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 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 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 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

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, agri-

(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.

cultural 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:

— 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.

Done at Brussels, 3 December 1987.

For the Council
The President
Chr. CHRISTENSEN

ANNEX I

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

1. SCOPE

This Directive applies to the gaseous pollutants from all motor vehicles equipped with compression-ignition engines and to compression-ignition 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 88/76/EEC (2).

2. DEFINITIONS AND ABBREVIATIONS

For the purposes of this Directive :

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

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;

2.4. *'gaseous pollutants'* means carbon monoxide, hydrocarbons (assuming a ratio of $C_1H_{1,85}$) and oxides of nitrogen, the last-named being expressed in nitrogen dioxide (NO_2) equivalent;

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);

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;

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**

P	kW	net power output non-corrected (4)
CO	g/kWh	carbon monoxide emission
HC	g/kWh	hydrocarbon emission
NO_x	g/kWh	emission of oxides of nitrogen
conc	ppm	concentration (ppm by volume)
mass	g/h	pollutant mass flow
WF		weighting factor
G_{EXH}	kg/h	exhaust gas mass flow rate on wet basis
V'_{EXH}	m^3/h	exhaust gas volume flow rate on 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 (wet air at 0 °C and 101,3 kPa)
G_{FUEL}	kg/h	fuel mass flow rate
HFID		heated flame ionization detector
NDUVR		non-dispersive ultraviolet resonance absorbtion
NDIR		non-dispersive infra-red

(1) OJ No L 76, 6. 4. 1970, p. 1.
(2) See page 1 of this Official Journal.
(3) OJ No L 375, 31. 12. 1980, p. 46.
(4) As described in Annex I to Directive 80/1269/EEC.

CLA	chemiluminescent analyser
HCLA	heated chemiluminescent analyser

3. APPLICATION FOR EEC TYPE-APPROVAL

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 pollutants shall be submitted by the engine manufacturer or by a duly accredited representative.

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

3.1.2.1. a description of the engine type 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.

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 with regard to emission of gaseous pollutants by its engine shall be submitted by the vehicle manufacturer or a duly accredited representative.

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

3.2.2.1. a description of the vehicle type 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.

6. SPECIFICATIONS AND TESTS

6.1. **General**

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

6.2. **Specifications concerning the emission of gaseous pollutants**

The emission of gaseous pollutants by the engine submitted for testing shall be measured by the method described in Annex III. Other methods may be approved if it is found that they yield equivalent results.

(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.

6.2.1. 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) grams per kWh	Mass of hydrocarbons (HC) grams per kWh	Mass of nitrogen oxides (NO_x) grams per kWh
11,2	2,4	14,4

7. INSTALLATION ON THE VEHICLE

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

7.1.1. intake depression shall not exceed that specified for the type-approved engine in Annex 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 and the mass of the oxides of nitrogen obtained shall not exceed the amounts shown in the table below :

Mass of carbon monoxide (CO) grams per kWh	Mass of hydrocarbons (HC) grams per kWh	Mass of nitrogen oxides (NO_x) grams per kWh
12,3	2,6	15,8

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 ($\bar{x}$) of the results obtained with the sample shall then be determined for each gaseous pollutant. The production of the series shall then be deemed to conform if the following condition is met :

$$\bar{x} + k \cdot S \leq L \,(^1)$$

where :

L is the limit value laid down in section 8.3.1.1 for each gaseous pollutant considered, and

(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.

k is a statistical factor depending on n and given in the following table:

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 partially or completely, according to the manufacturer's specifications.

ANNEX II

INFORMATION DOCUMENT No ...

PURSUANT TO ANNEX I OF DIRECTIVE 70/156/EEC

relating to EEC partial type-approval or type-approval as a separate technical unit of gaseous pollutant emissions from diesel engines for use in vehicles (Directive 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.	Liquid
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.	Air
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
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
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) In the case of non-conventional engines and systems, particulars equivalent to those referred to here shall be supplied by the manufacturer.

(2) Strike out what does not apply.

(3) Specify the tolerance.

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-smoke devices** (If any, and if not covered by another heading)

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

3. **Fuel feed**

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): .....

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 (2)

or characteristic diagram (1) (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: ...

.....

(1) Strike out what does not apply.

(2) Specify the tolerance.

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 (2), 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: .....

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 engine speeds		
	Idle	Intermediate	Rated
Total			

6.3. *Dynamometer settings (kW)*

Per cent load	Engine speed		
	Idle	Intermediate	Rated
10	—		
25	—		
50	—		
75	—		
100	—		

7. **Engine performances**

7.1. *Engine speeds* (3)

Idle: ..... rpm

Intermediate: ..... rpm

Rated: ..... rpm

(1) Strike out what does not apply.

(2) OJ No L 375, 31. 12. 1980, p. 46.

(3) Specify the tolerance.

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

	Engine speed		
	Idle	Intermediate	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	Intermediate	Rated
Total			

ANNEX III

TEST PROCEDURE

1. INTRODUCTION

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

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

2. MEASUREMENT PRINCIPLE

The gaseous emissions from the exhaust of the engine include hydrocarbons, carbon monoxide and oxides of nitrogen. During a prescribed sequence of warmed-up-engine operating conditions the amounts of the above gases in the exhaust shall be examined continuously. The prescribed sequence of operations 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 pollutant, exhaust flow and power output shall be determined and the measured values weighted and used to calculate the grams of each pollutant emitted per kilowatt hour, as described in this Annex.

3. EQUIPMENT

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;

3.1.4. a non-insulated and uncooled exhaust system extending at least 0,5 metres past the point where the exhaust probe is 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;

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.

3.2. **Analytical and sampling equipment**

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

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

3.3. **Gases**

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

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

3.4. **Support gases**

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 CO_2, ≤ 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 NO_x 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.

4.3. **Operating procedure for analysers and sampling system**

The operating procedure for analysers shall follow the start-up and operating instructions of the instrument manufacturer. The 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 and NO_x analysers shall be set at zero; dry air shall be purified for the HC analyser. Using appropriate calibrating gases, the analysers shall be reset.

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

4.3.2. *Establishment of the calibration curve*

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.

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 NO_x 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 NO_x 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 NO_x 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 NO_x analyser.

4.3.3.11. The efficiency of the converter must not be less than 90 %.

NB:

If the analyser operating range is above the highest range that the NO_x generator can operate to give a reduction from 80 to 20 %, then the highest range the NO_x 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.

4.4. **Fuel**

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:

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

4.6. **Test run**

During each mode of the test cycle the specified speed shall be held to within ± 50 rpm and the specified torque shall be held to within ± 2 % of the maximum torque at the test speed. The fuel temperature at the injection pump inlet shall be 306 to 316 K (33 to 43 °C). The governor and fuel system shall be adjusted as established by the manufacturer's sales and service literature. The following steps shall be taken for each test:

4.6.1. instrumentation and sample probes shall be installed as required;

4.6.2. the cooling system shall be started;

4.6.3. the engine shall be started and warmed up until all temperatures and pressures have reached equilibrium;

4.6.4. the torque curve at full load shall 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, shall be taken into account. The dynamometer setting for each engine speed and load shall be calculated using the formula:

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

where

s = dynamometer setting,

P_{min} = 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} = total permissible power absorbed by engine driven equipment minus the power of any such equipment actually driven by the engine : (d)−(b) of section 7.2 of Appendix 1 to Annex II;

4.6.5. the emission analysers shall be set at zero and spanned;

4.6.6. the test sequence shall be started (see section 4.1). The engine shall be operated for six minutes in each mode, completing engine speed and load changes in the first minute. The responses of the analysers shall be 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. The engine speed and load, intake air temperature and depression exhaust temperature and back pressure, fuel flow and air of exhaust flow shall be recorded during the last five minutes of each mode, with the speed and load requirements being met 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);

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. **Chart reading**

The last 60 seconds of each mode shall be located, and the average chart reading for HC, CO and NO_x over this period shall be determined. The concentration of HC, CO and NO_x during each mode shall be 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**

4.8.1. The final reported test results shall be derived through the following steps :

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;

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 NO_x emissions shall not be converted according to Annex VI;

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

4.8.1.4. the pollutant mass flow for each mode shall be calculated as follows:

(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) $NO_{x\ mass} = 0{,}00205 \times NO_{x\ conc} \times V'_{EXH}$ (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 emissions shall be calculated in the following way:

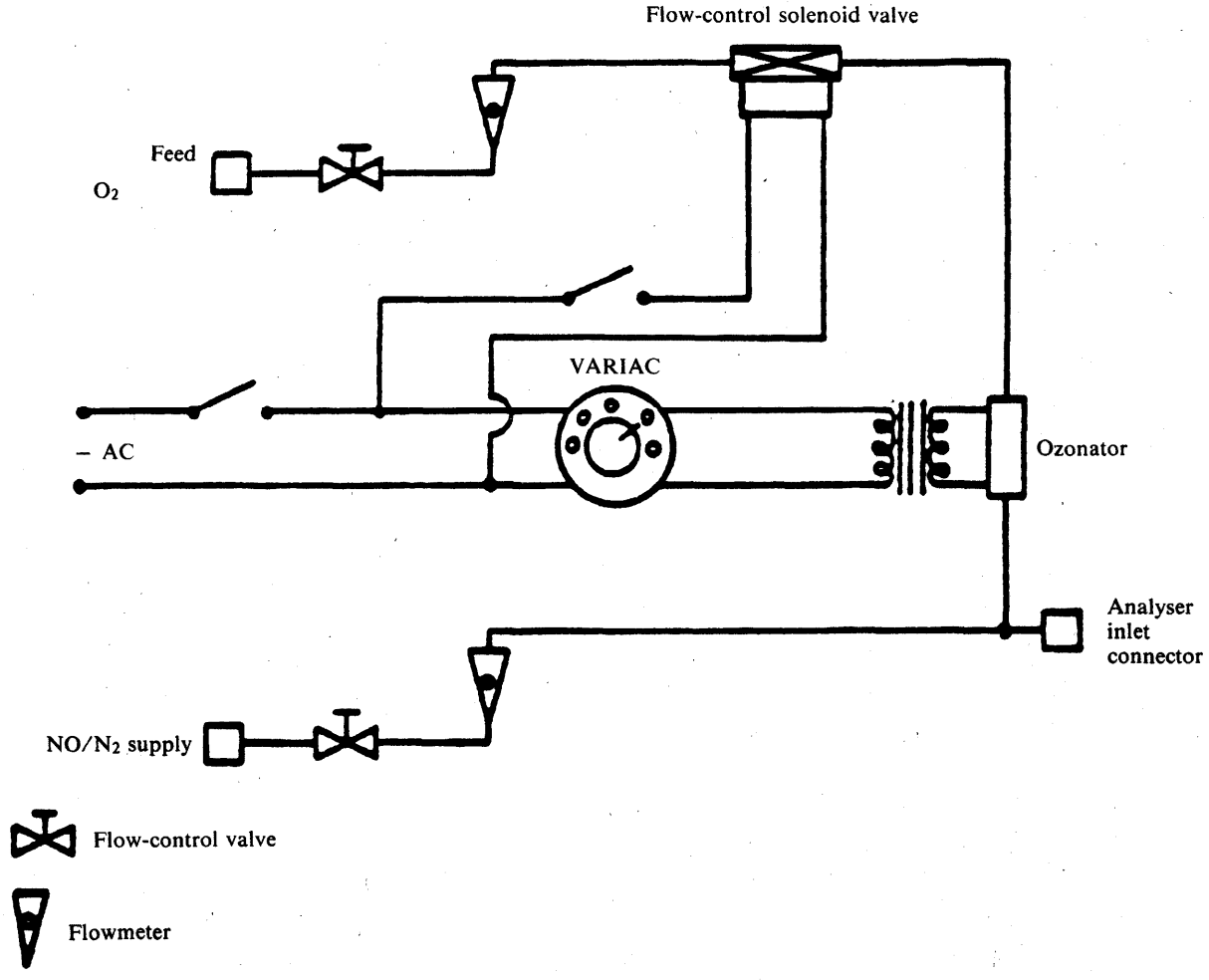
$$NO_x = \frac{\Sigma NO_{x\ mass} \times WF}{\Sigma P \times WF}$$

$$CO = \frac{\Sigma CO_{mass} \times WF}{\Sigma P \times WF}$$

$$HC = \frac{\Sigma HC_{mass} \times WF}{\Sigma P \times WF}$$

The weighting factors used in the above calculation are according to the following table:

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

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 max. 53	D 613
Density 15 °C (kg/l)	min. 0,835 max. 0,845	D 1298
Distillation (2) :		
— 50 % point	min. 245 °C	D 86
— 90 % point	min. 320 °C max. 340 °C	
— final boiling point	max. 370 °C	
Flash point	min. 55 °C	D 93
CFPP	min. — max. −5 °C	EN 116 (CEN)
Viscosity 40 °C	min. 2,5 mm^2/s max. 3,5 mm^2/s	D 445
Sulphur content	min. (to be reported) max. 0,3 % mass	D 1266/D 2622 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/100 ml	D 2274
Additives (5)		

(1) Equivalent ISO 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 :

$$\text{Specific energy (calorific value) (net) in MJ/kg} = (46{,}423 - 8{,}792d^2 + 3{,}170d)(1 - (x + y + s)) + 9{,}420s - 2{,}499x$$

where :

d = the density at 15 °C
x = the proportion by mass of water (% divided by 100)
y = the proportion by mass of ash (% divided by 100)
s = the proportion by mass of sulphur (% divided by 100).

ANNEX V

ANALYTICAL SYSTEMS

Three analytical systems 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.

System 1

A schematic diagram of the analytical and sampling system using the chemiluminescent analyser for measuring NO_x 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 °C).
HSL	Heated sampling line, temperature shall be kept at 453 to 473 K (180 to 200 °C); 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 °C).
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 °C) 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 NO_x 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 °C) (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 °C); 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 °C).
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.
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 °C) 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 NO_x analyser it shall have minimum effect on NO_x 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 NO_x 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 °C).
HSL_1	Heated sampling line, temperature shall be kept at 453 to 473 K (180 to 200 °C); 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 °C).
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 °C); 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 °C) 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 flowmeters.
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.

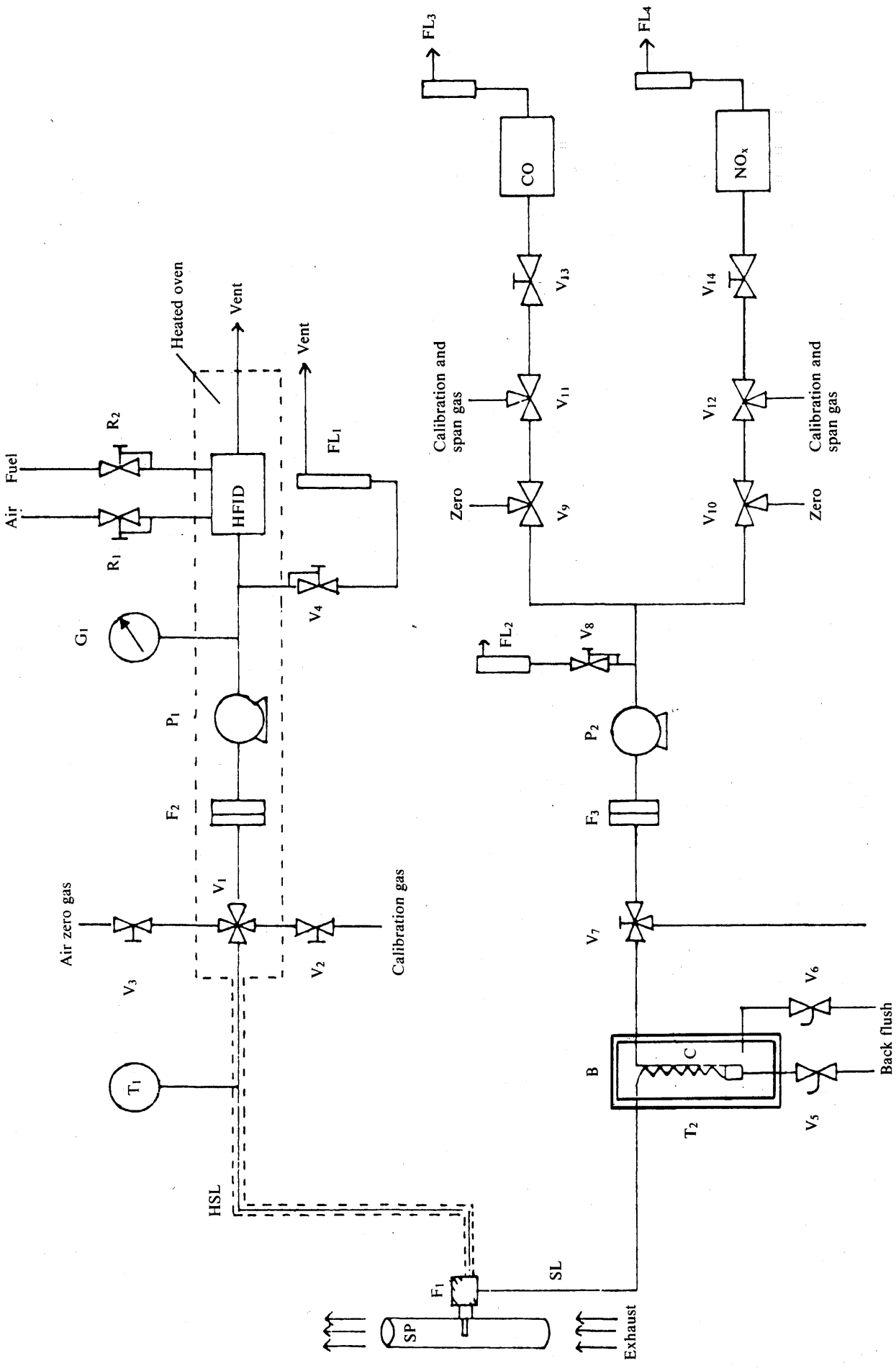


Figure 1

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

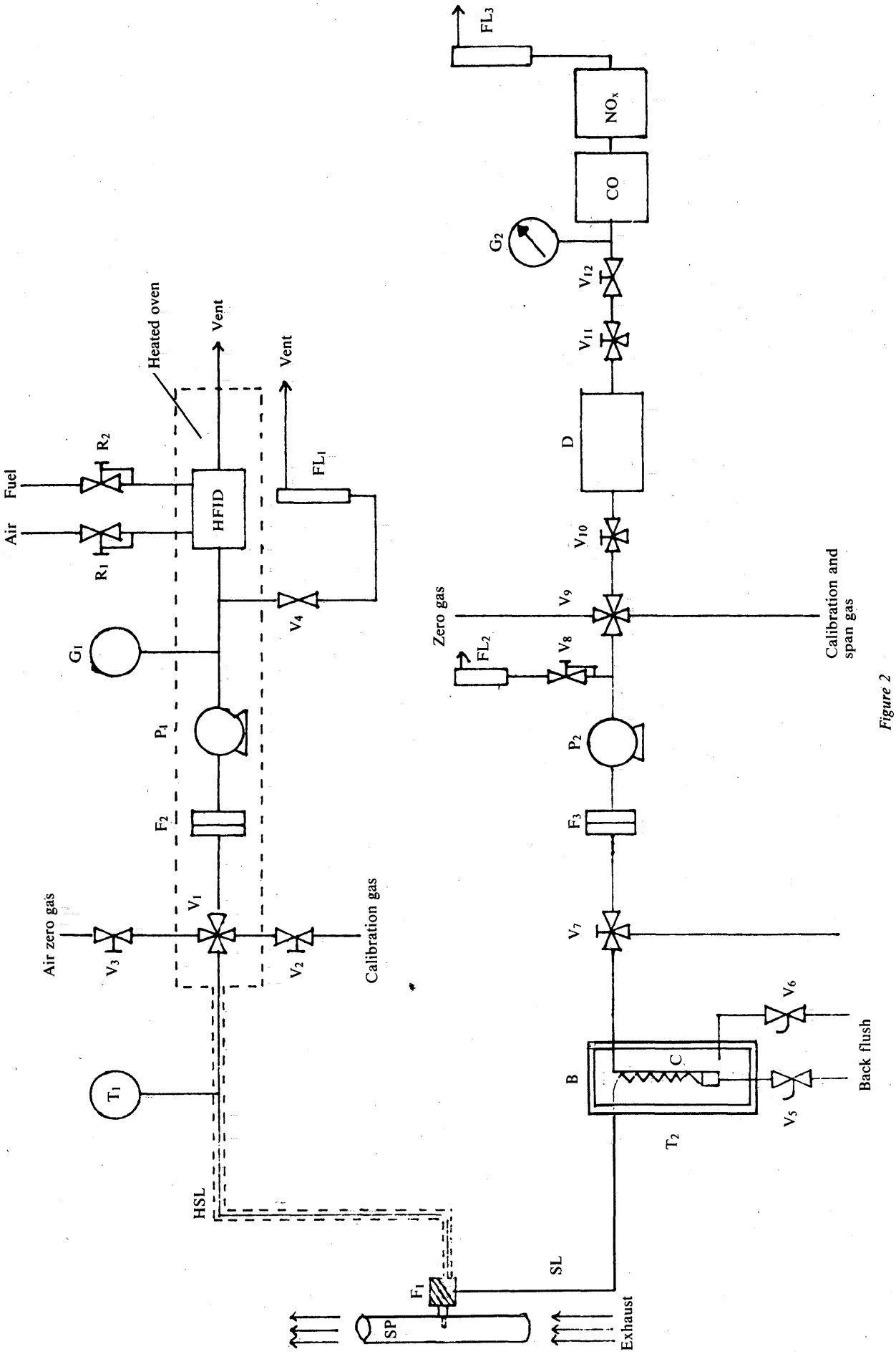


Figure 2

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

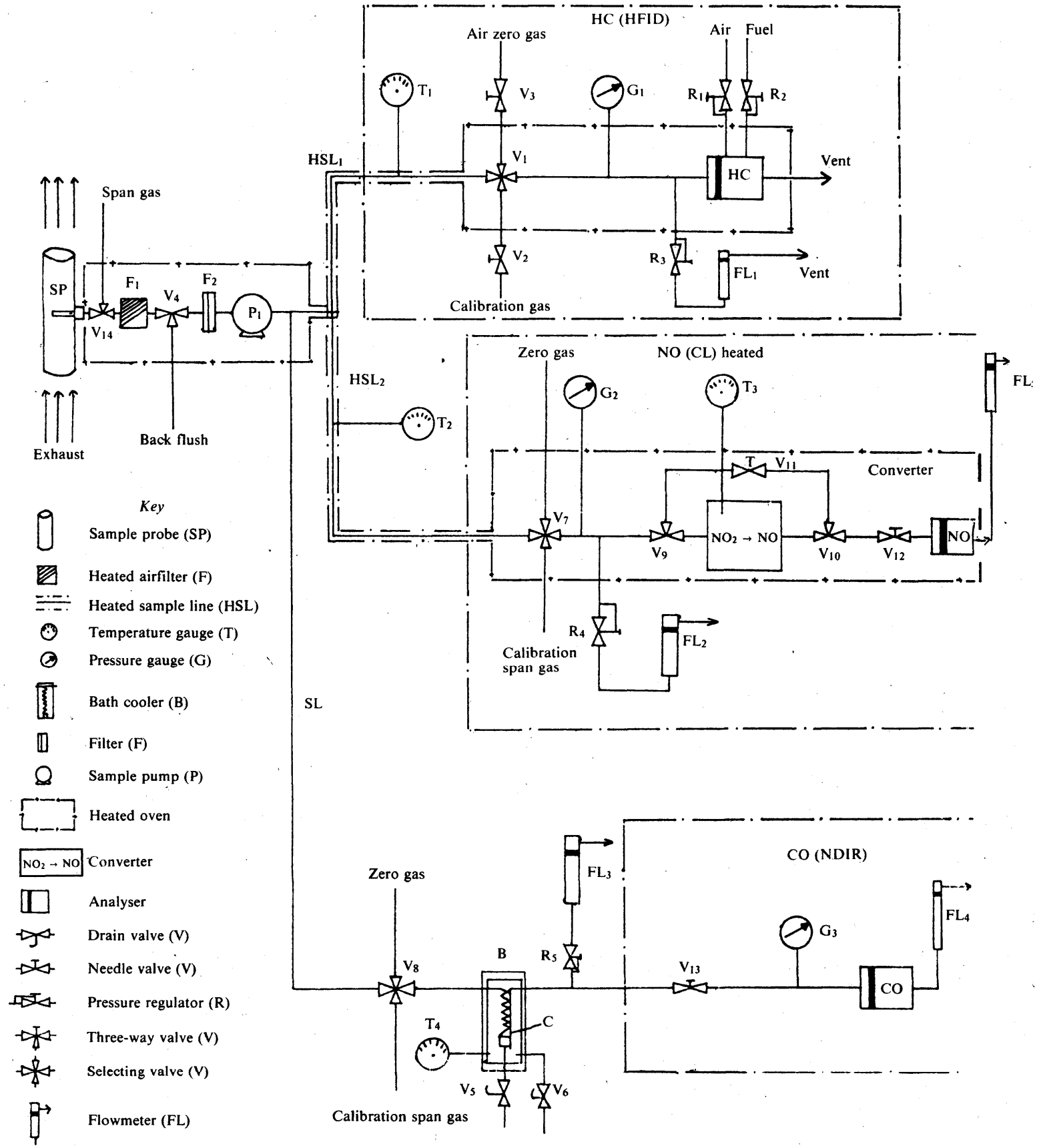


Figure 3

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

ANNEX VI

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:

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

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

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

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

.....

1.4. *Emission levels*

CO ..... g/kWh

HC ..... g/kWh

NO_x ..... g/kWh

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

.....

(1) Delete as appropriate.