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Title:
Instruments for measuring vehicle exhaust emissions

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Title of WD (English):
Instruments for measuring vehicle exhaust emissions
Part 1 Metrological and Technical Requirements

Title of WD (English):
Instruments de mesure des gaz d'échappement des véhicules
Partie 1: Exigences métrologiques et techniques

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Contents ISO 3930 / OIML R 99 - Part 1

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 3930 was prepared by Technical Committee ISO/TC 22, *Road vehicle*s, Subcommittee SC 5, *Engines test*s.

This ~~third~~ fourth edition cancels and replaces the ~~second~~ third edition (ISO 3930:~~1993~~2000), which has been technically revised.

Annexes A, B and F form an integral part of this International Standard/Recommendation. Annexes C, D and E are for information only.

NOTE Since this ISO International Standard is also an OIML International Recommendation, the designation “International Standard/Recommendation” is used throughout the text.

The International Organization of Legal Metrology (OIML) is a worldwide, intergovernmental organization whose primary aim is to harmonize the regulations and metrological controls applied by the national metrological services, or related organizations, of its Member States.

The two main categories of OIML publications are:

- International Recommendations (OIML R), which are model regulations that establish the metrological characteristics required of certain measuring instruments and which specify methods and equipment for checking their conformity; the OIML Member States shall implement these Recommendations to the greatest possible extent;
- International Documents (OIML D), which are informative in nature and intended to improve the work of the metrological services.

OIML Draft Recommendations and Documents are developed by technical committees or subcommittees which are formed by the Member States. Certain international and regional institutions also participate on a consultation basis.

Cooperative agreements are established between OIML and certain institutions, such as ISO and IEC, with the objective of avoiding contradictory requirements; consequently, manufacturers and users of measuring instruments, test laboratories, etc. may apply simultaneously OIML publications and those of other institutions.

International Recommendations and International Documents are published in French (F) and English (E) and are subject to periodic revision.

This publication — reference OIML R 99, edition ~~2000~~ 200x (E) — was developed by the OIML subcommittee TC 16/SC 1, *Air Pollution*. It was approved for final publication by the International Committee of Legal Metrology in ~~1997~~200x, and will be submitted to the International Conference of Legal Metrology in ~~2000~~ 200x for formal sanction; it supersedes the previous edition dated ~~1991~~2000.

OIML publications may be obtained from the Organization’s headquarters:
Bureau International de Métrologie Légale
11, rue Turgot - 75009 Paris - France
Telephone: 33 (0)1 48 78 12 82 and 42 85 27 11
Fax: 33 (0)1 42 82 17 27
E-mail: biml@oiml.org

NOTE Since this OIML International Recommendation is also an ISO International Standard, the designation “International Standard/Recommendation” is used throughout the text.

Instruments for measuring vehicle exhaust emissions

Part 1 - Metrological and technical requirements

0 Introduction

[This clause is to be drafted later. It will be an excerpt of the explanatory note (see: OIML Directives for the Technical Work, Part 2, clause 4.4)

1 Scope

This International Standard/Recommendation specifies the metrological and technical requirements and tests for measuring instruments [hereafter termed "instrument(s)"] that serve to determine the volume fractions of certain components of the exhaust gases emanating from motor vehicles, and establishes the conditions with which such instruments ~~must~~ shall comply in order to meet any regulatory ~~OIML~~ performance requirements within OIML Member States.

It is applicable to instruments, particularly those used according to the procedure defined in ISO 3929, intended for the inspection and maintenance of in-use motor vehicles with spark ignition engines. These instruments are used to determine the volume fraction of one or more of the following exhaust gas components:

- carbon monoxide (CO);
- carbon dioxide (CO_2);
- hydrocarbons (HC, in terms of n-hexane); and
- oxygen (O_2)

at the moisture level of the sample as analysed.

This International Standard/Recommendation covers instruments whose principle of detection is based on infrared absorption in gases for CO, CO_2 and HC. Oxygen is generally measured with a fuel cell. It is not intended, however, to exclude any other types of instruments that, although based on other principles of detection, meet the specified metrological and technical requirements and satisfy the associated tests. Three accuracy classes of the instruments, Class 0, Class I and Class II, are covered.

This Standard/Recommendation does not cover equipment for on-board diagnostics incorporated in motor vehicles.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard/ Recommendation.
For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard/Recommendation are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.
Members of ISO and IEC maintain registers of currently valid International Standards.

2.1 ISO standards:

ISO 3929:~~1995~~2003, *Road vehicles — Measurement methods for exhaust gas emissions during inspection or maintenance.*

ISO 6142 (2001), *Gas analysis - Preparation of calibration gas mixtures - Gravimetric method*

ISO 6145 (all parts), *Gas analysis — Preparation of calibration gas mixtures — Dynamic volumetric methods.*

ISO 7504 (2001), *Gas analysis - Vocabulary*

ISO 7637-1 (2002), *Road vehicles - Electrical disturbance from conducting and coupling - Part 1: Definitions and general considerations*

ISO 7637-2 (2004) *Road vehicles - electrical disturbance by conducting and coupling – Part 2: Electrical transient conduction along supply lines only*

ISO 7637-3 (1995) with correction 1 (1995) *Road vehicles - Electrical disturbance by conducting and coupling - Part 3: Passenger cars and light commercial vehicles with nominal 12 V supply voltage and commercial vehicles with 24 V supply voltage - Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines*
~~ISO 7395, *Gas analysis — Preparation of calibration gas mixtures — Mass dynamic method*~~

ISO 14912 (2003), *Gas analysis - conversion of gas mixture composition data*

2.2 IEC standards:

IEC 60068-2-1:1990, *Environmental testing — Part 2: Tests — Test A: Cold*
With amendments 1 (1993) and 2 (1994).

IEC 60068-2-2:1974, *Environmental testing — Part 2: Tests — Test B: Dry heat.*
With amendments 1 (1993) and 2 (1994)

IEC 60068-2-~~3~~78: ~~1969~~2001, *Environmental testing — Part 2: Tests — Test Ca~~b~~: Damp heat, steady state.*

IEC 60068-3-1: 1974, *Environmental testing — Part 3-1 Cold and dry heat tests*
With Supplement A: 1978.

IEC 60068-~~2-28~~3-4:~~1990~~2001, *Environmental testing — Part ~~2~~3-4: ~~Tests —~~ Supporting documentation and ~~G~~guidance ~~-for~~ D~~d~~amp heat tests.*

IEC 60068-2-31:1969, *Environmental testing — Part 2: Tests — Test Ec: Drop and topple, primarily for equipment type specimens,*
With ~~and its~~ Amendment 1: 1982.

IEC 60068-2-~~3~~64:19~~9~~73, *Environmental testing — Part 2: Test~~s~~ methods — Test ~~Fd~~Fh: ~~Random vibration wide band — General requirements~~Vibration, broad band random (digital control) and guidance.*
With Correction 1: 1993

~~IEC 60068-2-36:1973, *Environmental testing — Part 2: Tests — Test Fdb: Random vibration wide band — Reproducibility medium, and its Amendment 1: 1983.*~~

IEC 60068-3-1:1974, *Environmental testing — Part 3: Background information — Section 1: Cold and dry heat tests.* *With Amendment 1: 1978*

~~IEC 60068-3-1A:1978, *Environmental testing — Part 3: Background information — First supplement.*~~

IEC 61000-4-2:1995, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 2: Electrostatic discharge immunity test.*
With amendments 1 (1998) and 2 (2000)
(Consolidated edition 2001)

IEC 61000-4-3: ~~Ed. 1.1, 1998~~2006, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 3: Radiated, radio-frequency, electromagnetic field immunity test.*

IEC 61000-4-4:~~1995~~2004, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 4: Electrical fast transient/burst immunity test.*

IEC 61000-4-5: *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 5: Surge immunity test*
Consolidated edition 2001

IEC 61000-4-6:~~1996~~2003, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 6: Immunity to conducted disturbances, induced by radio-frequency fields.* *Wit amendment 1 (2004)*
(Consolidated edition 2004)

IEC 61000-4-8: 1993 *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 8: Power frequency immunity test.*
With Amendment 1: 2000
Consolidated edition 2001.

2.3 OIML publications:

OIML International Vocabulary of Terms in Legal Metrology (VIML), edition 2000

OIML D 11 General requirements for electronic measuring instruments (2004)

2.4 Other publications~~BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML:~~

International Vocabulary of Basic and General Terms in Metrology (VIM), Second edition, 1993.
joint publication by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, and OIML

3 Terms and definitions

For the purposes of this International Standard/Recommendation, the following terms and definitions apply.

3.1
sampling probe
tube that is introduced into the exhaust tail pipe of a vehicle to take gas samples

3.2
water separator
device that removes water from the exhaust gas sample to a level that prevents condensation within the gas handling system downstream from its location

3.3
filter unit
device that removes ~~particulate matter~~particles from the exhaust gas sample

3.4

gas handling system
all instrument components, from the sampling probe to the gas sample outlet, through which the exhaust gas sample is conveyed by the pump

3.5
adjustment (of a measuring instrument)
operation of bringing a measuring instrument into a state of performance suitable for its use (VIM: 1993, 4.30)

3.6
user adjustment (of a measuring instrument)
adjustment employing only the means at the disposal of the user (VIM: 1993, 4.31)

3.7
manual adjustment facility
facility allowing the adjustment of the instrument by the user

3.8
semi-automatic adjustment facility
facility allowing the user to initiate an adjustment of the instrument without having the possibility of influencing its magnitude, whether the adjustment is automatically required or not

NOTE For those instruments that require the values of the volume fractions of the ~~calibration~~ reference gas to be entered manually, the facility is considered to be semi-automatic.

3.9
automatic adjustment facility
facility performing the adjustment of the instrument as programmed without the intervention of the user, to initiate the adjustment or its magnitude

3.10
zero-setting facility
facility to set the indication of the instrument to zero

3.11
~~calibration~~ reference gas adjustment facility
facility to adjust the instrument to the value of a ~~calibration~~ reference gas

3.12
internal adjustment facility
facility to adjust the instrument to a designated value without the use of an external ~~calibration~~ reference gas

3.13
warm-up time
elapsed time between the instant power is applied to an instrument and the instant at which the instrument is capable of complying with the metrological requirements

3.14
response time
time interval between the instant when the instrument is subjected to a specified abrupt change in gas mixture composition and the instant when the response reaches within specified limits its final steady value

NOTE Adapted from VIM: 1993, 5.17.

3.15
error (of indication)
indication of a measuring instrument minus a true value of the corresponding input quantity. (VIM: 1993, 5.20)

3.16
intrinsic error
error of a measuring instrument, determined under reference conditions (VIM: 1993, 5.24)

3.17
absolute error of measurement
result of a measurement minus the conventional true value of the measurand

NOTE Adapted from VIM: 1993, 3.10.

3.18
relative error
absolute error of measurement divided by the conventional true value of the measurand

NOTE Adapted from VIM: 1993, 3.12.

3.19
fault
difference between the error of indication and the intrinsic error of the instrument (OIML D 11: 2004, 3.9)

3.20
significant fault
fault the magnitude of which is greater than the magnitude of the maximum permissible error on initial verification

NOTE The following faults are considered not to be significant.

a) fault arising from simultaneous and mutually independent causes in the instrument itself or in its checking facilities;

b) faults implying the impossibility to perform any measurement;

c) transitory faults being momentary variations in the indication, which cannot be interpreted, recorded or transmitted as a measurement result; and

d) faults giving rise to variations in the measurement results that are so large as to be noticed by all users of the instruments.

NOTE Adapted from OIML D 11: 2004, 3.10.

3.21

influence quantity
quantity that is not the measurand but which affects the result of the measurement (VIM: 1993, 2.7)

3.22
rated operating conditions
conditions of use giving the ranges of the influence quantities for which the metrological characteristics of an instrument are intended to lie within the specified maximum permissible errors

NOTE Adapted from VIM: 1993, 5.5.

3.23
influence factor
influence quantity having a value within the rated operating conditions of the instrument

NOTE Adapted from OIML D 11: 2004, 3.13.1.

3.24
disturbance
influence quantity having a value within the limits specified in this International Standard/Recommendation but outside the rated operating conditions of the instrument

NOTE Adapted from OIML D 11: 2004, 3.13.2.

3.25
reference conditions
conditions of use prescribed for testing the performance of a measuring instrument or for intercomparison of results of measurements (VIM: 1993, 5.7)

3.26
checking facility
facility that is incorporated in the instrument and that enables significant faults to be detected and acted upon

NOTE "Acted upon" means any adequate response by the instrument (luminous or acoustic signal, blocking of process, etc.)

NOTE Adapted from OIML D 11: 2004, 3.18.

3.27
automatic checking facility
checking facility operating without the intervention of the user

NOTE Adapted from OIML D 11: 2004, 3.18.1.

3.27.1
permanent automatic checking facility (type P)
automatic checking facility operating during each measurement cycle

NOTE Adapted from OIML D 11: 2004, 3.18.1.1

3.27.2
intermittent automatic checking facility (type I)
automatic checking facility operating at certain time intervals or per fixed number of measurement cycles

NOTE Adapted from OIML D 11: 2004, 3.18.1.2.

3.28
test
series of operations intended to verify the compliance of the equipment under test (EUT) with specified requirements

3.29
lambda
dimensionless value representative of the burning efficiency of an engine in terms of the air/fuel ratio in the exhaust gases and determined with a referenced standardised formula

3.30
~~calibration~~ reference gas
~~stable~~ gas mixture of sufficient stability and homogeneity whose composition is properly established for use in~~of known concentration used for periodic calibration of the instruments and for~~ various performance tests
Notes:
1 Adapted from ISO 7504, 4.1 (calibration gas mixture) and 4.1.1 (reference gas mixture) and "VIM", 6.13 (reference material) and 6.14 (certified reference material)
2 In the referred ISO standards, the expression "calibration gas" is generally used.

3.x
binary gas
reference gas consisting of a prescribed concentration of one single gas component in nitrogen (N_2)

3.y
Gas mixture (Blended gas ???? see 5.1)
reference gas consisting of a prescribed concentration of several gas components in nitrogen (N_2)

3.31
modulus (of a number) absolute value
value of the number without regard to its sign

3.32
hand-held instrument
type of instrument that is designed for hand-held transportation by one person with its standard accessories, and that rests on a suitable surface during use

3.33
Mains power
primary external source of electrical power for the instrument, including all sub assemblies.

(Examples: public power (AC or DC), generator, external battery or other DC supply systems) (OIML D 11: 2004, 3.21)

3.34
Power converter (power supply device)
sub assembly converting the voltage from the mains power to a voltage suitable for other sub assemblies. (OIML D 11: 2004, 3.22)

3.35
Back-up battery
battery that is intended to power specific functions of an instrument in the absence of the primary power supply (For example: to preserve stored data) (OIML D 11: 2004, 3.24)

3.36
Abbreviations

AC	Alternating Current
AM	Amplitude Modulation
ASD	Acceleration Spectral Density
DC	Direct Current
EM	Electro Magnetic
EMC	Electro Magnetic Compatibility
ESD	Electrostatic Discharge
EUT	Equipment Under Test
IEC	International Electrotechnical Committee
ISO	International Organization for Standardization
OIML	International Organization of Legal Metrology
PEF	Propane/hexane Equivalency Factor
RMS	Root Mean Square

4 Description of the instruments

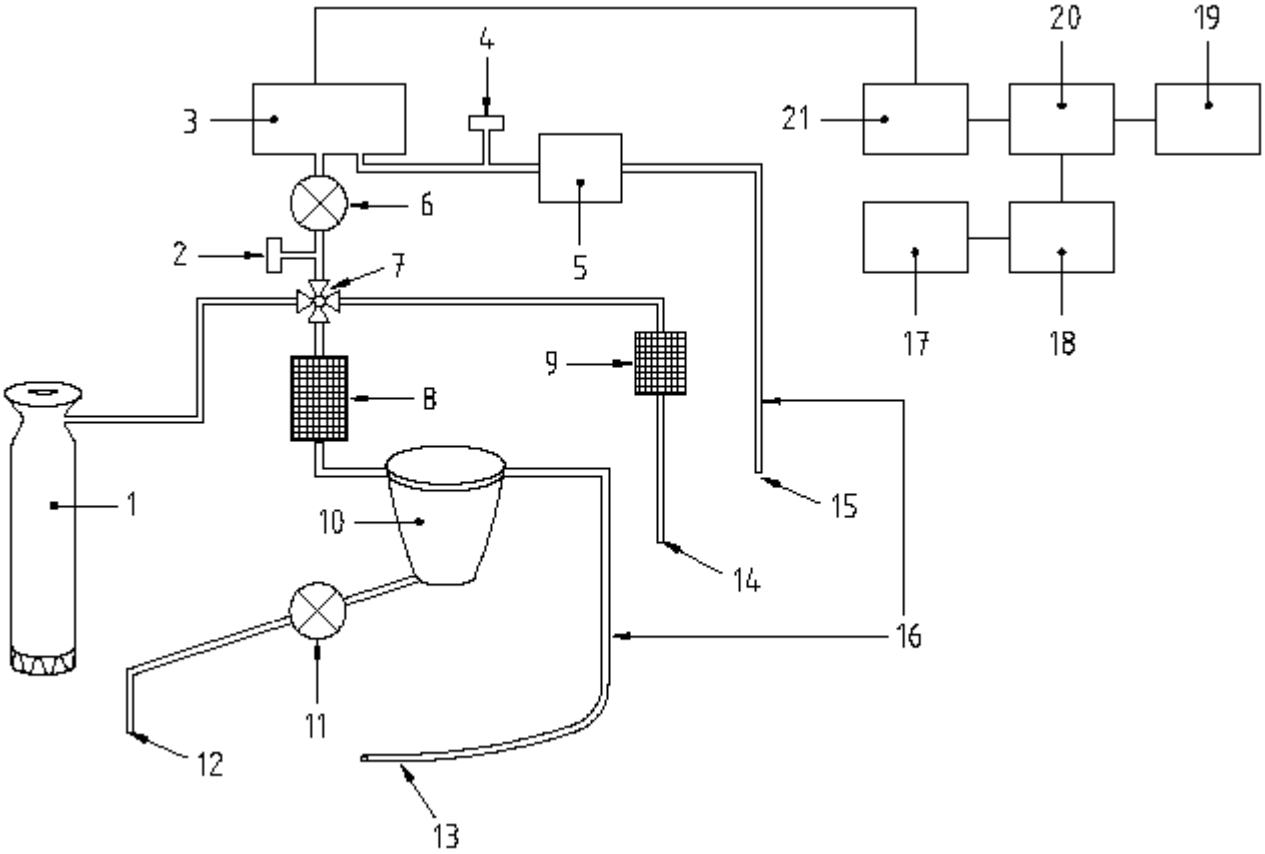
4.1 Generally, the instruments provide a means for sampling and then measuring the exhaust gases emitted from the tail pipe of a motor vehicle. A pump provides the means for conveying the gas sample through a gas handling system. One or more detection devices, incorporated in the gas handling system, analyse the sample and provide signals related to the volume fractions of gas components of interest, namely CO, CO_2, HC and O_2 . The detector signals are then electrically processed to display and possibly record the results of a measurement in volume fractions of the gas components together with other important related information such as a lambda value calculation.

4.2 Acceptable overall performance of the instrument is dependent upon its various components for the associated characteristics. An example of an instrument using gas ~~calibration for~~ adjustment is shown in Figure 1.

4.3 The major instrument components are as follows:

- a sampling probe introduced in the tail pipe of a~~n operating motor~~ vehicle, to collect the exhaust gas sample;
- a hose with associated tubing connected to the probe to provide a path for the gas sample to enter, pass through and exit the instrument;
- a pump to convey the gases through the instrument;
- a water separator to prevent water condensation from forming in the instrument;
- a filter to remove ~~particulate matter~~particles that could cause contamination of various sensitive parts of the instrument;
- ports downstream from the water separator and filter to introduce ambient air and ~~calibration~~ reference gas when required by the technology used;
- detection devices to measure the volume fractions of~~analyse~~ the gas sample ~~into its components according to volume fractions~~;
- a data system to process the signal and an indicating device to display the results of a measurement; and
- a control facility to initiate and check instrument operations and a manual, semi-automatic, or automatic adjustment facility to set instrument operating parameters within prescribed limits.

4.4 The instruments can be provided with ancillary facilities for measuring the oil temperature and/or the engine speed.
This standard/Recommendation however excludes requirements for these facilities.



Key

1 ~~Calibration~~ Reference gas input for adjustment(6.1.5)
2 Differential pressure sensor (6.1.7)
3 CO, CO_2 and HC analysis
4 Atmospheric pressure sensor
5 O_2 analysis
6 Gas pump (6.1.6)
7 Electrovalve
8 Filter gas (6.1.3)
9 Charcoal filter (6.1.5)
10 Water separator (6.1.4)
11 Water pump
12 Water output
13 Sampling probe (6.1.2)
14 Gas input for zero-setting (6.1.5)
15 Gas output
16 Gas handling system (6.1.8)
17 Seals (6.3.~~8~~9)
18 Adjustment facilities (6.2)
19 Interfaces (6.1.9)
20 Indicating device (6.2 and 6.3)
21 Signal conversion

Figure 1 — Diagrammatic illustration of an instrument for measuring vehicle exhaust emissions (references in parenthesis are to the relevant sub-clauses in the text)

[Temporary remark:
the references to the relevant sub-clauses will be updated in a later stage]

5 Metrological requirements

5.1 Indication of the measured result

The volume fractions of the gas components shall be expressed as a percentage (% vol) for CO, CO_2 and O_2 and in parts per million (ppm vol) for HC. The inscriptions for these units shall be assigned unambiguously to the indication, for example "% vol CO", "% vol CO_2", "% vol O_2" and "ppm vol HC". The indication of the measuring result of the different components shall be displayed simultaneously.

NOTE Historically, the units of volume fraction have been used for field inspection; however blended gases can generally be manufactured in molar fractions to more accurate standards. Assuming the gas mixtures obey the ideal gas law, molar fractions are considered to be equal to volume fractions in this International Standard/Recommen-dation. Accurate conversion from mole fraction to volume fraction is prescribed in ISO 14912.

5.2 Measuring range

The minimum indicating ranges that may be subdivided shall be as given in Table 1.

Table 1

Class	Measuring ranges			
	CO % vol	CO_2 % vol	O_2 % vol	HC ppm vol
0 and I	0 to 5	0 to 16	0 to 21	0 to 2 000
II	0 to 7	0 to 16	0 to21	0 to 2 000

5.3 Resolution of indication

5.3.1 Analog scale intervals and scale marks

To be deleted? [Discussion!, see question 3]

The scale intervals for an analog instrument shall be 0,1 % vol or 0,2 % vol for CO, CO_2 and O_2 ,and 10 ppm vol or 20 ppm vol for HC. The minimum scale spacing shall be 1,25 mm. The thickness of the needle shall not be greater than one quarter of the scale spacing. The needle shall overlap at least one third of the shortest mark and shall be clearly visible. The graduation shall be designated with figures at least 5 mm high and designed in such a way as to prevent misinterpretation.

5.3.2 Digital indication

Digital figures shall be at least 5 mm high. The least significant figure of the display shall provide a resolution equal to or one order of magnitude higher than the values given in Table 2.

Table 2

Class	Minimum resolutions			
	CO % vol	CO_2 % vol	O_2 % vol	HC ppm vol
0 and I	0,01	0,1	a	1
II	0,05	0,1	0,1	5

a ~~0,02~~0,01 % vol for measurand values ≤ 4 % vol
0,1 % vol for measurand values > 4 % vol

5.x Printing device

If the instrument is provided with a printing device, the following requirements apply:

a) printing shall be clear and permanent for the intended use;

b) the resolution of the printed data shall be the same as the resolution of the indication;

c) printed figures shall be at least 2 mm high;

d) If printing takes place, the name or the symbol of the unit of measurement shall be either to the right of the value or above a column of values.

e) in case of an external printing device, the data transmission shall comply with 6.1.9;

5.4 Maximum permissible errors

5.4.1 Maximum permissible intrinsic errors

The maximum permissible errors given in Table 3 shall apply for an instrument under the reference conditions specified in 5.5.1.

Table 3

Class	Type of indication error	Maximum permissible errors [a]			
		CO	CO_2	O_2	HC
0	Absolute	± 0,03 % vol	± 0,4 % vol	± 0,1 % vol	± 10 ppm vol
	relative	± 3 %	± 4 %	± 3 %	± 5 %
I	Absolute	± 0,06 % vol	± 0,4 % vol	± 0,1 % vol	± 12ppm vol
	relative	± 3 %	± 4 %	± 3 %	± 5 %
II	Absolute	± 0,15 % vol	± 0,5 % vol	± 0,2 % vol	± 20 ppm vol
	relative	± 5 %	± 5 %	± 5 %	± 5 %

[a] Absolute or relative, whichever is greater.

5.4.2 Maximum permissible errors on initial verification

The maximum permissible errors given in Table 4 shall apply for instruments at initial verification and at type approval under the rated operating conditions specified in 5.5.2.

Table 4

Class	Type of indication error	Maximum permissible errors [a]			
		CO	CO_2	O_2	HC

0	Absolute	± 0,03 % vol	± 0,5 % vol	± 0,1 % vol	± 10 ppm vol
	relative	± 5 %	± 5 %	± 5 %	± 5 %
I	Absolute	± 0,06 % vol	± 0,5 % vol	± 0,1 % vol	± 12ppm vol
	relative	± 5 %	± 5 %	± 5 %	± 5 %
II	Absolute	± 0,2 % vol	± 1 % vol	± 0,2 % vol	± 30 ppm vol
	relative	± 10 %	± 10 %	± 10 %	± 10 %
[a] Absolute or relative, whichever is greater.					

5.4.3 Maximum permissible errors on subsequent verification

The maximum permissible errors on subsequent verification shall be ~~provided and may be equal to or greater than the errors on initial verification~~in accordance with table 4.

5.5 Influence quantities

5.5.1 Reference conditions

a)	temperature:	20 °C ± 2 °C;
b)	relative humidity:	60 % ± 10 %;
c)	atmospheric pressure:	stable ambient;
d)	mains voltage: Mains frequency:	nominal voltage ± 2 %, nominal frequency ± 1 %;
e)	presence of influencing gas components:	none except the measurands in N_2 .
f)	vibration	none / negligible
g)	Voltage of road vehicle battery	Nominal voltage of the battery

NOTE In case of infrared technology, a relative humidity range from 30 % to 60 % is acceptable.

5.5.2 Rated operation conditions

a)	environmental temperature:	+5 °C to +40°C;	
b)	relative humidity:	up to ~~90~~ 85 %, no condensation;~~;~~	
c)	atmospheric pressure:	Class 0 and Class I: 860 hPa to 1 060 hPa; Class II: ambient ± 25 hPa;	
d)	mains voltage and frequency: ~~variation:~~	- 15 % to + 10 % of the nominal voltage, and ± 2 % of the nominal frequency.	
e)	voltage of road vehicle battery	12 V battery 24 V battery	9 V - 16 V 16 V - 32 V

~~If a battery is used to power the instrument, the limits of power supplied shall be within the instrument manufacturer's specifications. If a portable generator is used, its requirements shall comply with the specifications for the mains voltage.~~

The type of instrument is presumed to comply with the requirements 5.5.2 if it passes the following tests in Part 2 of this Standard/Recommendation:

Requirement	Test (in Part 2)
5.5.2, a)	A.5 + A.6
5.5.2, b)	A.7
5.5.2, c)	A.8
5.5.2, d)	A.9.1
5.5.2, e)	A.9.2

5.5.3 Influence of gases other than the measurand (cross sensitivity)

The design of the instruments shall be such that measurements do not vary by more than half the modulus of the maximum permissible error on initial verification when gases other than the measurand are present in the following maximum volume fractions:

- 16 % vol CO_2 ;
- 6 % vol CO;
- 10 % vol O_2;
- 5 % vol H_2;
- 0,3 % vol NO;
- 2 000 ppm vol HC (as n-hexane);
- water vapor up to saturation.

However, the presence of H_2 is not necessary for testing the O_2 channel and the presence of O_2 and H_2 is not necessary in case of infrared technology.

5.6 Disturbances

Significant faults as defined in 3.20 shall not occur or shall be detected and acted upon by means of checking facilities for the following disturbances:

a) mechanical shock and vibrations;

b) AC mains voltage dips, short interruptions and voltage variations~~short time power reductions~~;

c) bursts (transients) ~~from the mains~~on power lines, and signal, data and control lines ~~(transients)~~;

d) electrostatic discharges;

e) ~~radiated~~ radio frequency electromagnetic fields; ~~and~~

f) mains frequency magnetic fields;~~,~~ and

g) Surges on power lines and/or signal lines

The type of instrument is presumed to comply with the requirements 5.6 if it passes the following examinations and tests in Part 2 of this Standard/Recommendation:

Requirement	Test (in Part 2)
5.6, a)	A.11
5.6, b)	A.12
5.6, c)	A.13 + A.x
5.6, d)	A.14
5.6, e)	A.15
5.6, f)	A.16
5.6, g)	A.y

5.7 Response time

For measuring CO, CO_2 and HC, instruments including the specified gas handling system shall indicate 95 % of the final value (as determined with ~~calibration~~ reference gases) within 15 s or less after changing from a gas with zero content.
For measuring O_2 the instruments shall indicate a value differing less than 0,1 % vol of the final value within 60 s after changing from air to oxygen-free ~~calibration~~ reference gas.

5.8 Warm-up time

After the warm-up time, the instruments shall meet the metrological requirements stated in this International Standard/Recommendation.
Class 0 or Class I instruments shall have the means to prevent an indication of measured gas volume fractions during the warm-up time.
Class II instruments shall have a warm-up time not exceeding 30 min.

5.9 Propane/hexane equivalency factor

The content of hydrocarbons shall be expressed in ppm vol n-hexane (C_6H_{14}) equivalent. The adjustment may be carried out using propane (C_3H_8). Therefore, a conversion factor referred to as "C_3 /C_6 equivalence factor", or PEF, shall be permanently and conspicuously marked or easily displayable on each instrument. Alternatively, display of an array of conversion factors is allowed provided that the associated volume fractions are also displayed. The conversion factor(s) for each individual instrument shall be provided to three significant figures by the manufacturer. If the gas-sensitive element is replaced or repaired, the new conversion factor(s) shall be attached to the instrument.
For instruments with one single conversion factor, the measuring values obtained when tested with n-hexane shall not differ by more than the applicable maximum permissible error from the curve established with propane.

For instruments capable of displaying an array of conversion factors, the measuring values obtained when tested with n-hexane shall not differ by more than half the value of the applicable maximum permissible error from the curve established with propane.

NOTE The value for this factor is usually between 0,490 and 0,540.

5.10 Lambda calculation

Instruments equipped with a lambda indication shall carry out the appropriate calculation with a suitable formula. For lambda values between 0,8 and 1,2, the maximum permissible error in the calculation with respect to the resolution and the application of the chosen formula shall not exceed 0,3 %. For this purpose, the conventional true value is calculated according to the formula specified in annex ~~F~~A.
The lambda value shall be displayed digitally to four figures and shall be identified by an appropriate symbol or sign (e.g. lambda or λ = x,xxx).

NOTE The choice of a specific formula with its parameters may be subject to national regulation; see annex ~~F~~ A for more information.

5.11 Stability with time or drift

When used in accordance with the manufacturer's operating instructions, the measurements made by the instruments, under stable environmental conditions and after adjustment using a ~~calibration~~ reference gas or the internal adjustment facility, shall remain within the maximum permissible errors on initial verification for at least 4 h without the need for ~~calibration~~ reference gas or internal readjustments by the user. If the instruments are equipped with a means for drift compensation, such as automatic zero or automatic internal adjustment, the action of these adjustments shall not produce an indication that can be confused with a measurement of an external gas.

5.12 Repeatability

For 20 consecutive measurements of the same ~~calibration~~ reference gas mixture carried out by the same person with the same instrument within relatively short time intervals, the experimental standard deviation of the 20 results shall not be greater than one third of the modulus of the maximum permissible error on initial verification taken from 5.4.2 for the relevant gas mixture.

6 Technical requirements

6.1 Construction

6.1.1 All components of the gas handling system shall be made of corrosion-resistant material.~~; in particular, t~~The material of the sampling probe shall withstand the exhaust gas temperature. The

materials used shall not influence the composition of the gas sample.

6.1.2 The sampling probe shall be so designed that it can be inserted at least 30 cm into the exhaust tail pipe of the vehicle and held in place by a retaining device regardless of the depth of insertion.

6.1.3 The gas handling system shall contain a filter unit with reusable or replaceable elements capable of removing particles larger than 5 µm in diameter. It shall be possible to use the instruments for a period of at least 0,5 h with exhaust gas from a specially adjusted test engine having an HC fraction of approximately 800 ppm. It shall be possible to observe the degree of a filter's contamination without its removal, and it shall also be possible to replace, when necessary, this filter easily without special tools.

6.1.4 The gas handling system shall contain a water separator that prevents water condensation from forming in the ~~measuring transducer~~instrument. In the case of saturation of the separator, it shall empty automatically or the measurement operation shall be automatically stopped.

6.1.5 In addition to the probe, instruments with an HC channel shall have a port for drawing in ambient air or other gas without hydrocarbons, to provide a reference for zero-setting of the measuring instruments. If used, ambient air shall pass through a charcoal filter or equivalent system. Instruments without an HC channel may also be equipped with this additional port. Oxygen measuring cells cannot use ambient air for zero-setting; if zero-setting is required an oxygen-free gas should be used.
Another additional port may be added in the gas handling system for introducing ~~calibration gas~~reference gas.
Both ports shall be located downstream of the water separator and filter unit in order to minimise potential
contamination of the gases introduced. A means shall be provided to maintain the same pressure within the detector during zero setting, gas ~~calibration~~adjustment, and sampling.

6.1.6 The pump conveying the exhaust gas shall be mounted so that its vibrations do not affect the measurements. It shall be possible to turn the pump on and off separately from the other instrument components by the user; however, it shall not be possible to make a measurement when the pump is switched off.

NOTE It is recommended to flush the gas handling system automatically with ambient air before the pump is switched off.

6.1.7 The instruments shall be equipped with a device that indicates when the gas flow rate decreases to a level that would cause the detection to exceed the response time or half the modulus of the maximum permissible error on initial verification and, for Class 0 or Class I instruments, when that limit is reached, the device shall prevent measurements.

6.1.8 The gas handling system shall be airtight to such an extent that the influence of dilution with ambient air on the measuring results shall not be more than:

- for CO, CO_2 and HC: half the modulus of the maximum permissible error on initial verification;
- for O_2: 0,1 % vol.

A leakage test procedure with sufficient accuracy to detect this specific maximum leakage shall be provided in the manufacturer's operating instructions.
Class 0 or Class I instruments shall not be able to make a measurement if this value is exceeded.

6.1.9 The instruments may be equipped with an interface permitting coupling to any peripheral devices or other instruments.
An interface shall not allow the metrological functions of the instruments or their measurement data to be inadmissibly influenced by the peripheral devices, by other interconnected instruments, or by disturbances acting on the interface.
Functions that are performed or initiated via an interface shall meet the relevant requirements and conditions of clause 6.
If the instruments are connected to a data printer then the data transmission from the instruments to the printer shall be designed so that the results cannot be falsified. It shall not be possible to print out a document for legal purposes if the instrument checking facility(ies) detect(s) a significant fault or a malfunction.

6.2 Adjustment facilities

6.2.1 The instruments shall have an adjustment facility that provides operations for zero-setting~~, gas calibration (if applicable),~~ and ~~internal~~ adjustment. The facility may be manual, semi-automatic or automatic.

6.2.2 For Class 0 or Class I instruments, the adjustment facility shall be automatic for zero-setting and internal adjustment.

6.2.3 For Class II instruments, the adjustment facility may be manual, semi-automatic, or automatic.

NOTE For legal control, the responsible legal authority may forbid the use of manual adjustment facilities.

6.2.4 The internal adjustment shall neither influence the adjusted zero nor the linearity of the response of the instruments and these shall be coupled to any adjustment made with a ~~calibration gas~~reference gas. A method for coupling shall be provided such that each time a gas ~~calibration~~ adjustment is conducted, the gas value and the internal adjustment value are adjusted and the indication equals the ~~calibration gas~~reference gas value.

6.2.5 Class 0 or Class I instruments shall be provided with a means to observe negative indications near zero for certain tests.
Class II instruments shall be capable of displaying negative indications near zero in order to make zero adjustment when necessary.

6.3 Security of operation

6.3.1 ~~The i~~Instruments shall be designed and manufactured such that when exposed to any of the disturbances listed in 5.6, significant faults do not occur or are detected and acted upon by means of a checking facility. If this is achieved by the use of automatic self-checking facilities, then it shall be possible to check the correct functioning of such facilities.

6.3.2 ~~The i~~Instruments with an HC-channel shall be equipped with a checking facility for detecting HC gas residues. This facility serves to ascertain that before a measurement is made the value indicated is less than 20 ppm vol n-hexane for an ambient air sample taken through the probe.

6.3.3 ~~The~~ Class 0 or ~~the~~ Class I instruments shall not be able to make a measurement if the HC residue value exceeds 20 ppm vol n-hexane. If the measuring instruments are provided with a measuring cycle, this requirement shall be fulfilled at the beginning of each measuring cycle; otherwise, the manufacturer shall indicate what constitutes the beginning of the measurement.

6.3.4 Instruments with an O_2 -channel shall be equipped with a device for automatically recognising any malfunctioning of the sensor due to aging or a break in the connecting line.

6.3.5 Class 0 or Class I instruments shall be controlled by an automatic self-checking facility that shall operate in such a way that before a measurement can be indicated or printed, all internal adjustments, ~~calibration gas~~reference gas adjustments, and all other checking facility parameters shall be confirmed for proper values or status (i.e. within limits). The checking facility for the instrument parameters shall, as a minimum requirement, be of the types given in Table 5.

Table 5

Instrument parameter	Type of checking facility [a]
Warm-up check	P
Low flow check	P
HC residue check	I
Internal reference adjustment check	I
Gas ~~calibration~~ adjustment check [b]	I
Leak check [b]	I

[a] P = permanent automatic
I = intermittent automatic

[b] The time interval shall be specified in the manufacturer's operating instructions and shall be subject to ~~pattern~~type approval.

6.3.6 Instruments equipped with an automatic adjustment facility or a semi-automatic adjustment facility shall not be able to make a measurement until correct adjustments have been completed.

6.3.7 Instruments equipped with a semi-automatic adjustment facility shall not be able to make a measurement when an adjustment is required.

6.3.8 A means for warning of a required adjustment may be provided for both automatic and semi-automatic adjustment facilities.

6.3.9 Effective sealing devices shall be provided on all parts of the instruments that ~~cannot~~ are not ~~be~~ materially protected in another way against operations liable to affect the accuracy or the integrity of the instruments.

This applies in particular to:

- adjustment means;

- software integrity;

- disposable oxygen fuel cell.

6.3.x T The software shall be designed such that changes of the software, leading to an identification code which has not been investigated in the type approval, is not possible without breaking a seal.

The software shall contain a routine, generating an identification code that is automatically changed in case of any modification in the software.

A fixed version number shall be assigned by the manufacturer to all software which, together with the identification code generated by the software itself, forms the full identification of the software. This version number shall be updated by the manufacturer in the case of a software change that may affect the functions and accuracy of the measuring device.

6.3.y The metrological characteristics of an instrument shall not be influenced in any inadmissible way by the connection to it of another device, by any feature of the connected device itself or by any remote device that communicates with the measuring instrument.

6.3.10 For instruments without a pressure compensating device, daily ~~calibration~~ adjustment is required. The operating instructions shall contain this requirement.

6.3.11 A battery-operated instrument shall function correctly with new or fully charged batteries of the specified type and either continue to function correctly or not indicate any values whenever the voltage is below the manufacturer's specified value. Specific voltage limits for road vehicle batteries are prescribed in 5.5.2, e).

7 Inscriptions and operating instructions

7.1 Inscriptions

7.1.1 The instruments shall have a permanent, non-transferable, and easily readable label or labels giving the following information:

a) manufacturer's trade mark/corporate name;

b) year of manufacture;

c) ~~OIML~~ Class designation in accordance with this Standard/Recommendation;

d) ~~pattern~~type approval mark and model number;

e) serial number of the instrument and of the measuring transducer;

f) minimum and nominal flow rate;

g) details of the electrical power:

- in case of mains power: nominal mains voltage, frequency and power required;
- in case of power by a road vehicle battery: the nominal battery voltage and power required;

h) gas components and respective maximum measured value;

i) type description and model of the oxygen fuel cell.

7.1.2 ~~Furthermore, t~~The value of the propane/hexane equivalency factor for each instrument, and the warm-up time for Class II instruments shall be marked permanently on the front panel of the instrument or shall be displayable on the indicating device.

In the case where more than one single propane/hexane equivalency factor is available, these factors shall be displayed with the associated concentrations.

7.1.3 For instruments with software-controlled metrological functions the identification of the legally relevant software shall be attached to a label in accordance with 7.1.1 or be displayable on the indicating device.
The instrument shall be provided with a facility to display the identification code mentioned in 6.3.x.

7.2 Operating instructions

7.2.1 The manufacturer shall provide written operating instructions for each instrument in the language(s) of the country in which it will be used.

7.2.2 The operating instructions shall include:

a) the time intervals and the procedures for adjustment and maintenance that shall be followed to comply with the maximum permissible errors (see also 6.3.5, table 5 and 6.3.10);

b) a description of the leakage test procedure;

c) an instruction for the user to conduct an HC-residue check prior to each HC measurement, including a description of the HC-residue check procedure;

d) the maximum and minimum storage temperatures;

e) if applicable: a specification of the voltage and frequency required of a~~ny~~ portable generator ~~consistent with 5.5.2~~, taking into account varying load conditions typical of those encountered at the location of use;

f) a statement of the rated operating conditions listed in 5.5.2, and other relevant mechanical and electromagnetic environmental conditions;

g) in case a lambda value is calculated, a description of the applied formula; ~~and~~

h) an instruction for the replacement of the oxygen fuel cell~~.~~

i) for instruments, powered by an external power converter: specifications of this power converter; and

j) if applicable: details about compatibility with ancillary equipment.

Annex ~~F~~A - Lambda calculation
(normative/mandatory)

A.1 Introduction

The value of lambda is determinant for the burning efficiency of an engine. The value depends on the composition of the fuel, the air that is used for the combustion and on the combustion products as found in the exhaust gases.

A basic formula, taking into account:

- components of the fuel: carbon, hydrogen, oxygen and water content;
- water content of the air;
- components of the exhaust gases: carbon dioxide, carbon monoxide, hydrocarbons and nitrogen oxide;

has been developed by J. Brettschneider[1].

A simplified formula, derived from the basic formula, and based on the assumption that the water content of fuel and air and the NO_x content in the exhaust gases are negligible, allows the computation of lambda when certain components of the exhaust are measured.

A.2 Simplified lambda formula

For lambda calculation, based upon measurements of CO, CO_2 , HC and O_2 , the following formula is standardized:

$$\lambda = \frac{[CO_2] + \frac{[CO]}{2} + [O_2] + \left\{ \left(\frac{H_{CV}}{4} \times \frac{3{,}5}{3{,}5 + \frac{[CO]}{[CO_2]}} - \frac{O_{CV}}{2} \right) \times ([CO_2] + [CO]) \right\}}{\left(1 + \frac{H_{CV}}{4} - \frac{O_{CV}}{2}\right) \times \{([CO_2] + [CO]) + (K_1 \times [HC])\}}$$

where

[ ] is the concentration in % vol, for HC only in ppm vol;

K_1 is the conversion factor for HC if expressed in ppm vol n-hexane (C_6H_{14}) equivalent. Its value in this formula is 6×10^{-4} ;

H_{CV} is the atomic ratio of hydrogen to carbon in the fuel. The arbitrary value is 1,7261

O_{CV} is the atomic ratio of oxygen to carbon in the fuel. The arbitrary value is 0,0176

NOTE The simplified lambda calculation is only valid for measurements on cars with negligible NO_x concentrations in the exhaust gas.

A.3 Other formulae

Other formulae may also be applied. As specified in 7.2.2 the operating instructions shall include the applied model.

[1] J. Brettschneider, Berechnung des Luftverhältnisses λ von Luft-Kraftstoff-Gemischen und des Einflusses von Meßfehlern auf λ in Bosch Technische Berichte, Volume 6 (1979), No. 4, pages 177-186.