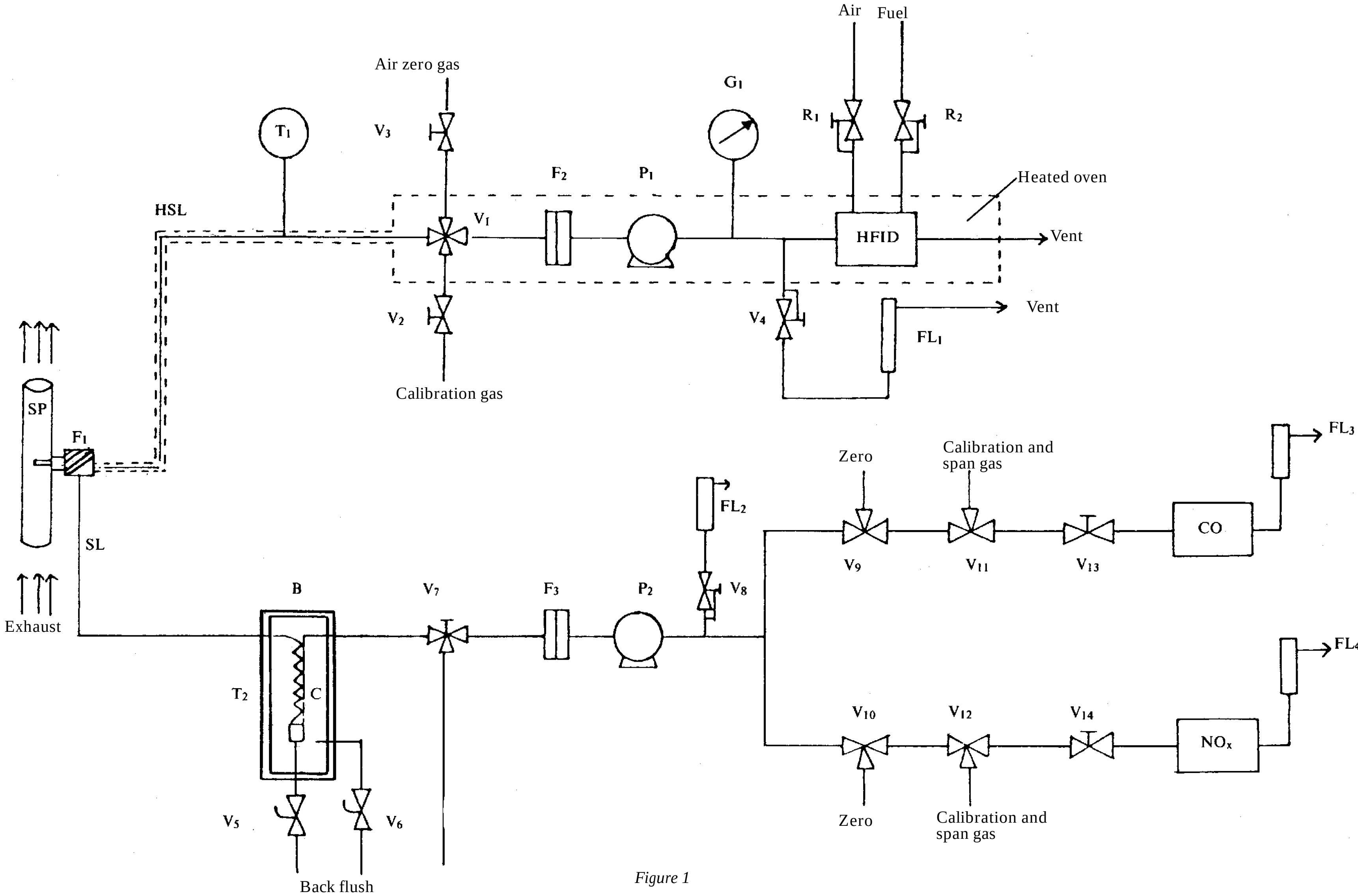

Figure 1

Flow diagram of exhaust gas analysis system for CO, NOx, HC (NOx analysis by CLA)

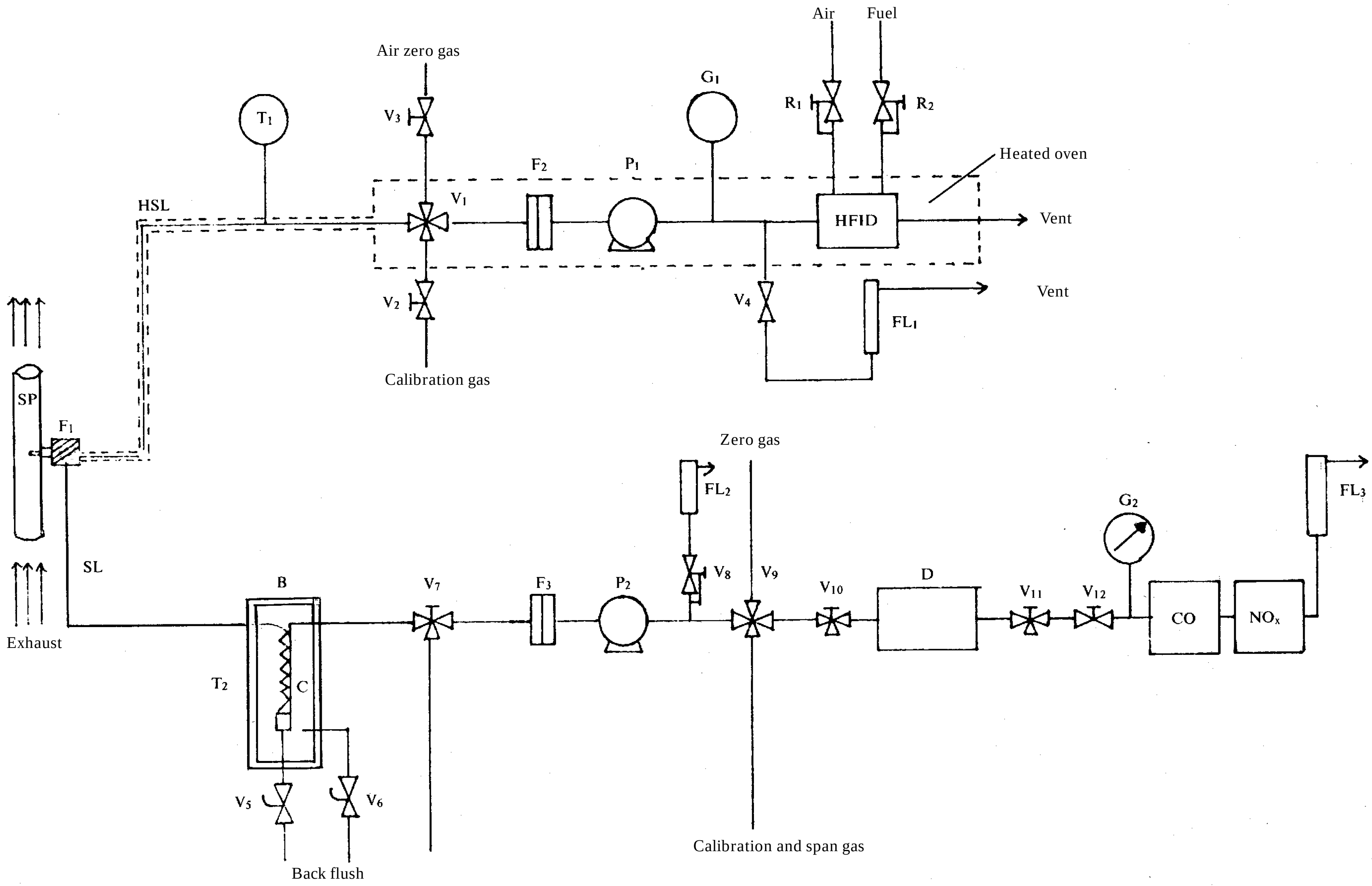

Figure 2

Flow diagram of exhaust gas analysis system for CO, NOx, HC (NOx analysis by NDIR)

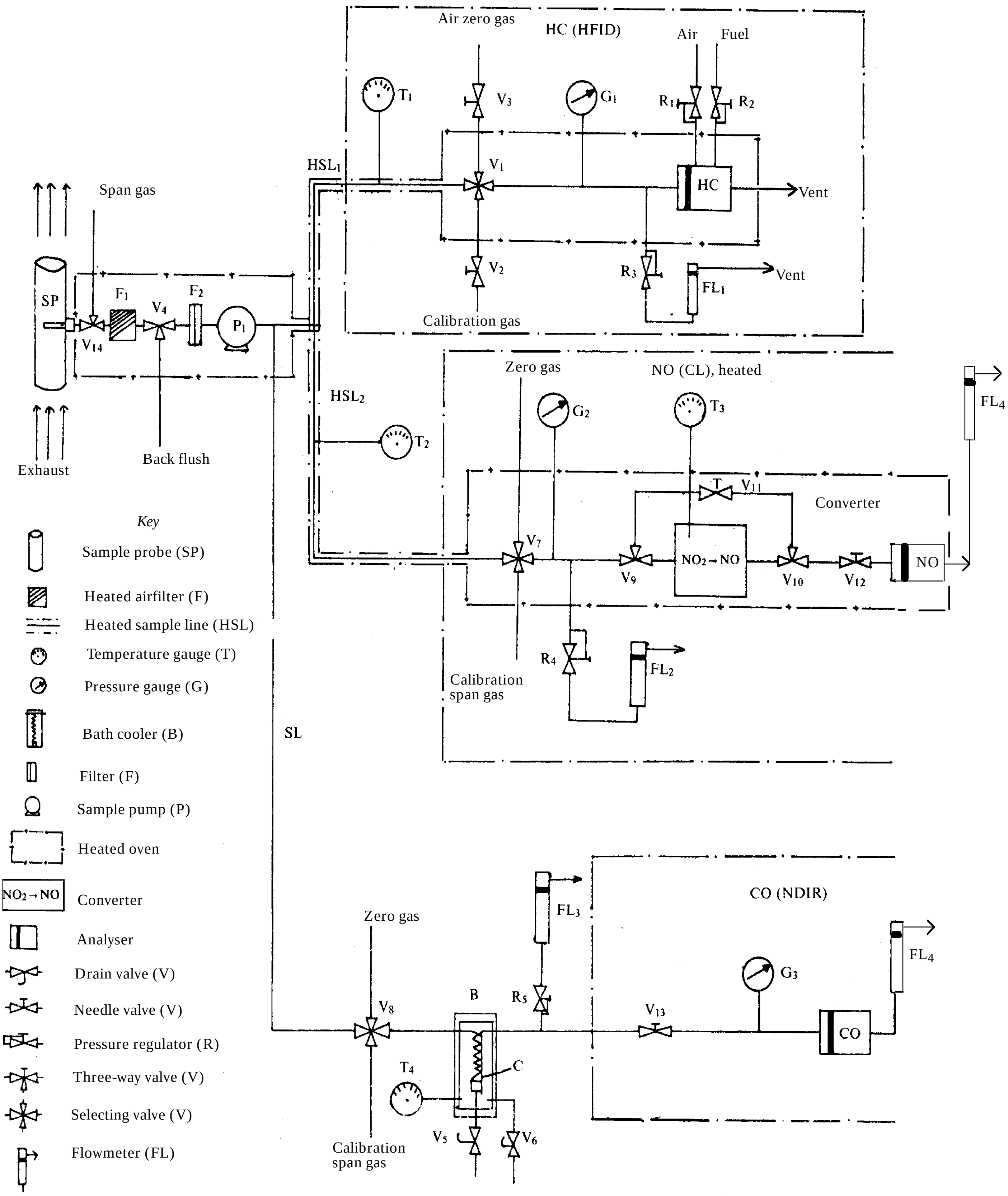

Figure 3

Flow diagram of exhaust gas analysis system for CO, NOx and HC (analysis by HCLA and heated sample line)

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 oC), 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 (20û and 30 ûC) 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.

S y s t e m 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 ûC).

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 mixttLre 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 4000) 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 ûC) 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 ûC) 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 ûC) 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 ûC) ± 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 sufficienfly 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 ûC) + 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 ûC) ± 5 K.

S y s t e m 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 Ill, 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.

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

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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 (15() ûC). If the gas temperature is below 423 K (150 ûC) 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 ûC) ± 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[B2[B 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 ûC) ± 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 (SIC! thoroughly) 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.

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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*

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

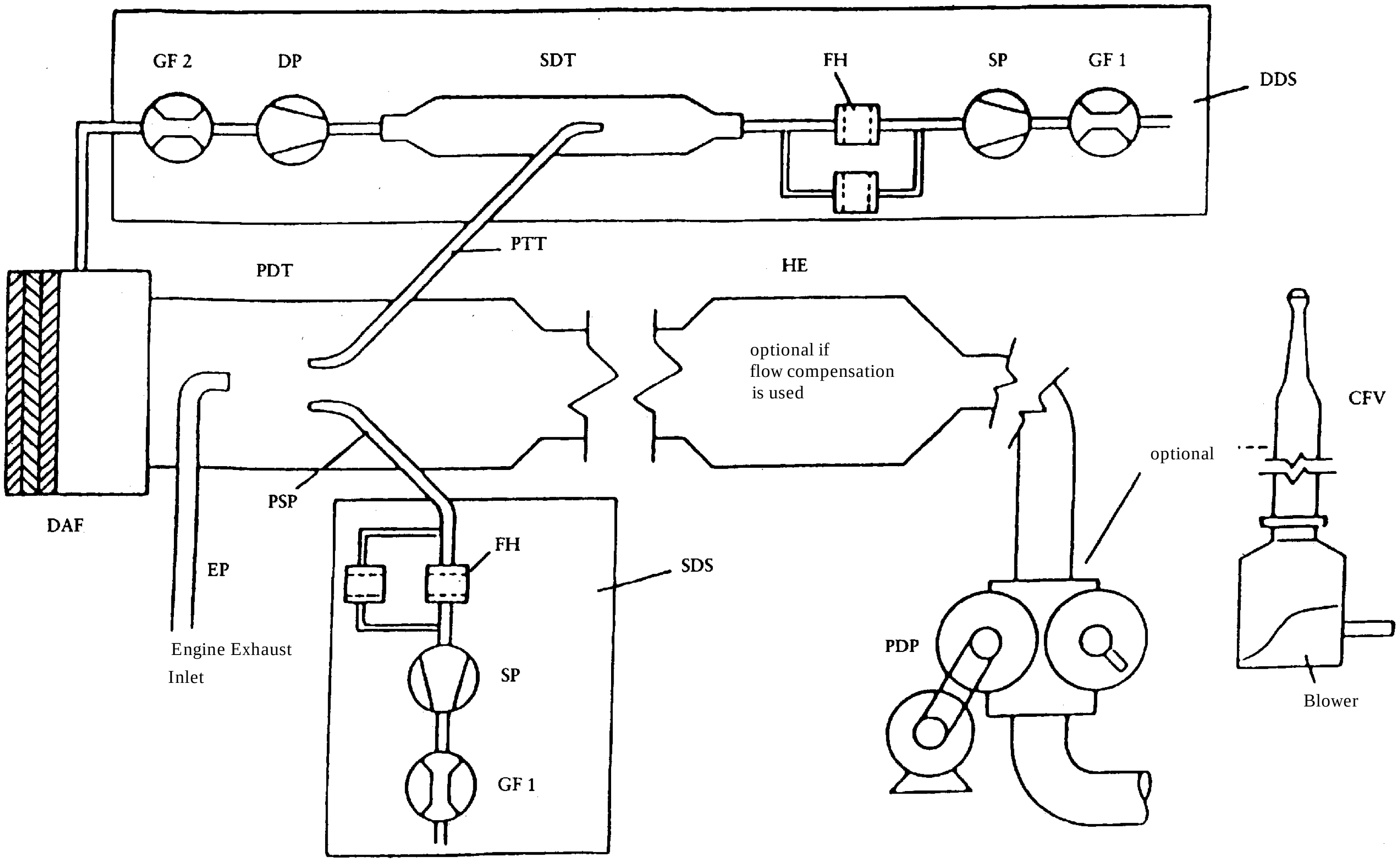
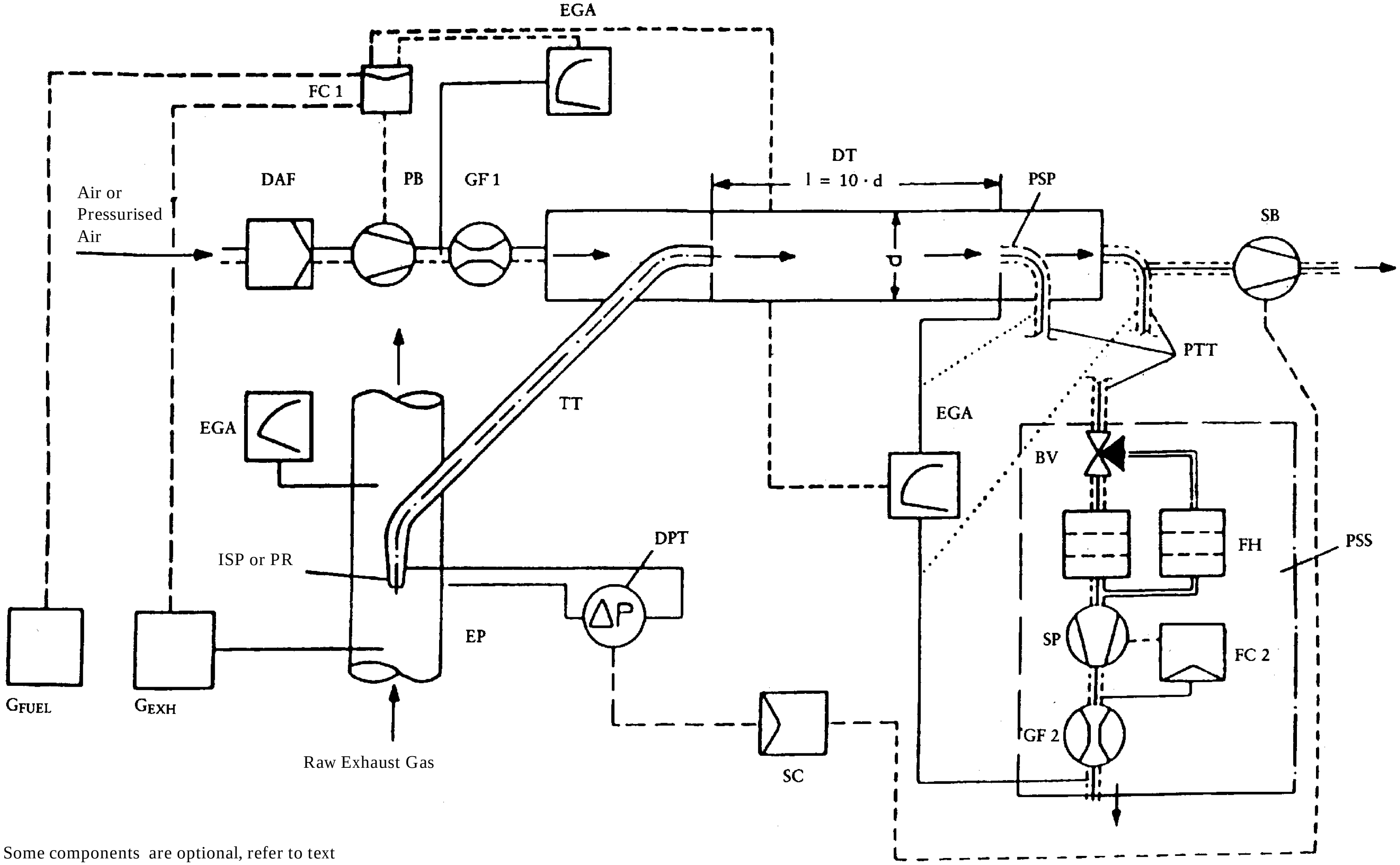


Figure 4

Full-flow-dilution system



Some components are optional, refer to text

Figure 5

Partial-flow-dilution system

CONVERSION OF CO AND NO_x CONCENTRATION TO A WET BASIS

The CO and NO_x exhaust gas concentrations as measured in this procedure are on a dry basis. To convert the measured values to the concentrations present in the exhaust (wet basis), the following relationship may be employed:

$$\text{ppm (wet basis)} = \text{ppm (dry basis)} \times [1 - 1{,}85\ (\frac{G_{FUEL}}{G_{AIR}})]$$

where:

G_{FUEL} = the fuel flow (kg/s) (kg/h),

G_{AIR} = the air flow (kg/s) (kg/h) (dry air).

ANNEX VII

HUMIDITY CORRECTION FACTOR FOR NITROGEN OXIDES

The values of the oxides of nitrogen shall be multiplied by the following humidity correction factor:

$$\frac{1}{1 + A\ (7m - 75) + B \times 1{,}8\ (T - 302)}$$

where:

A = $0{,}044\ \frac{G_{FUEL}}{G_{AIR}} - 0{,}0038$,

B = $0{,}116\ \frac{G_{FUEL}}{G_{AIR}} + 0{,}0053$,

m = humidity of the inlet air in grams of water per kilogram of dry air

T = temperature of the air in K

$\frac{G_{FUEL}}{G_{AIR}}$ = fuel air ratio (dry air basis).

ANNEX VIII

(MODEL)

EEC TYPE-APPROVAL CERTIFICATE

Stamp of administration

Communication concerning the:

— type-approval [1]

— extension of type-approval (1) of a type of a vehicle/separate technical unit/component (1) with regard to Directive 88/77/EEC as last amended by Directive. . .

EEC 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 type/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. Name and address of manufacturers: . . . .
. . . .

0.6. Name and address of manufacturer's authorized 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.

Appendix

88/77/EEC

to EEC type-approval certificate No ... concerning the type approval of a vehicle/separate technical unit/component [1] within the meaning of Directive 88/77/EEC

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. Name and address of manufacturer: ....

1.1.6. Name and address of manufacturer's authorized 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: ....

1.3. *Particulars to be completed in relation to the type-approval of an engine 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. Maximum permissible power absorbed by the engine-driven equipment: ....

1.3.3.1. Idle: .... kW; Intermédiaire: ...... kW; Rated: .... kW

1.3.4. Restrictions of use (if any): ....

1.4. *Emission levels*

91/542/EEC

$\overline{CO}$ .... g/kWh

$\overline{HC}$ .... g/kWh

$\overline{NO}$ .... g/kWh

$\overline{PT}$ .... g/kWh

} determined by a full/partial flow system (1)

6. **Remarks (if any)**: ....

88/77/EEC

[1] Delete as appropriate.