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12 October 1993

AGREEMENT

CONCERNING THE ADOPTION OF UNIFORM CONDITIONS OF APPROVAL AND RECIPROCAL RECOGNITION OF APPROVAL FOR MOTOR VEHICLE EQUIPMENT AND PARTS

done at Geneva on 20 March 1958

Addendum 48: Regulation No.49

Revision 2

Incorporating:

the 01 series of amendments - Date of entry into force: 14 May 1990
the 02 series of amendments - Date of entry into force: 13 December 1992
the corrigendum 1 to the 02 series of amendments referred to in the depositary notification C.V.232.1992.TREATIES-32 of 11 September 1992

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF COMPRESSION IGNITION (C.I.) ENGINES AND VEHICLES EQUIPPED WITH C.I. ENGINES WITH REGARD TO THE EMISSIONS OF POLLUTANTS BY THE ENGINE

UNITED NATIONS

Regulation No.49

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UNIFORM PROVISIONS CONCERNING THE APPROVAL OF COMPRESSION IGNITION (C.I.) ENGINES AND VEHICLES EQUIPPED WITH C.I. ENGINES WITH REGARD TO THE EMISSIONS OF POLLUTANTS BY THE ENGINE

1. SCOPE

This Regulation applies to the emission of gaseous and particulate pollutants from c.i. engines used for driving motor vehicles having a design speed exceeding 25 km/h of categories 1/, 2/ M1 having a total mass exceeding 3.5 tonnes, M2, M3, N1, N2 and N3.

2. DEFINITIONS AND ABBREVIATIONS

For the purposes of this Regulation,

2.1. "Approval of a vehicle" means the approval of a vehicle type with regard to the level of the emission of gaseous and particulate pollutants by the engine;

2.2. "Approval of an engine" means the approval of an engine type with regard to the level of the emission of gaseous and particulate pollutants;

2.3. "compression ignition (C.I.) engine" means an engine which works on the compression-ignition principle (eg. diesel engine);

2.4. "engine type" means a category of engines which do not differ in such essential respects as engine characteristics as defined in Annex 1 to this Regulation;

2.5. "vehicle type" means a category of vehicles which do not differ in such essential respects as engine and vehicle characteristics as defined in Annex 1 to this Regulation;

2.6. "gaseous pollutants" means carbon monoxide, hydrocarbons (assuming a ratio of $C_1 H_{1.85}$) and oxides of nitrogen, the last named being expressed in nitrogen dioxide (NO_2) equivalent;

2.7. "particulate pollutants" means any material collected on a specified filter medium after diluting c.i. engine exhaust gas with clean filtered air so that the temperature does not exceed 325 K (52°C);

2.8. "net power" means the power in ECE kW obtained on the test bench at the end of the crankshaft, or its equivalent, measured in accordance with the ECE method of

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1/ In conformity with consolidated Resolution R.E.3 (TRANS/SC1/WP29/78/Amend.3).

2/ C.I. engines used by category N1, N2 and M2 power-driven vehicles are not approved according to this Regulation, provided that such vehicles are approved according to Regulation No.83.

measuring the power of internal combustion engines for road vehicles; 3/

2.9. "rated speed" means the maximum full load speed allowed by the governor as specified by the manufacturer in his sales and service literature;

2.10. "per cent load" means the fraction of the maximum available torque at an engine speed;

2.11. "maximum torque speed" means the engine speed at which the maximum torque is obtained from the engine, as specified by the manufacturer.

2.12. "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;

2.13. Abbreviations and units

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

3/ As described in Regulation No.85.

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 the cross sectional areas of the sampling probe and the 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 ionisation detector;
NDUVR		non-dispersive ultraviolet resonance absorption;
NDIR		non-dispersive infrared;
HCLA		heated chemiluminescent analyser;
S	kW	dynamometer setting, as indicated in Annex 4, paragraph 4.2.4;
P_{min}	kW	minimum net engine power as indicated in line (e) in the table of paragraph 7.2. in Annex 1;
L		per cent load as indicated in paragraph 4.1. of Annex 4;
P_{aux}	kW	maximum permissible power absorbed by the engine-driven equipment as specified in paragraph 5 of Annex 2, Appendix 1, minus the total power absorbed by the engine-driven equipment during the test as specified in paragraph 6.2.2. of annex 1.

3. APPLICATION FOR APPROVAL

3.1. Application for approval of an 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 his duly accredited representative.

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

A description of the engine type comprising the particulars referred to in Annex 1 to this Regulation.

3.1.3. An engine conforming to the "engine type" characteristics described in Annex 1 shall be submitted to the technical service responsible for conducting the approval tests defined in paragraph 5.

3.2. Application for approval of a vehicle 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 his duly accredited representative.

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

A description of the engine type and of engine-related vehicle parts comprising the particulars referred to in Annex 1, as applicable, and a copy of the ECE Type-Approval Communication document (Annex 2A) for the engine as a separate technical unit which is installed in the vehicle type.

3.3. Arrangements for control of conformity of production

The competent authority shall verify the existence of satisfactory arrangements for ensuring effective control of the conformity of production before type approval is granted.

4. APPROVAL

4.1. If the engine or the vehicle submitted for approval pursuant to paragraph 3.1 or 3.2 of this Regulation meets the requirements of paragraphs 5 and 6 below, approval of that type of engine or the vehicle shall be granted.

4.2. An approval number shall be assigned to each type approved. Its first two digits (at present 02 corresponding to the 02 series of amendments which entered into force on 13 December 1992) shall indicate the series of amendments incorporating the most recent major technical amendments made to the Regulation at the time of issue of the approval. The same Contracting Party shall not assign the same number to another engine type or vehicle type.

4.3. Notice of approval or of extension or of refusal of approval or production definitely discontinued of an engine type or vehicle type pursuant to this Regulation shall be communicated to the Parties to the 1958 Agreement which apply this Regulation, by means of a form conforming to the model in Annex 2A or 2B, as applicable, to this Regulation. Values measured during the type test shall also be shown.

4.4. There shall be affixed, conspicuously and in a readily accessible place to every engine conforming to an engine type approved under this Regulation, or to every vehicle conforming to a vehicle type approved under this Regulation, an international approval mark consisting of:

4.4.1. a circle surrounding the letter "E" followed by the distinguishing number of the country which has granted approval; 4/

4.4.2. the number of this Regulation, followed by the letter "R", a dash and the approval number to the right of the circle prescribed in paragraph 4.4.1.

4.4.3. an additional symbol consisting of the letter A or B indicating the emission level (paragraph 5.2.1.) according to which the engine/vehicle has been approved.

4.5. If the vehicle or engine conforms to an approved type under one or more other Regulations annexed to the Agreement, in the country which has granted approval under this Regulation, the symbol prescribed in paragraph 4.4.1 need not be repeated; in such a case, the regulation and approval numbers and the additional symbols of all the Regulations under which approval has been granted under this Regulation shall be placed in vertical columns to the right of the symbol prescribed in paragraph 4.4.1.

4.6. The approval mark shall be placed close to or on the data plate affixed by the manufacturer to the approved type.

4.7. Annex 3 to this Regulation gives examples of arrangements of approval marks.

4.8. The engine approved as a technical unit must bear, in addition to the approval mark:

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

4.8.2. the manufacturer's commercial description.

4.9. These marks must be clearly legible and indelible.

5. SPECIFICATIONS AND TESTS

5.1. General

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

4/ 1 for Germany, 2 for France, 3 for Italy, 4 for The Netherlands, 5 for Sweden, 6 for Belgium, 7 for Hungary, 8 for the Czech Republic, 9 for Spain, 10 for Yugoslavia, 11 for United Kingdom, 12 for Austria, 13 for Luxembourg, 14 for Switzerland, 15 (vacant), 16 for Norway, 17 for Finland, 18 for Denmark, 19 for Romania, 20 for Poland, 21 for Portugal, 22 for the Russian Federation, 23 for Greece, 24, 25 (vacant) and 26 for Slovenia. Subsequent numbers shall be assigned to other countries in the chronological order in which they ratify the Agreement concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts, or in which they accede to that Agreement, and the numbers thus assigned shall be communicated by the Secretary-General of the United Nations to the Contracting Parties to the Agreement.

5.2. Specifications concerning 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 4. Annex 4, appendix 4 describes the recommended analytical systems for the gaseous and particulate 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 Regulation, the determination of equivalency must be based upon the calculation of repeatability and reproducibility by an inter-laboratory test, as described in ISO 5725.

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

	Mass of Carbon Monoxide (CO) g/kWh	Mass of Hydrocarbons (HC) g/kWh	Mass of Oxides of Nitrogen (NOx) g/kWh	Mass of Particulates (PT) g/kWh
A (1.7.92)	4.5	1.1	8.0	0.36 */
B (1.10.95)	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 shown for particulate emissions.

**/ If necessary, this limit value for particulate emissions will be revised upwards, depending upon the availability of technologies for controlling air polluting emissions from diesel engines, particularly those of less than 85 kW.

6. INSTALLATION ON THE VEHICLE

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

6.1.1. Intake depression shall not exceed that specified for the type-approved engine in Annex 2A.

6.1.2. Exhaust back pressure shall not exceed that specified for the type-approved engine in Annex 2A.

6.1.3. Maximum power absorbed by the engine-driven equipment shall not exceed the maximum permissible power specified for the type approved engine in Annex 2A.

7. CONFORMITY OF PRODUCTION

7.1. Every engine or vehicle bearing an approval mark as prescribed under this Regulation shall be so manufactured as to conform, with regard to the description as given in the approval form and its annexes, to the approved type.

7.2. In order to verify that the requirements of paragraph 7.1 are met, suitable controls of the production shall be carried out.

7.3. The holder of the approval shall in particular:

7.3.1. ensure existence of procedures for the effective control of the quality of the product.

7.3.2. have access to the control equipment necessary for checking the conformity to each approved type.

7.3.3. ensure that data of test results are recorded and that annexed documents shall remain available for a period to be determined in accordance with the administrative service.

7.3.4. analyse the results of each type of test, in order to verify and ensure the stability of the engine characteristics, making allowance for variations in the industrial production process.

7.3.5. ensure that any sampling of engines or components giving evidence of non-conformity with the type of test considered shall give rise to another sampling and another test. All the necessary steps shall be taken to re-establish the conformity of the corresponding production.

7.4. The competent authority which has granted type-approval may at any time verify the conformity control methods applicable to each production unit.

7.4.1. In every inspection, the test books and production survey records shall be presented to the visiting inspector.

7.4.2. When the quality level appears unsatisfactory or when it seems necessary to verify the validity of the data presented in application of paragraph 7.4.1, the following procedure is adopted:

7.4.2.1. An engine is taken from the series and subjected to the test described in Annex 4. The mass of the carbon monoxide, the mass of the hydrocarbons, the mass of the oxides of nitrogen and the mass of the particulates must not exceed the amounts shown in the table below:

	Mass of Carbon Monoxide (CO) g/kWh	Mass of Hydrocarbons (HC) g/kWh	Mass of Oxides of Nitrogen (NOx) g/kWh	Mass of Particulates (PT) g/kWh
A (1.10.93)	4.9	1.23	9.0	0.40 */
B***/ (1.10.96)	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 shown for particulate emissions.

**/ If necessary, this limit value for particulate emissions will be revised upwards, depending upon the availability of technologies for controlling air polluting emissions from diesel engines, particularly those of less than 85 kW.

***/ For the application of the limit values of step B a new statistical method for monitoring of the production conformity will be adopted.

7.4.2.2. If the engine taken from the series does not satisfy the requirements of paragraph 7.4.2.1. the manufacturer may ask for measurements to be performed on a sample of engines taken from the series and including the vehicle 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 subject to a test. The arithmetical mean ($\bar{x}$) of the results obtained from the sample is then determined for each pollutant. The production of the series shall then be deemed to conform if the following condition is met:

$$\bar{x} + k.S \leq L \text{ 5/}$$

where:

L is the limit value laid down in paragraph 7.4.2.1. for each pollutant considered; and

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

5/

$$S^2 = \frac{\sum (x-\bar{x})^2}{n-1}$$

where x is any one of the individual results obtained with the sample n.

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

$$if\ n \geq 20, \quad k = \frac{0.860}{\sqrt{n}}$$

7.4.3. 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.

7.4.4. The normal frequency of inspections authorised by the competent authority shall be 1 per year. If the requirements of paragraph 7.4.2 are not met, the competent authority shall ensure that all necessary steps are taken to re-establish the conformity of production as rapidly as possible.

8. PENALTIES FOR NON-CONFORMITY OF PRODUCTION

8.1. The approval granted in respect of an engine type pursuant to this Regulation may be withdrawn if the requirements laid down in paragraph 7.1. are not complied with or if the engine or engines taken fail to pass the tests prescribed in paragraph 7.4.

8.2. If a Contracting Party to the 1958 Agreement applying this Regulation withdraws an approval it has previously granted, it shall forthwith so notify the other Contracting Parties applying this Regulation, by means of a communication form conforming to the model in Annexes 2A or 2B to this Regulation.

9. MODIFICATION AND EXTENSION OF APPROVAL OF THE APPROVED TYPE

9.1. Every modification of the approved type shall be notified to the administrative department which approved the type. The department may then either:

9.1.1. Consider that the modifications made are unlikely to have an appreciable adverse effect and that in any case the modified type still complies with the requirement; or

9.1.2. Require a further test report from the technical service conducting the tests.

9.2. Confirmation or refusal of approval, specifying the alterations, shall be communicated by the procedure specified in paragraph 4.3 to the Parties to the 1958 Agreement which apply this Regulation.

9.3. The competent authority issuing the extension of approval shall assign a series number for such an extension and inform thereof the other Parties to the 1958 Agreement applying this Regulation by means of a communication form conforming to the model in Annexes 2A or 2B to this Regulation.

10. PRODUCTION DEFINITELY DISCONTINUED

If the holder of the approval completely ceases to manufacture the type approved in accordance with this Regulation he shall so inform the authority which granted the approval. Upon receiving the relevant communication that authority shall inform thereof the other Parties to the 1958 Agreement which apply this Regulation by means of a communication form conforming to the model in Annexes 2A or 2B to this Regulation.

11. TRANSITORY PROVISIONS

11.1. From the date of entry into force of this 02 series of amendments, Parties to the Agreement may no longer issue approvals to the 01 series of amendments to this Regulation.

11.2. From 1 October 1993 approvals granted under the 01 series of amendments to this Regulation shall cease to be valid.

11.3. From 1 October 1995 Parties to the Agreement may no longer issue approvals to this Regulation unless the emissions of gaseous and particulate pollutants from the engine comply with the limit values set out in line B of the table in paragraph 5.2.1.

11.4. From 1 October 1996 approvals granted under this Regulation shall cease to be valid unless the emissions of gaseous and particulate pollutants from the engine comply with the limit values set out in line B of the table in paragraph 5.2.1.

12. NAMES AND ADDRESSES OF TECHNICAL SERVICES RESPONSIBLE FOR CONDUCTING APPROVAL TESTS AND OF ADMINISTRATIVE DEPARTMENTS

The Parties to the 1958 Agreement applying this Regulation shall communicate to the United Nations Secretariat the names and addresses of the technical services responsible for conducting approval tests and the administrative departments which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval, issued in other countries, are to be sent.

Annex 1

ESSENTIAL CHARACTERISTICS OF THE ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TEST

1. Description of Engine

1.1. Manufacturer: .....
1.2. Manufacturer's engine code: .....
1.3. Cycle: four stroke/two stroke 1/
1.4. Bore: ..... mm
1.5. Stroke: ..... mm
1.6. Number and layout of cylinders: .....
1.7. Engine capacity: ..... cm^3
1.8. Rated Speed: .....
1.9. Maximum Torque Speed: .....
1.10. Volumetric compression ratio 2/: .....
1.11. Combustion system description: .....
1.12. Drawing(s) of combustion chamber and piston crown
1.13. Minimum cross-sectional area of inlet and outlet ports: .....
1.14. Cooling system
1.14.1. Liquid
1.14.1.1. Nature of liquid: .....
1.14.1.2. Circulating pump(s): yes/no 1/
1.14.1.3. Characteristics or make(s) and type(s) (if applicable): .....
1.14.1.4. Drive ratio(s) (if applicable): .....
1.14.2. Air
1.14.2.1. Blower: yes/no 1/
1.14.2.2. Characteristics or make(s) and type(s) (if applicable): .....
1.14.2.3. Drive ratio(s) (if applicable): .....
1.15. Temperature permitted by the manufacturer
1.15.1. Liquid cooling: Maximum temperature at outlet: ..... K
1.15.2. Air cooling: Reference point: .....
Maximum temperature at reference point: ..... K
1.15.3. Maximum charge air outlet temperature of the inlet intercooler (if applicable): ..... K
1.15.4. Maximum exhaust temperature at the point in the exhaust pipe(s) adjacent to the outer flange(s) of the exhaust manifold(s): ..... K
1.15.5. Fuel temperature: min:..... K, max:..... K
1.15.6. Lubricant temperature: min ... K, max:..... K
1.16. Pressure charger: yes/no 1/
1.16.1. Make: .....
1.16.2. Type: .....
1.16.3. Description of the system (eg: max charge pressure, wastegate, if applicable): .....

1/ Strike out what does not apply.

2/ Specify the tolerance.

1.16.4. Intercooler: yes/no 1/
1.17. Intake system: Maximum allowable intake depression at rated engine speed and at 100% load: ..... kPa
1.18. 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): .....
3. Fuel feed
3.1. Feed pump
Pressure 2/:. . . . . .kPa or characteristics 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 2/: ..... rpm
3.2.4.4. Maximum no-load speed 2/: ..... rpm
3.2.4.5. Idling speed 2/: ..... 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 or equivalent data: .....
4.2. Reference and/or setting ranges 1/
5. Engine-driven equipment
Maximum permissible power, declared by the manufacturer absorbed by the

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1/ Strike out what does not apply.

2/ Specify the tolerance.

engine-driven equipment as specified in and under the operating conditions of the UN/ECE Regulation No. 85 regarding the measurement of the engine power, at the engine speeds defined in paragraphs 2.9. and 2.12. of the Definitions and Abbreviations to this Regulation.

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 (if applicable)

6.2.1. Enumeration and identifying details: . . . . . .

6.2.2. Power absorbed at indicated engine speeds (as specified by the manufacturer):

Equipment	Power absorbed (kW) at various engine speeds	
	Intermediate	Rated
Total:		

6.3. Dynamometer setting (kW)

Per cent load	Dynamometer setting (kW) at various engine speeds	
	Intermediate	Rated
10		
25		
50		
75		
100		

7. Engine performance

7.1. Engine speeds

Idle: ..... rpm
Intermediate: ..... rpm
Rated: ..... rpm

7.2. Engine power 1/

Condition	Power (kW) at various engine speeds	
	Intermediate	Rated
Maximum power measured on test kW (a)		
Total power absorbed by engine driven equipment as per paragraph 6.2. kW (b)		
Gross engine power kW (c)		
Maximum permissible power absorbed as per paragraph 5 kW (d)		
Minimum net engine power kW (e)		

$c = a + b$ and $e = c - d$

1/ Measured in accordance with the provision of UN/ECE Regulation No.85.

Annex 1 - Appendix

CHARACTERISTICS OF THE ENGINE-RELATED VEHICLE PARTS
(FOR TYPE APPROVAL OF A VEHICLE TYPE IN RESPECT OF
ITS ENGINE)

1. Description of vehicle

1.1. Make: .....
1.2. Type: .....
1.3. Name and address of manufacturer: .....
1.4. Engine type and approval number: .....

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

3. Exhaust system back pressure at rated engine rpm and at 100% load 1/: ..... kPa

4. Power absorbed by the engine-driven equipment as specified in and under the operation conditions of the UN/ECE Regulation No. 85 regarding the measurement of the engine power at the engine speeds defined in paragraphs 2.9 and 2.12 of the Definitions and Abbreviations to this Regulation.

Equipment	Power absorbed (kW) at engine speed	
	Intermediate	Rated
Total:		

1/ To be within the limits specified in paragraph 1.17. and 1.18. of Annex 1.

Annex 2A

COMMUNICATION

(Maximum format: A4 (210 x 297 mm))

issued by: Name of administration

. . . . . .
. . . . . .
. . . . . .

concerning 2/: APPROVAL GRANTED
APPROVAL EXTENDED
APPROVAL REFUSED
APPROVAL WITHDRAWN
PRODUCTION DEFINITELY DISCONTINUED

of a diesel engine type as a separate technical unit with regard to the emission of pollutants pursuant to Regulation No.49.

Approval No. ..... Extension No. .....

1. Trade name or mark of the engine: . . . . . .
2. Engine type: . . . . . .
3. Manufacturer's name and address: . . . . . .
4. If applicable, name and address of manufacturer's representative: . . . . . .
5. Maximum allowable intake depression: . . . . . kPa
6. Maximum allowable back pressure: . . . . . kPa
7. Maximum permissible power absorbed by the engine-driven equipment:
   Intermediate:. . . . . .kW; Rated: . . . . . kW
8. Restrictions of use (if any): . . . . . .
9. Emission levels - 13 mode emission test values:
   CO: ..... g/kWh; HC: ..... g/kWh; NOx: ..... g/kWh;
   PT: ..... g/kWh determined by a full/partial flow system 2/

1/ Distinguishing number of the country which has granted/extende/refused/with-drawn approval (see approval provisions in the Regulation)

2/ Strike out what does not apply.

10. Engine submitted for tests on: .....
11. Technical service responsible for conducting the approval tests: .....
12. Date of test report issued by that service: .....
13. Number of test report issued by that service: .....
14. Site of approval mark on the engine: .....
15. Place: .....
16. Date: .....
17. Signature: .....
18. The following documents, bearing the approval number shown above, are annexed to this communication:

One copy of Annex 1 to this Regulation completed and with the drawings and diagrams referred to attached.

Annex 2B

COMMUNICATION

(Maximum format: A4 (210 x 297 mm))

issued by: Name of administration

. . . . . .
. . . . . .
. . . . . .

concerning 2/: APPROVAL GRANTED
APPROVAL EXTENDED
APPROVAL REFUSED
APPROVAL WITHDRAWN
PRODUCTION DEFINITELY DISCONTINUED

of a vehicle type with regard to the emission of pollutants by the engine pursuant to UN/ECE Regulation No.49.

Approval No. ..... Extension No. .....

1. Trade name or mark of the engine: . . . . . .
2. Vehicle type: . . . . . .
3. Manufacturer's name and address: . . . . . .
4. If applicable, name and address of manufacturer's representative: . . . . . .
5. Maximum allowable intake depression: . . . . . kPa
6. Maximum allowable back pressure: . . . . . kPa
7. Maximum permissible power absorbed by the engine-driven equipment:
   Intermediate:. . . . . .kW; Rated: . . . . . kW
8. Make and type of the engine: . . . . . .
9. Emission levels

1/ Distinguishing number of the country which has granted/extende/refused/with-drawn approval (see approval provisions in the Regulation)

2/ Strike out what does not apply.

9.1. 13 mode emission test values 2/

CO: ..... g/kWh; HC: ..... g/kWh; NOx: ..... g/kWh; PT: ..... g/kWh determined by a full/partial flow system 2/

9.2. Or, if the engine has been type approved as a separate technical unit 2/

9.2.1. Type approval number of the engine: .....

9.2.2. Holder of the engine approval: .....

10. Engine submitted for tests on: .....

11. Technical service responsible forconductingthe approval tests: .....

12. Date of test report issued by that service: .....

13. Number of test report issued by that service: .....

14. Site of approval mark on the vehicle/engine 2/: .....

15. Place: .....

16. Date: .....

17. Signature: .....

18. The following documents, bearing the approval number shown above, are annexed to this communication:

One copy of Annex 1 to this Regulation completed and with the drawings and diagrams referred to attached.

2/ Strike out what does not apply.

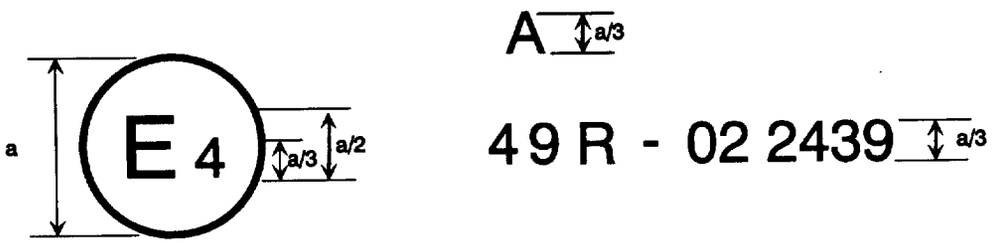
Annex 3

ARRANGEMENTS OF APPROVAL MARKS

I. ENGINES/VEHICLES APPROVED TO THE EMISSION LEVELS A (para. 5.2.1.)

Model A

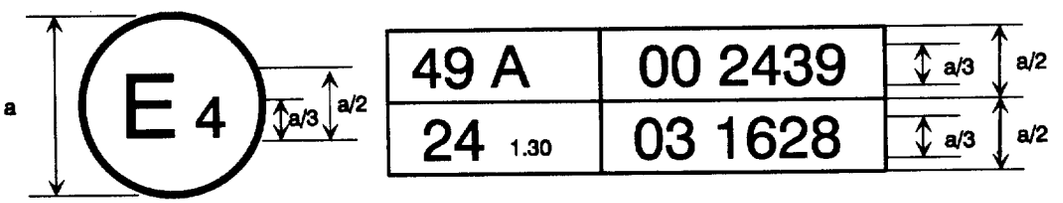
(See paragraph 4.4 of this Regulation)



The above approval mark affixed to an engine/vehicle shows that the engine/vehicle type concerned has been approved in the Netherlands (E4) pursuant to Regulation No.49 (emission level A) and under approval number 022439. The first two digits of the approval number indicate that, at the time of approval, Regulation No.49 already included the 02 series of amendments.

Model B

(See paragraph 4.5 of this Regulation)



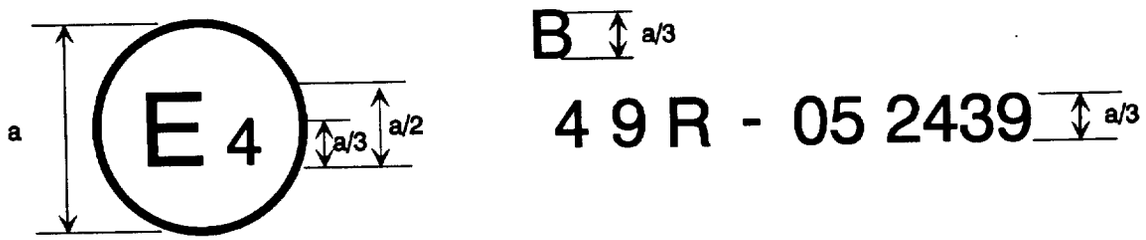
The above approval mark affixed to an engine/vehicle shows that the engine/vehicle type concerned has been approved in the Netherlands (E4) pursuant to Regulation No.49 (emission level A) and Regulation No.24 1/. The first two digits of the approval numbers indicate that, at the dates when the respective approvals were given, Regulation No.49 included the 02 series of amendments, while Regulation No.24 already included the 03 series of amendments.

1/ The second Regulation number is given merely as an example; the corrected absorption coefficient is 1.30 m^{-1}.

II. ENGINES/VEHICLES APPROVED TO THE EMISSION LEVELS B (para. 5.2.1.)

Model A

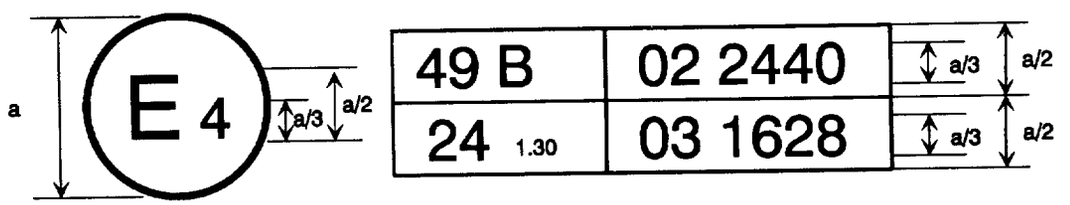
(See paragraph 4.4 of this Regulation)



The above approval mark affixed to an engine/vehicle shows that the engine/vehicle type concerned has been approved in the Netherlands (E4) pursuant to Regulation No.49 (emission level B) and under approval number 022439. The first two digits of the approval number indicates that, at the time of approval, Regulation No.49 already included the 02 series of amendments.

Model B

(See paragraph 4.5 of this Regulation)



The above approval mark affixed to an engine/vehicle shows that the engine/vehicle type concerned has been approved in the Netherlands (E4) pursuant to Regulation No.49 (emission level B) and Regulation No.24 1/. The first two digits of the approval numbers indicate that, at the dates when the respective approvals were given, Regulation No.49 included the 02 series of amendments, while Regulation No.24 already included the 03 series of amendments.

1/ The second Regulation number is given merely as an example; the corrected absorption coefficient is 1.30 m^{-1}.

Annex 4

TEST PROCEDURE

1. Introduction

1.1. This Annex describes the method of determining emissions of gaseous and particulate 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. Engine test conditions

2.1. The absolute temperature (T) of the engine air at the inlet to the engine expressed in Kelvin, and the dry atmospheric pressure (ps), expressed in kilopascals, shall be measured and the parameter F shall be determined according to the following provisions:

2.2. Naturally aspirated and mechanically supercharged engines:

$$F = \left(\frac{99}{ps}\right) \times \left(\frac{T}{298}\right)^{0.7}$$

2.3. Turbo-charged engines with or without cooling of inlet air:

$$F = \left(\frac{99}{ps}\right)^{0.7} \times \left(\frac{T}{298}\right)^{1.5}$$

2.4. For a test to be recognized as valid, the parameter F shall be such that;

$$0.96 \leq F \leq 1.06$$

3. Fuel

The fuel shall be the reference fuel specified in Annex 5.

4. Test Cycle

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

Mode Number	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. Test run

At least two hours before the test each filter for measurement of the emission of particulate pollutants shall be placed in a closed but unsealed petri dish and placed in the 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 , or a sealed filter holder until needed for testing. If the filter is not used within one hour of its removal from the weighing chamber, it must be re-weighed 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 - 316K (33°C - 43°C). The governor and fuel system must be adjusted as established by the manufacturer's sales and service literature. The following steps are taken for each test:

4.2.1. 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 gas back pressure re-adjusted accordingly. The total flow must be set so as to keep the temperature of the diluted exhaust at or below 325 K (52°C) immediately before the particulate filters at the mode with the maximum heat flow as determined from exhaust flow and/or temperature;

4.2.2. the cooling system and the full-flow-dilution system, or partial-flow-dilution-system, respectively, are started;

4.2.3. the engine is started and warmed up until all temperatures and pressures have reached equilibrium;

4.2.4. the torque curve at full load must be determined by experimentation to calculate the torque values for the specified test modes; the maximum permissible power absorbed by engine-driven equipment, declared by the manufacturer to be applicable to the engine

type, is taken into account. The dynamometer setting for each engine speed and load are calculated using the formula;

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

where

s = dynamometer setting.

P_{min} = minimum net engine power as indicated in line (e) in the table of paragraph 7.2. of Annex 1.

L = per cent load as indicated in paragraph 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 Annex 1, paragraph 7.2.

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

The range of the exhaust gas velocity and the pressure oscillations is checked and adjusted according to the requirements of Annex 4, Appendix 4, if applicable.

4.2.6. the test sequence is started (see paragraph 4.1 of this Annex). 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 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 4, Appendix 4) 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 within ± 7% of the average of all modes. The sample mass drawn through the particulate filters (M_{SAM}) must be adjusted at each mode to take account of the total modal weighting factor and the exhaust or fuel mass flow rate (see Appendix 4). 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;

4.2.7. any additional data required for calculation shall be read and recorded (see paragraph 5 of this Annex).

4.2.8. 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 paragraph 2.3.2 of Appendix 1 to this Annex.

5. Data evaluation

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

5.2. 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 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.

Annex 4 - Appendix 1

MEASUREMENT AND SAMPLING PROCEDURES

1. Introduction

The emissions from the exhaust of the engine include hydrocarbons, carbon monoxide, oxides of nitrogen and particulates. During a prescribed test cycle the amounts of the above pollutants are examined continuously. The test cycle consists of a number of speed and power modes which span the typical operating range of diesel engines.

During each mode the concentration of each gaseous pollutant, exhaust flow and power output are determined and the measured values weighted. For particulates one sample over the complete test cycle is taken. All values are used to calculate the grammes of each pollutant emitted per kilowatt hour, as described in Appendix 3 to this Annex.

2. Equipment

2.1. Dynamometer and engine equipment

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

2.1.1. an engine dynamometer with adequate characteristics to perform the test cycle described in paragraph 4 of this Annex.

2.1.2. 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 must satisfy the ECE method of measuring the power of the internal combustion engines of road vehicles (UN/ECE Regulation No. 85); other instruments must have an accuracy which satisfies the following requirements;

2.1.2.1. Temperatures.

Temperatures shall be measured with an accuracy of ± 1.5 K (1.5°C).

2.1.2.2. Absolute humidity.

The absolute humidity (H) shall be determined to an accuracy of ± 5%.

2.1.3. an engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures for the duration of the prescribed engine tests;

2.1.4. a non-insulated and uncooled exhaust system extending at least 0.5 m past the point where the raw exhaust sample probes are located, and presenting an exhaust back pressure within ± 650 Pa (± 5 mm Hg) of the upper limit at the maximum rated power, as established by the engine manufacturers sale and service literature for vehicle

application.

2.1.5. 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.

2.2. Exhaust gas flow

For calculation of the emission it is necessary to know the exhaust gas flow (see paragraph 1.1.1. of Appendix 3 to this Annex). 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 CO shall be measured in the dry exhaust. The emissions of CO shall be calculated from the dry exhaust gas volume (V'_{EXH}). If the exhaust mass flow rate (G_{EXH}) is used in the calculation, the CO and NOx concentrations shall be related to the wet exhaust. Calculation of the HC emissions will include G_{EXH} and V''_{EXH} according to the measuring method used.

2.3. Analytical and sampling equipment

Appendix 4 of this Annex describes the analytical system for gaseous and particulate pollutants in current use. Other systems or analysers which have proved to give equivalent results may be used.

2.3.1. Analysers.

Pollutant gases shall be analysed with the following instruments:

2.3.1.1. Carbon Monoxide (CO) analysis.

The carbon monoxide analyser shall be of the non-dispersive infra-red (NDIR) absorption type.

2.3.1.2. Hydrocarbon (HC) analysis.

The hydrocarbon analyser shall be of the heated flame ionization (HFID). Due to the heavy hydrocarbons present in the diesel exhaust, the HFID system must be heated and maintained at a temperature of 453 - 473 K (180°C -200°C). It shall be calibrated in accordance with paragraph 4.5.2 of Appendix 2 to this Annex.

2.3.1.3. Oxides of nitrogen (NOx) analysis.

The nitrogen oxide analyser shall be of the chemiluminescent (CLA), heated chemiluminescent (HCLA) or equivalent type.

2.3.1.4. Carbon dioxide (CO_2) analysis (for calculating dilution ratio).

The carbon dioxide analyser shall be of the non-dispersive infra-red (NDIR) absorbtion type.

2.3.2. Accuracy.

The analysers shall have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample pollutants. The accuracy of the analysers shall be ± 2.5% of full-scale deflection or better. For concentrations of less than 100 ppm, the measurement error shall not exceed ± 3 ppm.

2.3.3. Gas drying.

Optional gas drying devices must have no effect on the pollutant content of the gas stream.

2.3.4. Sampling.

A heated sample line for continuous HC analysis with the flame ionization detector (HFID), including recorder (R) must be used. Throughout the test, the temperature of the complete sampling system must be maintained at a temperature of 453 - 473 K (180°C - 200°C). The heated sampling line must be fitted with a heated filter (F) (99% efficient with particles ≥ 0.3 μm) to extract any solid particles from the continuous flow of gas required for analysis. A second heated sample line for NOx analysis must be used. The temperature of this line must be controlled at 368 - 473 K (95°C - 200°C). The sample line for CO (CO_2) analysis may be heated or unheated.

2.3.5. Determination of the particulates.

The determination of the particulates requires a dilution system capable of maintaining the temperature of the diluted exhaust gas at or below 325 K (52°C) and preventing water condensation, a particulate sampling system, specified particulate sampling filters and a microgram balance which shall be placed in an air-conditioned weighing chamber. Dilution may be accomplished by a full-flow-dilution or a partial-flow-dilution system. Annex 4, Appendix 4 describes the analytical systems in current use. Other systems which have proved to give equivalent results may be used.

Annex 4 - Appendix 2

CALIBRATION PROCEDURE

1. Introduction

Each analyser shall be calibrated as often as necessary to fulfil the accuracy requirements of this Annex. The calibration method that shall be used is described in this Appendix for the analysers indicated in paragraph 2.3 of Appendix 1 to this Annex.

2. Gases

2.1. Pure gases

The following gases must be available if necessary for operation:

Purified nitrogen (Purity ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0.1 ppm NO);

Purified oxygen (Purity ≥ 99.5% vol 0_2);

Hydrogen mixture (40 ± 2% hydrogen, balance helium) (Purity ≤ 1 ppm C, ≤ 400 ppm CO);

Purified synthetic air (Purity ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0.1 ppm NO) (Oxygen content between 18 - 21% vol.).

2.2. Calibration and span gases

Gases having the following chemical compositions shall be available:

Mixture of:

C_3H_8 and purified synthetic air (see paragraph 2.1. above);

CO and purified nitrogen;

NO and purified nitrogen (the amount of NO_2 contained in this calibration gas must not exceed 5% of the NO content);

The true concentration of a calibration and span gas must be within ± 2% of the nominal value. All concentrations of calibration gases shall be given on a volume basis (volume percent or volume ppm).

The gases used for calibration and span must 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 and span gases may be determined to within ± 2%.

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 requirement shall be included.

4. Calibration procedure

4.1. The calibration procedure shall be carried out within one month preceding the emissions 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.

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

4.1.2. 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.

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

4.1.4. Using purified dry air (or nitrogen), the CO (CO_2 if used) and NOx analysers shall be set at zero; dry air must be used for the HC analyser. Using appropriate calibration gases, the analysers shall be reset.

4.1.5. The zero setting shall be rechecked and the procedure described in paragraph 4.1.4. above repeated, if necessary.

4.1.6. 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 calibration device measurements must be within ± 1.0% of the maximum operating range or ± 2.0% of the point, whichever is smaller.

4.1.7. 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.

4.1.8. 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.

4.2. Establishment of the Calibration Curve

4.2.1. Each normally used operating range is calibrated in accordance with the following procedure.

4.2.2. 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.

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

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

4.2.5. 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

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

4.3. Verification of the Calibration

4.3.1. Each normally used operating range shall be checked prior to each analysis in accordance with the following:

4.3.2. The calibration is checked by using a zero gas and a span gas whose nominal value is near to the supposed value to be analysed.

4.3.3. If, for the two points considered, the value found does not differ by more than ± 5% of the full scale from the theoretical value, the adjustment parameters may be modified. Should this not be the case, a new calibration curve shall be established in accordance with paragraph 4.2 of this Appendix.

4.3.4. After testing, zero gas and the same span gas will be used for rechecking. The analysis will be considered acceptable if the difference between the two measuring results is less than 2%.

4.4. Efficiency test of the NOx Converter

4.4.1. The efficiency of the converter used for the conversion of NO_2 into NO is tested as follows:

4.4.2. 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.

4.4.3. 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.

4.4.4. Via a T fitting, oxygen is added continuously to the gas flow until the concentration indicated is about 10% less than the indicated calibration concentration given in paragraph 4.4.3. Record the indicated concentration (c). The ozonator is kept deactivated throughout the process.

4.4.5. 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 paragraph 4.4.3. Record the indicated concentration (d).

4.4.6. 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).

4.4.7. The ozonator is now deactivated. The mixture of gases described in paragraph 4.4.4 passes through the converter into the detector. Record the indicated concentration (b).

4.4.8. With the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NO_2 reading of the analyser must then be no more than 5% above the figure given in paragraph 4.4.3.

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

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

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

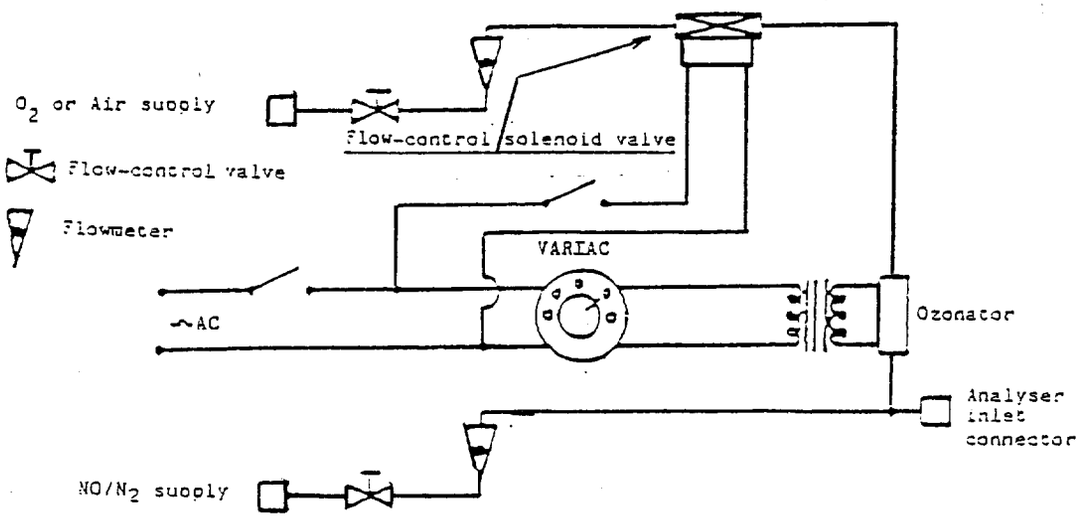


Diagram of NOx convertor efficiency device

4.4.11. The efficiency of the converter must not be less than 95%.

NOTE: 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.

4.5. Checking for FID hydrocarbon response

4.5.1. Detector response optimization.

The FID must be adjusted, as specified by the instrument manufacturer. Propane in air should be used, to optimize the response, on the most common operating range.

4.5.2. Calibration of the HC analyser.

The analyser should be calibrated using propane (C_3H_8) in air and purified synthetic air. See paragraph 2.2. of this Appendix (calibration and span gases).

Establish a calibration curve as described in paragraphs 4.2 to 4.3.4 of this Appendix.

4.5.3. Response factors of different hydrocarbons and recommended limits.

The response factor (Rf), for a particular hydrocarbon species is the ratio of the FID C1 reading to the gas cylinder concentration, expressed as ppm C1.

The concentration of the test gas must be at a level to give a response of approximately 80% of full scale deflection, for the operating range. The concentration must be known, to an accuracy of ± 2% in reference to a gravimetric standard expressed in volume. In addition the gas cylinder must be pre-conditioned for 24 hours at a temperature between 20°C and 30°C.

Response factors should be determined when introducing an analyser into service and thereafter at major service intervals. The test gases to be used and the recommended response factors are:

Methane and purified air	$1.00 \leq Rf \leq 1.15$
Propylene and purified air	$0.90 \leq Rf \leq 1.00$
Toluene and purified air	$0.90 \leq Rf \leq 1.00$

Relative to a response factor (Rf) of 1.00 for propane and purified air.

4.5.4. Oxygen interference check and recommended limits.

The response factor should be determined as described in paragraph 4.5.3 above. The test gas to be used and recommended response factor range are:

Propane and nitrogen	$0.95 \leq Rf \leq 1.05$

Annex 4 - Appendix 3

CALCULATION OF GASEOUS AND PARTICULATE EMISSIONS

1. Calculation.

1.1. The final reported test results of the gaseous emissions are derived through the following steps:

1.1.1. The exhaust gas mass flow rate G_{EXH} or V''_{EXH} and V'_{EXH} shall be determined (see paragraph 2.2. of Appendix 1) for each mode;

1.1.2. When applying G_{EXH} the measured concentrations are converted to a wet basis according to paragraph 1.1.2.1. below, if not already measured on a wet basis.

1.1.2.1. Exhaust gas concentrations measured on a dry basis are converted to a wet basis, which represents the condition in the exhaust, according to the following relationship:

- ppm (wet basis) = ppm (dry basis) x $(1 - 1.85\ G_{FUEL}/G_{AIR})$

where;

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

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

1.1.3. The NOx concentration shall be corrected for humidity according to paragraph 1.1.3.1. below.

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

$$\frac{1}{1 + A\,(7H-75) + B \times 1.8\,(T-302)}$$

where;

$$A = 0.044\ \frac{G_{FUEL}}{G_{AIR}} - 0.0038$$

$$B = -0.116\ \frac{G_{FUEL}}{G_{AIR}} + 0.0053$$

T = temperature of the air in K

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

H = humidity of the inlet air in grammes of water per kilogramme of dry air

in which;

$$H = \frac{6.211 \cdot R_a \cdot P_d}{P_B - P_d \cdot R_a \cdot 10^{-2}}$$

where;

R_a = Relative humidity of the ambient air expressed in %

P_d = Saturation vapour pressure at ambient temperature expressed in kPa

P_B = Atmospheric pressure expressed in kPa

1.1.4. The pollutant mass flow for each mode shall be calculated as follows:

(1) $NOx_{mass} = 0.001587 \times NOx_{conc} \times G_{EXH}$

(2) $CO_{mass} = 0.000966 \times CO_{conc} \times G_{EXH}$

(3) $HC_{mass} = 0.000478 \times HC_{conc} \times G_{EXH}$

or,

(1) $NOx_{mass} = 0.00205 \times NOx_{conc} \times V'_{EXH}$ (dry)

(2) $NOx_{mass} = 0.00205 \times NOx_{conc} \times V''_{EXH}$ (wet)

(3) $CO_{mass} = 0.00125 \times CO_{conc} \times V'_{EXH}$ (dry)

(4) $HC_{mass} = 0.000618 \times HC_{conc} \times V''_{EXH}$ (wet)

1.1.5. The emissions shall be calculated in the following way:

$$\overline{NOx} = \frac{\sum NOx_{mass,i} \times WF_i}{\sum (P_i - P_{aux,i}) \times WF_i}$$

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

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

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

Mode Number	Weighting Factor (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

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

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

1.2.1. The particulate mass flow rate is calculated as follows:

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

or,

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

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

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

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

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

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

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

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

or,

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

The value of the effective weighting factors must be within ± 0.003 of the weighting factors listed in paragraph 1.1.5. of this Appendix.

1.2.4. The final reported test results of the particulate emission are derived through the following steps, when using the full-flow-dilution system (Annex 4, Appendix 4, System 2):

1.2.4.1. 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 paragraph 1.2.2.

1.2.4.2. When using a single-dilution system, M_{SAM} is the mass through the sampling filters (GF1 in Annex 4, Appendix 4, System 2).

1.2.4.3. When using a double-dilution system, M_{SAM} is the mass through the sampling filters (GF1 in Annex 4, Appendix 4, System 2) minus the mass of the secondary dilution air (GF2 in Annex 4, Appendix 4, System 2).

1.3. The final reported test results of the particulate emission shall be derived through the following steps, when using the partial-flow-dilution-system (Annex 4, Appendix 4, System 3). 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.

1.3.1. Fractional sampling type with isokinetic probe

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

or,

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

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

or,

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

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

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

1.3.2. Fractional sampling type with CO_2 or NOx measurement

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

or,

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

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

where;

$conc_E$ = concentration of the raw exhaust
$conc_D$ = concentration of the diluted exhaust
$conc_A$ = concentration of the dilution air

Concentrations measured on a dry basis are converted to a wet basis according to paragraph 1.1.2.1. of this Appendix.

1.3.3. Total sampling type with CO_2 measurement and carbon balance method

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

where;

CO_{2D} = CO_2 concentration of the diluted exhaust gases
CO_{2A} = CO_2 concentration of the dilution air

(concentrations in vol.% on wet basis)

This equation is based upon the carbon balance assumption (carbon atoms supplied to the engine are emitted as CO_2) and derived through the following steps;

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

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

1.3.4. Total sampling type with mass flow control

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

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

Annex 4 - Appendix 4

ANALYTICAL AND SAMPLING SYSTEMS

1. Determination of the gaseous emissions

1.1. SYSTEM 1 (HCLA OR EQUIVALENT SYSTEM)

A schematic diagram of the analytical and sampling system using HCLA or equivalent systems for measuring NOx is shown in Figure 1 of this Appendix.

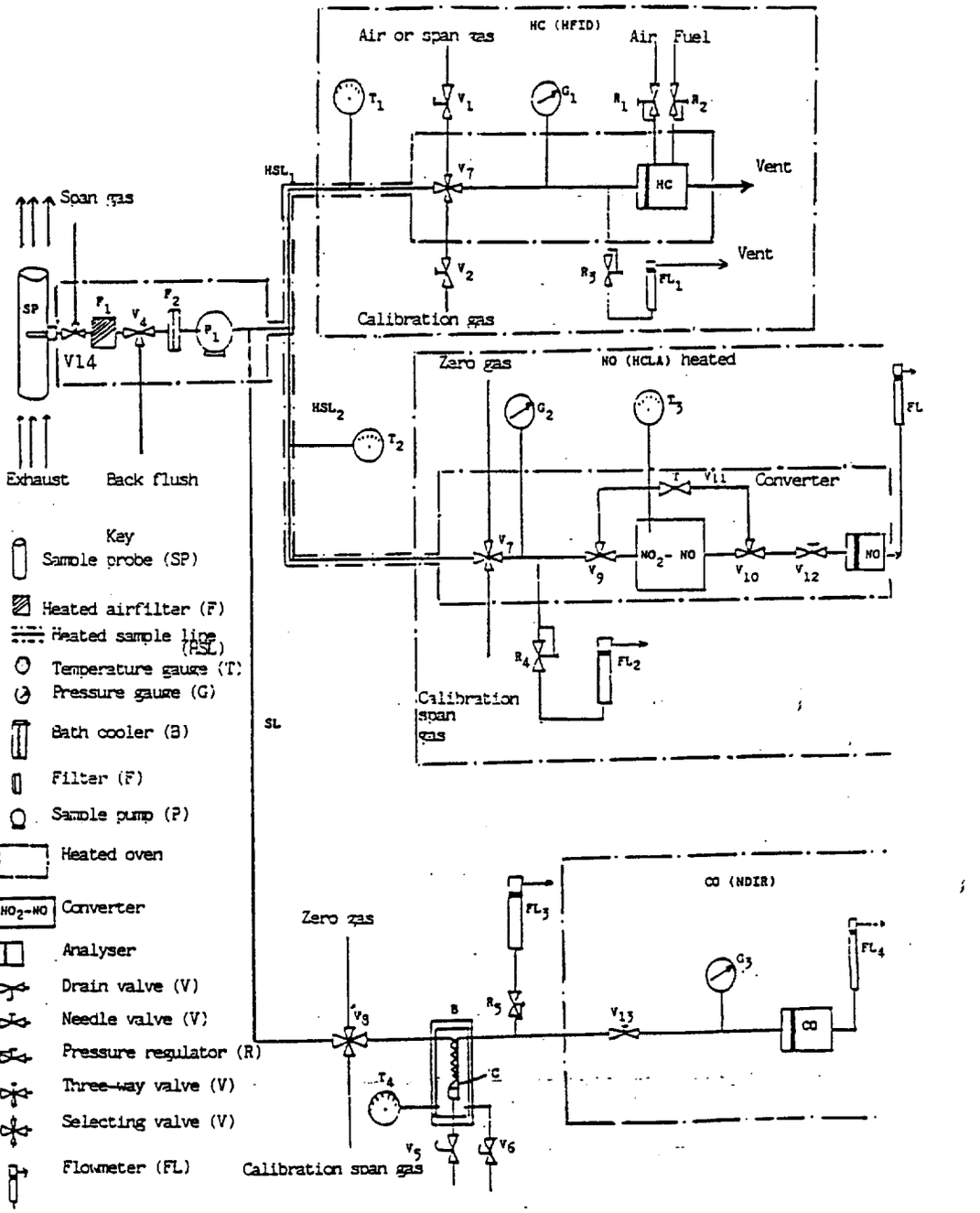
SP	-	Stainless steel sample probe, to obtain samples from exhaust system. A closed end, multi-hole straight probe extending at least 80% across the exhaust pipe is recommended. The exhaust gas temperature at the probe shall be not less than 343 K (70°C).
HSL1	-	Heated sampling line, temperature shall be kept at 453 - 473 K (180°C - 200°C); the line shall be made in stainless steel or PTFE.
F1	-	Heated pre-filter, if used; temperature shall be the same as HSL1.
T1	-	Temperature readout of sample streams entering oven compartment.
V1	-	Suitable valve for selecting sample, span gas or air or gas flow to the system. The valve shall be in the oven compartment or heated to the temperature of the sampling line HSL1.
V2, V3	-	Needle valves to regulate calibration gas and zero gas.
F2	-	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.
P1	-	Heated sample pump.
G1	-	Pressure gauge to measure pressure in sample line HC-analyser.
R3	-	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 - 473 K

(180°C - 200°C).

FL1,FL2,FL3	-	Flow meter to measure sample by-pass flow.
R1,R2	-	Pressure regulators for air and fuel.
HSL2	-	Heated sampling line, temperature shall be kept between 368 K and 473 K (95°C and 200°C); the line shall be made in stainless steel or PTFE.
HCLA	-	Heated chemiluminescence anlyser for oxides of nitrogen.
T2	-	Temperature readout of sample stream entering HCLA analyser.
T3	-	Temperature readout of NO_2 - NO converter.
V9,V10	-	Three-way valve to by-pass NO_2 - NO converter.
V11	-	Needle valve to balance flow through NO_2 - 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 - 277 K (0°C - 4°C) by ice or refrigeration.
C	-	Cooling coil and trap sufficient to condense and collect water vapour (optional with water insensitive analyser).
T4	-	Temperature readout of bath temperature.
V5,V6	-	Toggle valves to drain condensate traps and bath.
R4,R5	-	Pressure regulator to control sample flow.
V7,V8	-	Ball valve or solenoid valves to direct sample, zero gas or calibrating gas streams to the analysers.
V12,V13	-	Needle valves to regulate flows to the analysers.
CO	-	NDIR analyser for carbon monoxide.

NOx	-	HCLA analyser for oxides of nitrogen.
FL4,FL5	-	By-pass flowmeter.
V4,V14	-	Three-way ball or solenoid valves. The valves shall be in an oven compartment or heated to the temperatures of the sampling line HSL1.

Figure 1: 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

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 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/1075 mm^2 (ie. mass/stain area) are recommended for other filters.

2.2. Weighing chamber and microbalance 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 and 303 K (20°C and 30°C) during all filter conditioning and weighing. The relative humidity must be maintained to within ± 10% relative humidity of a set point between 35% and 55%.

2.2.2. The chamber (or room) environment must be free of any ambient contaminates (such as dust) that could settle on the particulate filters during their stabilization. At least two unused reference filters must be weighed within four hours of, but preferably at the same time, as the sample filter weighings. If the average weight of the reference filter changes between sample filter weighing by more than ± 6% 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%, 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 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 dilute exhaust gas must be designed to minimise the deposition or alteration of particulate matter. 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.

2.4 SYSTEM 2 (FULL-FLOW-DILUTION SYSTEM)

2.3.1. A particulate sampling system is described based upon the dilution of the total exhaust using the CVS (Constant Volume Sampling) concept.

Figure 2 is a schematic drawing of this system. The total flow of the mixture of exhaust and dilution air must be measured, and a sample must be collected for analysis.

2.3.2. 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 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 - The exhaust pipe length from the exit of the engine exhaust manifold or turbocharger outlet to the dilution tunnel is required to be not more than 10 m. If the system exceeds 4 m in length then all tubing in excess of 4 m must be insulated. The radial thickness of the insulation must be at least 25 mm. The thermal conductivity of the insulating material must have a value no greater than 0.1 W/mk measured at 673 K (300°C).

PDP - The positive displacement pump meters total diluted exhaust flow from the number of the pump revolutions and the pump displacement. The exhaust system backpressure shall not be artificially lowered by the PDP or dilution air inlet system. Static pressure measured with the operating CVS system shall 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 shall be within ± 6 K of the average operating temperature observed during the test, when no flow compensation is used.

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

HE - The heat exchanger shall be of sufficient capacity to maintain the temperature within the limits required above (optional if EFC is used).

EFC - If the temperature at the inlet to either PDP or CFV is not kept constant, an electronic flow computation system is required for continuous measurement of the flow rate (optional if HE is used).

PDT - The primary dilution tunnel shall be;

Small enough in diameter to cause turbulent flow (Reynolds Number > 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 shall be directed downstream at the point where it is introduced into the primary dilution tunnel, and thoroughly mixed.

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

DDS - The double-dilution system 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 collection filters. The flow capacity of the PDP or CFV must be sufficient to maintain the diluted exhaust stream in the PDP at a temperature of less than or equal to 464 K (191°C)

		at the sampling zone. The secondary dilution system must provide sufficient secondary dilution air to maintain the doubly-diluted exhaust stream at a temperature of less than or equal to 325 K (52°C) immediately before the primary particulate filter.
PSP	-	The particulate sample probe (for SDS only) must; Be installed facing upstream at a point where the dilution air and exhaust gas are well mixed (ie. 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 1020 mm. The sample probe must not be heated.
PTT	-	The particulate transfer tube (for DDS only) must be; Installed facing upstream at a point where the dilution air and exhaust gas are well mixed (ie. on the dilution tunnel centre-line, 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 sample probe must not be heated.
SDT	-	The secondary dilution tunnel (for DDS only) shall 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 double-diluted sample. The primary filter holder shall be located within 300 mm of the exit of the secondary dilution tunnel.
DAF	-	The dilution air may be filtered at the dilution air inlet, shall have a temperature of 298 (25°C) ± 5 K and may be sampled to determine background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.
FH	-	For primary and back-up filters one filter housing or

separate filter housings may be used. The requirements of paragraph 2.1.3. of this appendix have to be met. The filter holders shall not be heated.

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

DP - The dilution air pump (for DDS only) shall be located so that the secondary dilution air is supplied with a temperature of 298 (25°C) ± 5 K.

GF1 - The gas meter or flow instrumentation (for particulate sample flow) shall be located sufficiently distant from the tunnel so that the inlet gas temperature remains constant (± 3 K), if flow computation is not used.

GF2 - The gas meter or flow instrumentation (dilution air, for DDS only) shall be located so that the inlet gas temperature remains at 298 (25°C) ± 5 K.

2.5. SYSTEM 3 (PARTIAL-FLOW-DILUTION SYSTEM)

2.5.1. A particulate sampling system is described based upon the dilution of part of the exhaust gas. Figure 3 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.

2.5.2. 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 4, paragraph 4.2.6. and annex 4, appendix 3, paragraph 1.1.6.3. The components shall meet the following requirements;

EP - 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 shall 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 shall be higher than 10 m/s and lower than 200 m/s.

		Pressure oscillations of the exhaust gas shall not exceed ± 500 Pa on average. Any steps to reduce pressure oscillations beyond using a chassis-type exhaust system (including muffler) shall not alter engine performance nor cause the deposition of particulate.
PR	-	The sampling probe shall be installed facing upstream on the exhaust pipe centre-line at a point where the above flow conditions are met. The minimum inside diameter shall be 4 mm.
ISP	-	The isokinetic sampling probe (optional if EGA or mass flow control is used) shall 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 differential pressure transducer and a speed controller, to obtain isokinetic flow at the probe tip. The inside diameter shall be at least 12 mm.
EGA	-	Exhaust gas analysers (optional if ISP or mass flow control is used) for CO_2 or NOx analysis may be used (with carbon balance method CO_2 only). The analysers shall 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	-	The particulate sample transfer tube shall be; Heated or insulated so that the gas temperature in the transfer tube be not below 423 K (150°C). If the exhaust gas temperature is below 425 K (150°C) it shall not be below the exhaust gas temperature. Equal to or greater in diameter than the probe diameter, but no more than 25 mm in diameter. Not more than 1,000 mm from inlet plane to exit plane. The particulate sample shall exit on the centre-line of the dilution tunnel and point downstream.
SC	-	(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 total exhaust gas flow. The adjustment is done by controlling the speed of the suction blower (SB) and keeping the speed of the pressure blower (SP) constant during each mode. The remaining error in the pressure control loop shall not exceed ± 0.5 % of the measuring range of the pressure transducer (DPT). The pressure oscillations in the dilution tunnel shall not exceed ± 250 Pa on average.

DPT - (For ISP only). The differential pressure transducer shall have a maximum range of ± 500 Pa.

FC1 - A flow controller (dilution air) 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 pressurised air supply, FC1 directly controls the air flow.

GF1 - The gas meter or flow instrumentation (particulate sample flow) shall be located so that the inlet gas temperature remains at 298 K (25°C) ± 5 K.

SB - (For fractional sampling type only)

PB - To control the dilution air mass flow rate, PB shall be connected to FC1. Exhaust flow or fuel flow and/or CO_2 differential signals may be used as command signals. PB is not required when using a pressurised air supply.

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

DT - The dilution tunnel shall be;

Small enough in diameter to cause turbulent flow (Reynolds Number > 4000) 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 shall be directed downstream at the point where it is introduced into the dilution tunnel, and thoroughly mixed with the dilution air by means of a mixing orifice. For the fractional sampling type, the mixing quality shall 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 - The particulate sampling system shall 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 bypass system with a ball valve between the sample probe and the filter holder shall be used for passing the sample through the sampling filters at the desired times. Interference of the switching procedure on the control loops shall be corrected within less than three seconds.

PSP - The particulate sample probe shall be;

Installed facing upstream at 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 - The particulate transfer tube shall not be heated and shall not exceed 1020 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 - For primary and back-up filters one filter housing or separate filter housings may be used. The requirements of paragraph 2.1.3. of this appendix shall be met. The filter holders shall not be heated.

SP - The particulate sample pump shall be located

sufficiently distant from the tunnel so that the inlet gas temperature is maintained constant (± 3 K), if flow computation is not used.

FC2 - A flow controller (particulate sample flow, optional) may be used, in order to improve accuracy of the particulate sample flow rate.

GF2 - The gas meter or flow instrumentation (particulate sample flow) shall be located sufficiently distant from the tunnel so that the inlet gas temperature remains constant (± 3 K), if flow computation is not used.

BV - The ball valve shall have a diameter no less than the sampling tube and a switching time of less than 0.5 seconds.

Figure 2. Full-flow-dilution system.

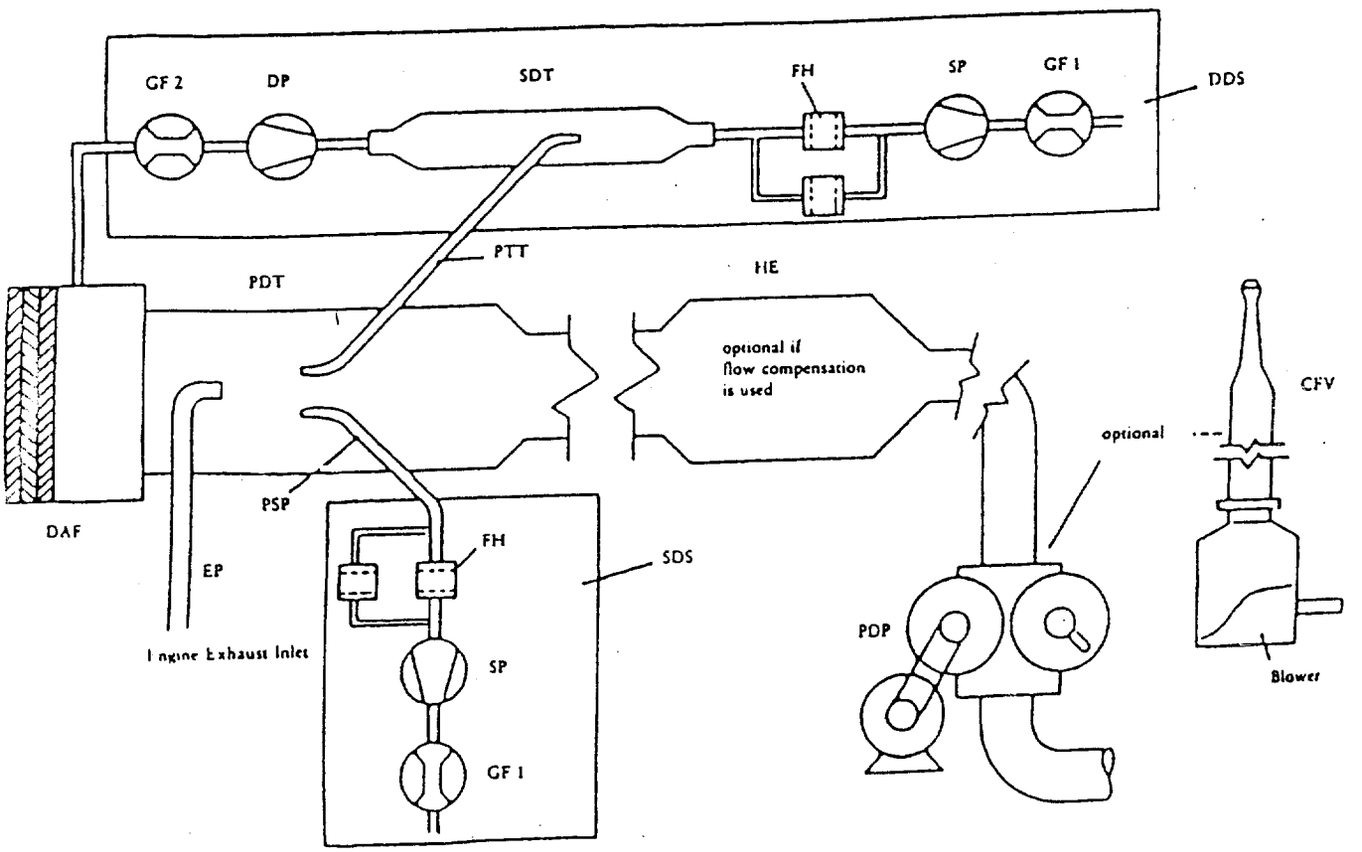
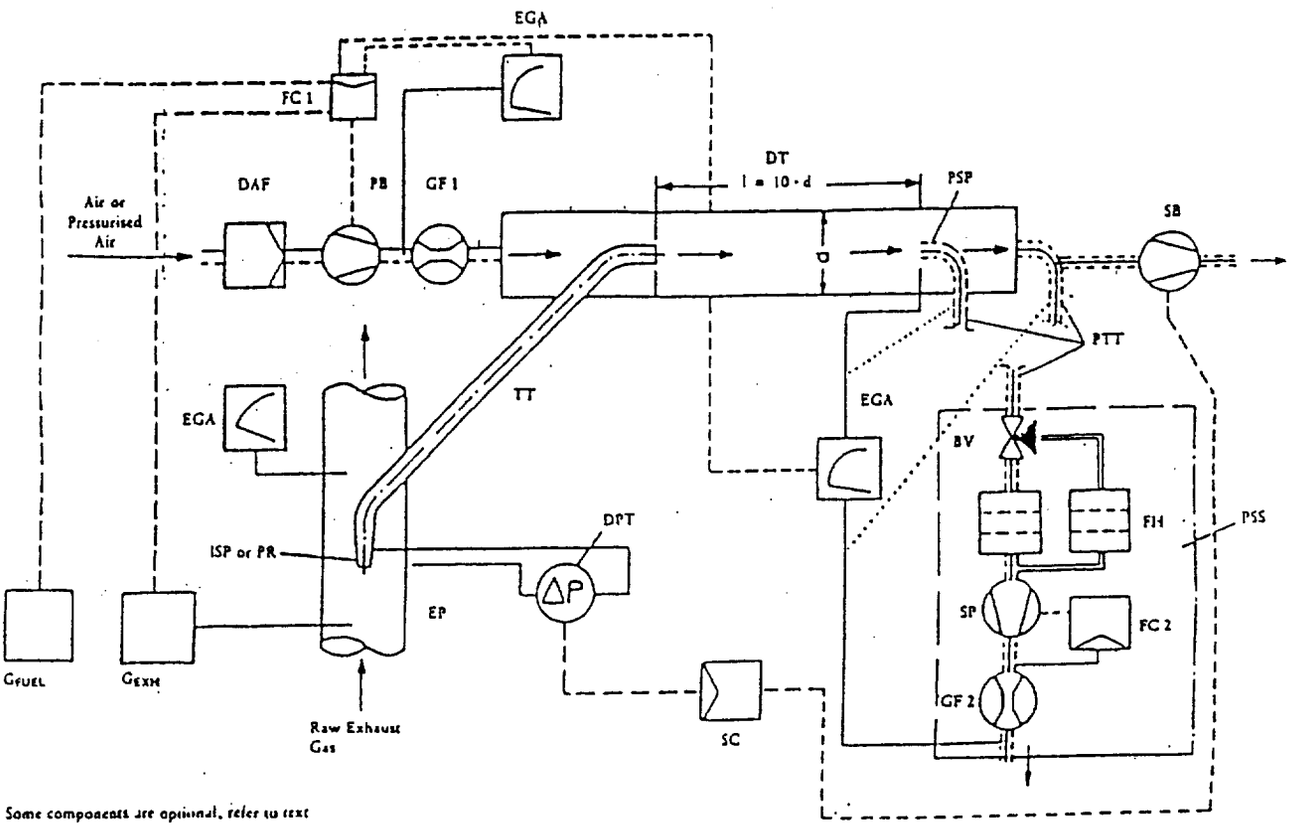


Figure 3. Partial-flow-dilution-system.



Annex 5

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

CEC reference fuel RF-03-A-84 7/

Type: Diesel fuel

	Limits and units 3/	ASTM Method 1/
Cetane Number 4/	min. 49 max. 53	D613
Density at 15°C (kg/l)	min. 0.835 max. 0.845	D1298
Distillation 2/: - 50% point - 90% point - final boiling point	 min. 245°C min. 320°C max. 340°C max. 370°C	D86
Flash point	min. 55°C	D93
CFPP	min. -- max. - 5°C	EN 116 (CEN)
Viscosity at 40°C	min. 2.5 mm^2/s max. 3.5 mm^2/s	D445
Sulphur content 8/	(to be reported) max. 0.3% mass	D1266/D2622/D2785
Copper corrosion	max. 1	D130
Conradson carbon residue (10% DR)	max. 0.2% mass	D189
Ash content	max. 0.01% mass	D482
Water content	max. 0.05% mass	D95/D1744
Neutralization (strong acid) number	max. 0.2 mg/KOH/g	
Oxidation stability 6/	max. 2.5 mg/100m	D2274
Additives 5/		
Carbon-Hydrogen ratio	(to be reported)	

Note 1/: Equivalent ISO methods will be adopted when issued for all properties listed above.

Note 2/: The figures quoted show the evaporated quantities (percentage recovered + percentage loss).

Note 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 produce quality disputes" have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility).

Notwithstanding this measure, which is necessary for statistical reasons, the manufacturer of 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.

Note 4/: The range of cetane is not in accordance with the requirement of a minimum range of 4R. However, in cases of dispute between fuel supplier and fuel 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.

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

Note 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.

Note 7/: If it is required to calculate thermal efficiency of an engine or vehicle, the calorific value of the fuel can be calculated from:

Specific energy (calorific value) (net) 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 (%/100)
y = the proportion by mass of ash (%/100)
s = the proportion by mass of sulphur (%/100)

Note 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.