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INTERNATIONAL RECOMMENDATION OIML R 99

Third edition
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AMENDMENT 1
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Instruments for measuring vehicle exhaust emissions

AMENDMENT 1

Instruments de mesure des gaz d'échappement des véhicules

AMENDEMENT 1

Reference numbers
ISO 3930:2000/Amd.1:2004(E)
OIML R 99:2000/Amd.1:2004(E)

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Web www.iso.org

Bureau International de Métrologie Légale
11, rue Turgot • F-75009 Paris
Tel. + 33 (0)1 48 78 12 82
Fax + 33 (0)1 42 82 17 27
E-mail biml@oiml.org
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Amendment 1 to ISO 3930:2000 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 5, *Engine tests*.

NOTE Since ISO 3930:2000 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.

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

This publication — reference OIML R 99:2000/Amd.1:2004(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 2003.

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Bureau International de Métrologie Légale
11, rue Turgot - 75009 Paris - France
Telephone: 33 (0)1 48 78 12 82
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Instruments for measuring vehicle exhaust emissions

AMENDMENT 1

Page 15, A.8.3

Replace the first paragraph of the subclause by the following:

“Test gases shall be supplied at the probe at ambient test pressure (to within 750 Pa). The measurements shall be performed using two mixtures composed of the recommended fractions given in columns 2 and 3 of Table A.7 at the following pressures:

— ambient pressure;

— extreme high pressure;

— extreme low pressure;

— ambient pressure.”

Page 19, Table A.16

Replace “0,5 % vol” by “0 % vol” as the volume fraction of mesurand O_2.

ICS 13.040.50; 43.180

Price based on 1 page

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11, rue Turgot • F-75009 Paris
Tel. + 33 (0)1 48 78 12 82
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International Standard ISO 3930 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 5, *Engines tests*.

This third edition cancels and replaces the second edition (ISO 3930:1993), 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.

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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
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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

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 comply in order to meet any OIML performance requirements.

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.

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.

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

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

ISO 7395, *Gas analysis — Preparation of calibration gas mixtures — Mass dynamic method.*

IEC 60068-2-1:1990, *Environmental testing — Part 2: Tests — Test A: Cold.*

IEC 60068-2-2:1974, *Environmental testing — Part 2: Tests — Test B: Dry heat.*

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

IEC 60068-2-28:1990, *Environmental testing — Part 2: Tests — Guidance for damp heat tests.*

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

IEC 60068-2-34:1973, *Environmental testing — Part 2: Tests — Test Fd: Random vibration wide band — General requirements.*

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.*

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.*

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

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

IEC 61000-4-6:1996, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 6: Immunity to conducted disturbances, induced by radio-frequency fields.*

BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML:

International Vocabulary of Basic and General Terms in Metrology (VIM), Second edition, 1993.

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 to a level that prevents condensation within the gas handling system downstream from its location

3.3
filter unit
device that removes particulate matter 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 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 gas adjustment facility
facility to adjust the instrument to the value of a calibration gas

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

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.

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

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

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.)

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

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

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

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 gas
stable gas mixture of known concentration used for periodic calibration of the instruments and for various performance tests

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

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 an 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 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 gas when required by the technology used;
- detection devices to 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.

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".

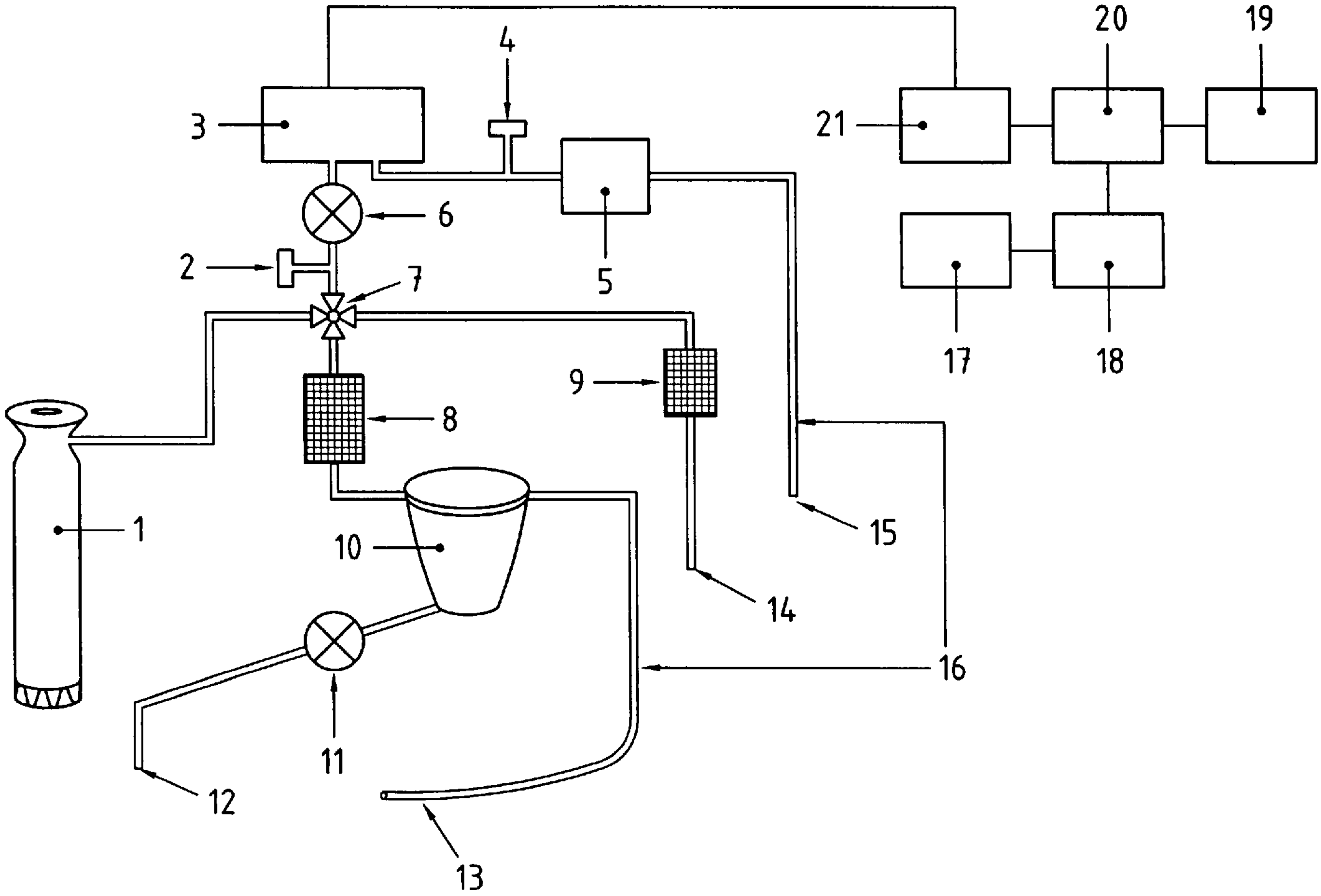
NOTE Historically, the units of volume fraction have been used for field inspection; however blended gases can generally be manufactured in molar fractions to more accurate standards. Assuming the gas mixtures obey the ideal gas law, molar fractions are considered to be equal to volume fractions in this International Standard/Recommendation.

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 to 21	0 to 2 000



Key

1	Calibration gas input (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)
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 subclauses in the text)

5.3 Resolution of indication

5.3.1 Analog scale intervals and scale marks

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 % vol for measurand values ⩽ 4 % vol
0,1 % vol for measurand values > 4 % vol

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 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	± 12 ppm 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.

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:	nominal voltage ± 2 %, nominal frequency ± 1 %;
e)	presence of influencing gas components:	none except the measurands in N_2.

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

5.5.2 Rated operation conditions

a) temperature:	5 °C to 40 °C;
b) relative humidity:	up to 90 %;
c) atmospheric pressure:	Class 0 and Class I: 860 hPa to 1 060 hPa; Class II: ambient ± 25 hPa;
d) mains voltage variation:	− 15 % to + 10 % of the nominal voltage, and ± 2 % of the nominal frequency.

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.

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) short time power reductions;

c) bursts from the mains (transients);

d) electrostatic discharges;

e) radiated radio frequency electromagnetic fields; and

f) mains frequency magnetic fields.

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 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 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.

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 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 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 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 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, 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. 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 added in the gas handling system for introducing calibration 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, 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. A method for coupling shall be provided such that each time a gas calibration is conducted, the gas value and the internal adjustment value are adjusted and the indication equals the calibration 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 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 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 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 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 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 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.

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

6.3.11 A battery-operated instrument shall either continue to function correctly or not indicate any values whenever the voltage is below the manufacturer's specified value.

7 Inscriptions and operating instructions

7.1 Inscriptions

7.1.1 The instruments shall have a permanent 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;

d) pattern approval mark and model number;

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

f) minimum and nominal flow rate;

g) nominal mains voltage, frequency 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, 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.

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;

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) a specification of the voltage and frequency required of any 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;

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.

8 Metrological controls

8.1 Pattern approval

8.1.1 Documentation

The documentation for an instrument supplied by the manufacturer when applying for pattern approval shall include:

a) a description of its general principle of measurement;

b) a list of its essential components with their characteristics;

c) a description of its essential components with drawings and diagrams that are necessary for testing and maintenance;

d) the general information on the software required for a micro-processor equipped measuring instrument;

e) in case a lambda calculation is included, a description of the applied formula with the values of the parameters and physical constants incorporated, and evidence showing that the requirement of 5.10 is met;

f) the operating instructions that shall be provided to the user.

Along with an application for pattern approval, the manufacturer shall provide any data or other information that may support the assertion that the design and construction of the instrument complies with the requirements of this International Standard/Recommendation.

8.1.2 General requirements

Pattern evaluation shall be carried out on at least one and normally not more than three units, which represent the definitive pattern. The evaluation shall consist of the tests specified in 8.1.3.

8.1.3 Inspection and tests

The inspection and testing of instruments is intended to verify compliance with the requirements of clauses 5, 6 and 7 of this International Standard/Recommendation.

As a rule, tests should be carried out on the complete instrument. If the size or configuration of the instrument do not render it suitably to being tested as a unit or if only a particular component or device of the instrument is concerned, a test may be carried out on the component or device separately. Such tests may only be performed if a simulated measurement set-up can be achieved that reflects the rated operating conditions of the component or device.

For all classes of instruments, the contents of gas mixtures used during pattern approval shall conform to those specified in annex A (normative) (generally a measurand gas in N_2). For initial verification, subsequent verification and routine testing, the use of more realistic gas mixtures containing CO and CO_2 and HC in N_2 when applicable, should be considered.

NOTE It is not intended that the instrument or its components should be dismantled for a test.

8.1.3.1 An instrument shall be given a visual inspection to obtain a general appraisal of its design and construction.

8.1.3.2 An instrument shall be tested according to clause 9 to determine its correct functioning.

8.1.3.3 The manufacturer's written operating instructions for an instrument shall be checked to ensure that correct procedures are clearly indicated especially those specified in 7.2.

8.2 Initial verification

8.2.1 General requirements

A new instrument shall undergo initial verification only after pattern approval. The verification shall be carried out using suitable testing means and certified calibration gases.

8.2.2 Inspection and tests

8.2.2.1 Initial verification of an instrument includes a visual inspection to determine conformance with the approved pattern.

NOTE Procedures should be provided for initial verification. An example of such a procedure is given in annex C (informative).

8.2.2.2 After adjusting an instrument according to the routine adjustment procedure described in the manufacturer's operating instructions, tests to determine its errors shall be carried out under rated operating conditions at several values over the measuring range.

The tests shall be performed using gas mixtures of at least three different volume fractions for an instrument of Class 0 and Class I and at least two volume fractions for a Class II instrument within the nominal ranges of the measurands given in Table 6.

Table 6

Class	Measurand	Nominal range
0 and I	CO	0,5 % vol to 5 % vol
	CO_2	4 % vol to 16 % vol
	HC	100 ppm vol to 2 000 ppm vol
II	CO	1 % vol to 7 % vol
	CO_2	6 % vol to 16 % vol
	HC	300 ppm vol to 2 000 ppm vol

For all classes the oxygen channel should be tested for zero reading and span reading using a calibration gas without oxygen (only CO and/or CO_2 and/or HC in N_2) and a calibration gas containing 20,9 % vol O_2.

The calibration gases shall be supplied at the probe at ambient pressure (to within 750 Pa).

The errors observed shall be within the limits of the maximum permissible errors of 5.4.2 on initial verification for each measurement.

8.3 Subsequent verification

Instructions about requirements and intervals for subsequent verification and advice about routine testing shall be provided.

NOTE 1 Examples of procedures for subsequent verification and routine testing are given in annexes D and E (informative) respectively.

NOTE 2 The user should be informed that measurements of volume fractions below the lower limits specified during initial verification will result in large relative errors, even though the absolute errors may remain within acceptable limits. The user should be promptly informed of current applicable lower limit values. These large relative errors should be carefully considered before using such low volume fractions to evaluate vehicle emission performance.

9 Performance tests for pattern approval

Prior to the pattern approval tests and when specified in the manufacturer's operating instructions provided under 8.1.1 f), the instrument shall be adjusted with calibration gases according to these instructions. The calibration gases shall be supplied to the probe at ambient pressure (to within 750 Pa).

9.1 Check of the calibration curve

This test shall be carried out according to clause A.2, under reference conditions. During this test, the errors shall not exceed the maximum permissible intrinsic error of 5.4.1 for any measurement.

9.2 Stability with time or drift

This test shall be carried out according to clause A.3, under reference conditions. During this test, the requirements of 5.11 shall be met.

9.3 Repeatability

This test shall be carried out according to clause A.4, under reference conditions. During this test, the requirements of 5.12 shall be met.

9.4 Effect of influence quantities

As a rule, only one influence quantity shall be varied during a test while all the others are kept at their reference values.

9.4.1 Environmental conditions and electrical supply

The indications of the instruments shall remain within the maximum permissible error on initial verification during the following tests covering the rated operating conditions specified in 5.5.2, except for power supply variations that shall not cause a variation of indication larger than half the modulus of the maximum permissible error on initial verification:

a) dry heat: see clause A.5;

b) cold: see clause A.6;

c) damp heat, steady state: see clause A.7;

d) atmospheric pressure: see clause A.8;

e) power supply variation: see clause A.9.

9.4.2 Influence of gas components other than the measurand (cross sensitivity)

This test shall be carried out under reference conditions except for 5.5.1 e). During this test (see clause A.9), the requirements of 5.5.3 shall be met where the absolute value of the variation of the indication found shall not exceed half the modulus of the maximum permissible error on initial verification.

9.5 Disturbances

Significant faults shall not occur, or shall be detected by means of checking facilities during the following tests, carried out to verify the requirements of 5.6 for the instruments under rated operating conditions (as specified in 5.5.2):

a) mechanical shock and vibrations: see clause A.11;

b) short time power reductions: see clause A.12;

c) bursts from the mains (transients): see clause A.13;

d) electrostatic discharges: see clause A.14;

e) radiated, radio frequency electromagnetic fields: see clause A.15;

f) mains frequency magnetic fields: see clause A.16.

9.6 Other important technical and metrological requirements

The instruments shall be tested for conformity to the following requirements:

a) warm-up time according to 5.8: see clause A.17;

b) response time according to 5.7: see clause A.18;

c) low flow according to 6.1.7: see clause A.19;

d) leakage according to 6.1.8: see clause A.20;

e) HC residue according to 6.3.2: see clause A.21;

f) filter unit according to 6.1.3: see clause A.22;

g) water separator according to 6.1.4: see clause A.23;

h) propane/hexane equivalency factor according to 5.9: see clause A.24.

9.7 Source of power for pattern evaluation

The appropriate source of power for field use of instruments shall be specified in the manufacturer's operating instructions. If a source of power is specified in addition to the mains, for example a battery or portable generator, then the instrument shall undergo pattern tests with each source of power with which it is intended to operate.

Each test specified in annex A (normative/mandatory) shall be started and completed without changing or recharging the power source.

Annex A
(normative/mandatory)

Description of performance tests for pattern approval

A.1 General

The HC volume fractions specified for these tests are expressed in terms of *n*-hexane; however, propane may be used as the HC component of the calibration gas as required for each performance test except the one specified in clause A.24 (see clause 1 and 5.9).

It is necessary to consult the referenced publications before conducting the tests.

A.2 Calibration curve

The errors of the instruments shall be determined separately for each measurand and for at least three values within their measuring range using the recommended volume fractions given in Table A.1.

Table A.1

Measurand	**Volume fraction of measurand**		
	1st	2nd	3rd
CO	0,5 % vol	1 % vol	3,5 % vol and/or 5 % vol
CO_2	6 % vol	10 % vol	14 % vol
HC	100 ppm vol	300 ppm vol	1 000 ppm vol
O_2	0,5 % vol	10 % vol	20,9 % vol

In addition, for Class 0 instruments, it is advisable to use volume fractions smaller than 0,3 % vol for CO and 50 ppm vol for HC.

The measurements shall be performed successively.

A.3 Stability with time or drift

This test shall be conducted for a period of 4 h following the warm-up time. Measurements shall be performed at least every half-hour using the recommended volume fractions given in Table A.2.

Table A.2

Measurand	**Volume fraction of measurand**	
	Class 0 and Class I	Class II
CO	0,5 % vol	3,5 % vol
CO_2	14 % vol	14 % vol
HC	100 ppm vol	1 000 ppm vol
O_2	0,5 % vol	0,5 % vol

A.4 Repeatability

The test procedure specified in 5.12 shall be carried out with the recommended volume fractions given in Table A.3.

Table A.3

Measurand	**Volume fraction of measurand**	
	Class 0 and Class I	Class II
CO	0,5 % vol	3,5 % vol
CO_2	14 % vol	14 % vol
HC	100 ppm vol	1 000 ppm vol
O_2	0,5 % vol	0,5 % vol

A.5 Dry heat

A.5.1 This test consists of exposure of the instruments to a temperature of 40 °C under “free air” conditions for 2 h (the time duration specified begins after the instrument has reached temperature stability). During the test, the rate of change in temperature shall not exceed 1 °C/min during heating up and cooling down, and the relative humidity in the testing atmosphere shall not exceed 50 %.

A.5.2 The calibration gas shall be supplied to the probe at ambient pressure (to within 750 Pa). During the test one measurement shall be performed every half-hour using the two mixtures composed of the recommended volume fractions given in columns 2 and 3 of Table A.4. See IEC 60068-2-2, IEC 60068-3-1 and IEC 60068-3-1A.

Table A.4

Measurand	Volume fraction of measurand	
	1st mixture	2nd mixture
CO	0,5 % vol	3,5 % vol
CO_2	14 % vol	14 % vol
HC	100 ppm vol	1 000 ppm vol
O_2	0,5 % vol	0,5 % vol

A.6 Cold

A.6.1 This test consists of exposure of the instruments to a temperature of 5 °C under "free air" conditions for 2 h (the time duration specified begins after the instruments have reached temperature stability). During the heating up or cooling down of the instrument, the rate of change in temperature shall not exceed 1 °C/min.

A.6.2 The calibration gas shall be supplied to the probe at ambient pressure (to within 750 Pa). During the test one measurement shall be performed every half-hour using two mixtures composed of the recommended volume fractions given in columns 2 and 3 of Table A.5. See IEC 60068-2-1, IEC 60068-3-1 and IEC 60068-3-1A.

Table A.5

Measurand	Volume fraction of measurand	
	1st mixture	2nd mixture
CO	0,5 % vol	3,5 % vol
CO_2	14 % vol	14 % vol
HC	100 ppm vol	1 000 ppm vol
O_2	0,5 % vol	0,5 % vol

A.7 Damp heat, steady state

A.7.1 This test consists of exposure of the instruments to a constant temperature of 30 °C and a constant relative humidity of 85 % for two days. The exposure shall be such that water does not condense on the instruments. The temperature is deemed to be steady when the difference between the extreme temperatures does not exceed 5 °C, and the rate of change does not exceed 5 °C/h.

A.7.2 The calibration gas shall be supplied to the probe at ambient pressure (to within 750 Pa). During the test, one measurement shall be performed every day using two mixtures composed of the recommended volume fractions given in columns 2 and 3 of Table A.6. See IEC 60068-2-3 and IEC 60068-2-28.

Table A.6

Measurand	Volume fraction of measurand	
	1st mixture	2nd mixture
CO	0,5 % vol	3,5 % vol
CO_2	14 % vol	14 % vol
HC	100 ppm vol	1 000 ppm vol
O_2	0,5 % vol	0,5 % vol

A.8 Atmospheric pressure

A.8.1 For Class 0 and Class I instruments, the test consists of measurements under the extreme pressures of the rated operating conditions or extreme pressures outside these limits when specified by the manufacturer.

The extreme values shall be reached gradually from stable ambient pressure conditions and shall then be kept stable during 30 min before starting the measurements as specified in A.8.3.

A.8.2 For Class II instruments, the test applies to the instruments having a pressure compensation device. It consists of measurements under the extreme pressures of the rated operating conditions or extreme pressures outside these limits when specified by the manufacturer. The pressure shall be kept stable during 30 min before starting the measurements as specified in A.8.3.

A.8.3 Test gases shall be supplied at the probe at ambient test pressure (to within 750 Pa). At least two measurements shall be performed at each extreme pressure value using two mixtures composed of the recommended volume fractions given in columns 2 and 3 of Table A.7.

The errors observed shall be within the limits of the maximum permissible errors specified in Table 4 on initial verification for each measurement.

NOTE If an automatic or semi-automatic adjustment is part of the pressure compensation process, care must be taken to ensure that the measurements at both extreme pressure values are performed after such adjustment has been carried out.

Table A.7

Measurand	Volume fraction of measurand	
	1st mixture	2nd mixture
CO	0,5 % vol	3,5 % vol
CO_2	14 % vol	14 % vol
HC	100 ppm vol	1 000 ppm vol
O_2	0,5 % vol	0,5 % vol

A.9 Power supply variation[1]

A.9.1 The a.c. power supply test consists of exposure of the instruments to extreme values of the nominal power supply voltage U_{nom} and nominal frequency f_{nom} for a period long enough to perform the required measurement. The conditions given in Table A.8 shall be applied.

Table A.8

Parameter	Relative tolerance, %
Nominal voltage U_{nom}, V	+ 10 − 15
Nominal frequency f_{nom}, Hz	± 2

A.9.2 The d.c. power supply test consists of exposure of the instruments to the specified power supply conditions for a period long enough to perform the required measurement. The upper tolerance limit shall be as specified by the manufacturer. The lower tolerance limit shall be the lowest voltage at which the instrument provides measurement results.

A.9.3 While the instruments are exposed separately to each type of mains variation indicated in A.9.1 or A.9.2, measurements shall be performed using the recommended volume fractions given in Table A.9.

Table A.9

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.10 Influence of gas components other than the measurand (cross sensitivity)

A.10.1 The cross sensitivity shall be determined by the following two tests:

A.10.1.1 Test with N_2 alone:

a) Supply the instrument with N_2 alone.

b) Supply the instrument successively with each influencing gas alone in N_2 at its maximum value as specified in 5.5.3.

c) Compare the “zero” responses of the instruments determined in a) and b) for each measurand. The difference of indications shall meet the requirements specified in 5.5.3 for “zero”.

A.10.1.2 Test with all measurands in N_2:

a) Supply the instrument with a measurand in N_2 alone. Repeat the operation for the other measurands.

b) Supply the instrument with all measurands together in N_2.

c) For each measurand, the difference between the errors of the instruments determined in a) and the error determined in b) shall meet the requirements specified in 5.5.3.

A.10.2 For test in A.10.1.2 and for instruments that detect with infra red absorption and for O_2 channel, the following volume fractions are recommended for the measurands in N_2:

- 3,5 % vol CO;
- 14 % vol CO_2;
- 1 000 ppm vol HC; and
- water up to saturation.

Referring to 5.5.3, if the presence of O_2 and H_2 is necessary, two different gas mixtures shall be used to avoid explosive risk. The recommended volume fractions for the measurand in N_2 are the following:

— mixture A: 3,5 % vol CO,

14 % vol CO_2,

1 000 ppm HC,

10 % O_2.

— mixture B: 3,5 % vol CO,

14 % vol CO_2,

1 000 ppm HC,

5 % H_2.

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1) For instruments powered by a road vehicle battery, electrical disturbances for tests A.9, A.12 and A.13 are treated in ISO 7637-1 and ISO 7637-2. Application of these disturbances is under consideration.

A.11 Mechanical shock and vibrations

A.11.1 For mechanical shock testing, the tested instrument shall be placed in its normal position of use on a rigid surface. It shall be tilted on one bottom edge and then allowed to fall freely onto the test surface. The following conditions shall be applied:

- height of fall: 25 mm;
- number of falls: 1 on each bottom edge.

See IEC 60068-2-31.

A.11.2 For vibrations testing (only for hand-held instruments as defined in 3.32), the instrument shall be mounted in its normal position. It shall be exposed to random vibrations with the following conditions:

- total frequency range: 10 Hz to 150 Hz;
- total RMS level: 1,6 m·s^{-2};
- ASD level 10 Hz to 20 Hz: 0,048 m^2·s^{-3};
- ASD level 20 Hz to 150 Hz: – 3 dB/octave;
- number of axes: 3;
- duration per axis 10 Hz to 150 Hz: 2 min.

See IEC 60068-2-36 and IEC 60068-2-34.

A.11.3 Before and after the test, measurements shall be performed using the recommended volume fractions given in Table A.10.

Table A.10

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.12 Short time power reductions[2)]

A.12.1 A test generator suitable for reducing the amplitude of the a.c. mains voltage is used. It shall be adjusted before being connected to the instruments. The mains voltage interruptions and reductions shall be repeated 10 times with an interval of at least 10 s between successive disturbances. 100 % reductions shall be effectuated for a duration of 10 ms; 50 % reductions shall be effectuated for a duration of 20 ms.

A.12.2 During the test, measurements shall be performed using the recommended volume fractions given in Table A.11.

Table A.11

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.13 Bursts from the mains (transients)[2)]

A.13.1 The test consists of exposure of the instruments to bursts of voltage spikes of 1 kV and having a double exponential waveform. Each spike shall have a rise time of 5 ns and a half amplitude duration of 50 ns. The burst length shall be 15 ms, the burst period (repetition time interval) shall be 300 ms. Repetition frequency of the impulses and peak values of the output voltage on 50 Ω load: 5 kHz ± 1 kHz. The transient generator shall have an output impedance of 50 Ω and shall be adjusted before connecting the instruments. At least 10 positive and 10 negative bursts randomly phased shall be applied. Insertion of blocking filters in the cables to the instrument may be necessary to prevent the burst energy being dissipated in the mains.

A.13.2 During the test, measurements shall be performed using the recommended volume fractions given in Table A.12. See IEC 61000-4-4.

Table A.12

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.14 Electrostatic discharges

A.14.1 A capacitor of 150 pF shall be charged by a suitable d.c. voltage source of 6 kV in contact mode and 8 kV in air mode. Then it shall be discharged through the instrument by connecting one terminal to the instrument's ground chassis and the other through a 330 Ω resistance to the instrument's surfaces that

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2) See footnote to A.9.

are normally accessible to the user. At least 10 successive discharges shall be applied with a time interval between discharges of at least 10 s. An instrument not equipped with a grounding terminal shall be placed on a grounded plane surface that projects beyond the instrument by at least 0,1 m on all sides. The associated grounded connection to the capacitor shall be as short as possible.

A.14.2 In the contact discharge mode, to be carried out on conductive surfaces, the electrode shall be in contact with the instrument and the discharge shall be actuated by the discharge switch of the generator. In the air discharge mode, on insulating surfaces, the electrode is approached to the instrument and the discharge occurs by spark.

A.14.3 During the test, measurements shall be performed using the recommended volume fractions given in Table A.13. See IEC 61000-4-2.

Table A.13

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.15 Radiated, radio frequency, electromagnetic fields

A.15.1 Instruments shall be exposed to an electromagnetic field strength as follows:

— frequency range: 26 MHz to 1 000 MHz;

— field strength: 10 V/m;

— modulation: 80 % AM, 1 kHz sine wave.

A.15.2 The field strength may be generated in the following ways:

a) a strip line for low frequencies for small instruments from d.c. to 150 MHz;

b) a TEM cell (Transverse Electromagnetic Mode cell) for higher frequencies, up to 1 GHz;

c) a biconical antenna (26 MHz to 300 MHz);

d) a log periodic antenna (100 MHz to 1 000 MHz).

The specified field strength shall be established prior to the actual testing (without the instruments in the field).

When the test is carried out in a shielded enclosure to comply with international laws prohibiting interference to radio communications, care needs to be taken to handle reflections from walls. Anechoic shielding may be necessary.

A.15.3 During the test, measurements shall be performed using the recommended volume fractions given in Table A.14. See IEC 61000-4-3.

NOTE The attention of the experts is drawn to the fact that IEC 61000-4-3 refers to a frequency range from 80 MHz to 1 000 MHz.

The lower frequencies are covered by IEC 61000-4-6.

Consequently, laboratories having to apply this International Standard/Recommendation, are invited to apply its provision with a test level of severity 3.

The above applies only if the instruments are made of several subparts connected together with cables.

Table A.14

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.16 Mains frequency magnetic fields

The instrument tested shall be exposed in all directions to a magnetic field of 30 A/m at mains frequency.

During the test, measurements shall be performed using the recommended volume fractions given in Table A.15.

Table A.15

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.17 Warm-up time

A.17.1 At reference conditions and at 5 °C, the warm-up time test to verify compliance with 5.8 shall consist of the following steps:

a) stabilise the instrument at each temperature;

b) let the instrument warm up;

c) immediately after either the manufacturer's prescribed warm-up period has elapsed or an automatic warm-up lockout has been de-activated, perform a volume fraction measurement (with any necessary internal adjustment being performed prior to this measurement);

d) at time intervals of 2 min, 5 min and 15 min after warm-up, perform a measurement with the same calibration gas as in step c).

A.17.2 The difference between any of the four measured values in c) and d) in A.17.1 shall not exceed the modulus of the maximum permissible error on initial verification.

NOTE At reference conditions, the warm-up time test may be included with the drift test.

A.18 Response time

A.18.1 A measurement shall be taken to determine the time required for an instrument to respond to a calibration gas after sampling ambient air supplied at the probe. A means shall be employed for instantly changing from sampling ambient air to sampling calibration gas through the probe. The gases shall be supplied at the probe at ambient pressure (to within 750 Pa). The response time shall not exceed the appropriate values specified in 5.7.

A.18.2 The recommended volume fractions given in Table A.16 shall be used.

Table A.16

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.19 Low flow

A.19.1 A measurement shall be performed with a calibration gas that is initially supplied to the gas handling system at a gas flow rate greater than the minimum required by the tested instrument. During the measurement, the gas flow rate shall be reduced until the low flow indicator responds according to the requirements of 6.1.7.

A.19.2 The recommended volume fractions given in Table A.17 shall be used.

Table A.17

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.20 Leakage

A.20.1 When a gas mixture is used, the adjustment of the leakage and the test shall be performed successively for each component.

A.20.2 An adjustable leak shall be introduced artificially into the gas handling system near the pump where a leak of an appropriate orifice size will have the greatest effect on the measurement. With this artificial leak closed, a calibration gas shall be supplied at the probe at ambient pressure (to within 750 Pa).

A.20.3 While sampling the calibration gas, record the indication, then adjust the leakage rate so that the indication of the calibration gas differs from the value indicated previously (without the leak) by an amount equal to the requirement of 6.1.8. Without disturbing the artificial leak, remove the calibration gas supplied at the probe, and conduct the leakage test procedure as described in the manufacturer's operating instructions.

A.20.4 The recommended volume fractions given in Table A.18 shall be used.

NOTE Since the leakage test is performed by introducing air into the system, the calibration gas supplied at the probe should have a volume content of O_2 close to 0 %.

Table A.18

Measurand	Volume fraction of measurand
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0 % vol

A.21 HC residue

A.21.1 The exhaust of a specially adjusted test engine shall be sampled for at least 5 min by an instrument in thermal equilibrium at 5 °C. The exhaust gas shall contain at least 5 % CO and 800 ppm HC. Immediately after the sampling, conduct an HC residue check as described by the manufacturer's operating instructions. Repeat this operation as many times as necessary to obtain an HC residue that complies with the requirements of 6.3.2. Then calibration gases shall be supplied to the probe to check compliance with the maximum permissible error on initial verification.

A.21.2 For this test, the measurements shall be performed using the recommended volume fractions given in Table A.19 shall be used which shall be supplied at the probe at ambient pressure (to within 750 Pa).

Table A.19

Measurand	Volume fraction of measurand
CO	3,5 % vol
HC	1 000 ppm vol

A.22 Filter unit

A.22.1 At reference conditions, the instrument shall be exposed to exhaust gases from a specially adjusted test engine according to 6.1.3 for a period of at least half an hour.

Immediately after the sampling, conduct an HC residue check as described by the manufacturer's operating instructions. Repeat this operation as many times as necessary to obtain an HC residue that complies with requirements of 6.3.2. The instrument shall be checked immediately with a calibration gas that shall be supplied to the gas handling system at ambient pressure (to within 750 Pa). The instrument shall comply with the requirements for the maximum permissible error on initial verification and for the response time.

A.22.2 The test shall be carried out using the recommended volume fractions given in Table A.20.

Table A.20

Measurand	Volume fraction of measurand
CO	3,5 % vol
CO_2	14 % vol
HC	1 000 ppm vol
O_2	0,5 % vol

A.23 Water separator

A.23.1 The water separator shall be subjected to the following two tests.

a) High temperature test:

   — stabilize the instrument at 40 °C, and

   — expose the instrument to water saturated N_2 at 40 °C, or water saturated ambient air at 40 °C, supplied to the gas handling system for 30 min.

b) Low temperature test:

   — stabilize the instrument at a low ambient temperature within the rated operating conditions, and

   — expose the instrument to exhaust gases from any (except two stroke engine) car attached to the probe for 30 min.

A.23.2 After each test, the instrument shall be checked immediately with the same volume fractions of gases as recommended in A.22.2. It shall comply with the requirements of the maximum permissible error on initial verification and with the response time requirements of 5.7 before and after the test.

A.24 Propane/hexane equivalency factor

A.24.1 The test procedure is as follows:

a) make a measurement for each of the following recommended volume fractions of propane calibration gas: 200 ppm vol and 2 000 ppm vol;

b) calculate the absolute error of the instruments for each of these two volume fractions of propane calibration gas. To this end, the true value is determined as follows:

$I_{\text{true}} = C \times \text{PEF}$

where

C is the true value of the volume fraction of propane, and

PEF is the value of the propane/hexane equivalency factor given by the manufacturer;

c) make a measurement for each of the following recommended fractions of hexane calibration gas:

100 ppm vol and 1 000 ppm vol;

d) calculate the absolute error of the instrument for each of these two volume fractions of hexane;

e) for each of the two volume fractions, calculate the difference between the error obtained with propane and that obtained with hexane.

A.24.2 The difference between the errors shall not exceed (according to the case — see 5.9) the applicable maximum permissible intrinsic error or half of the applicable maximum permissible intrinsic error.

NOTE It is assumed that the error of the instruments are constant both near 100 ppm vol and near 1 000 ppm vol.

CAUTIONARY NOTE — Because of its low vapor pressure, hexane can condense at ordinary temperatures of shipment, storage and use. Such condensation would invalidate the certified gas mixture concentration. Therefore, extreme care shall be taken at all times during shipment, storage, and use to ensure that hexane cylinders are maintained sufficiently above the condensation temperature for the specified gas volume fraction at the cylinder pressure.

Annex B
(normative/mandatory)

Designation of calibration gases and their composition

B.1 General requirements

B.1.1 The calibration gases shall be supplied either in gas cylinders or by dynamic blending.

a) Each gas cylinder shall be identified with the following information (included as a mark, label and/or certificate):

- supplier of the gas cylinder and serial number;
- composition of the gas mixture;
- temperature limits for use and storage;
- date of analysis and expiration date;
- testing authority; and
- the marking "calibration gas mixture".

b) Blended gases shall meet the requirements of ISO 6145 and 7395 as well as the requirements of B.1.2 and B.2.

B.1.2 The composition of calibration gases used for pattern approval and verification shall be certified as complying with the requirements of B.2 by a competent authority and as being traceable to national, regional or international standards.

B.1.3 Calibration gases for all purposes except pattern approval and verification shall be certified by the supplier of the gases and shall be traceable to the appropriate standards.

B.1.4 The material of gas cylinders shall be inert to the gases contained therein.

B.1.5 The appropriate safety regulations shall be followed in the handling of the gases.

B.2 Specifications and uncertainties of composition of the gas mixtures

B.2.1 The unit for the quantity of gases contained or delivered shall be either in molar or volume fractions (see 5.1).

B.2.2 The blend tolerances of the calibration gas mixtures shall not exceed 15 % of the volume fraction of each component.

B.2.3 For gas mixtures the uncertainty in the composition shall be 1 % or less of the volume fraction of each measurand except for HC of 1 000 ppm and below, where the uncertainty shall be 2 % or less. The composition of each component not subject to measurement shall have an uncertainty of 5 % or less.

The specified uncertainty values are values relative to the standards referred to in B.1.2.

B.3 Preparation of gases in special cases

B.3.1 Propane shall be used for calibration gas mixtures requiring HC; therefore the propane/hexane equivalency factor shall be taken into account.

B.3.2 Volume fractions of O_2, H_2, NO, and water vapor shall be blended with the other gases as required during the tests specified in annex A. The volume fraction of water vapor required shall not be supplied in high pressure gas cylinders because of instability and corrosion effects, and mixtures of O_2 shall only be blended with N_2.

B.3.3 Ambient air shall be drawn through a charcoal filter or equivalent system when it is used to set zero for instruments measuring HC.

Annex C
(informative)

Procedure for initial verification

The initial verification of the instruments may include the following tests.

a) Check the power supply voltage and frequency at the location of use to determine compliance with the specifications on the measuring instrument's label.

b) Check the activation of the warm-up lockout for the Class 0 or Class I instruments by attempting to make a measurement within 1 min of initial power-on of the instruments.

c) After the instruments have warmed up, perform the calibration curve check as described in 8.2.2.2.

d) Check the air-tightness of the system by performing a leak check as described in the manufacturer's operating instructions.

e) Check for HC residues with the procedure described in the manufacturer's operating instructions.

f) Check for the activation of the low gas flow device (and also for the low flow lockout for a Class 0 or Class I instrument) by restricting the gas flow supplied to the probe while sampling ambient air.

g) Check the response time of the CO channel.

Annex D
(informative)

Procedure for subsequent verification

Subsequent verification of an instrument at the same location may include the following tests.

a) For short-term subsequent verification, perform all tests included in the initial verification except for the power check and the warm-up check.

b) For short-term subsequent verification, perform the calibration curve check using the number of gas mixtures required for initial verification, unless the responsible legal authority specifies fewer gas mixtures.

c) For long-term subsequent verification, perform all tests included in the initial verification.

d) When the instruments have been moved to a new location (e.g. change in business address as defined by the responsible legal authority), or have undergone repairs other than the replacement of components as defined in step e) of annex E or in the manufacturer's operating instructions, perform all tests included in the initial verification.

Annex E
(informative)

Procedure for routine testing

A routine test of the instruments should consist of at least the following.

a) Perform an internal adjustment check within 1 hour after performing each vehicle test.

b) Check for HC residues before testing each vehicle.

c) Check the instrument's gas calibration and internal adjustment with a calibration gas at intervals specified by the responsible legal authority or recommended in the manufacturer's operating instruction manual.

d) Perform a leak check at least once a day. Repair any leaks and conduct a successful leak check before testing any vehicle.

e) Conduct a leak check after each disassembly of the gas handling system (e.g. a probe or filter element replacement). Repair any subsequent leaks and conduct a successful leak check before testing any vehicle.

Annex F
(normative/mandatory)

Lambda calculation

F.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.

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.

F.2 Simplified lambda formula

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

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

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.

F.3 Other formulae

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

Bibliography

[1] ISO 7637-1, *Road vehicles — Electrical disturbance by conducting and coupling — Vehicles with nominal 12 V supply voltage.*

[2] ISO 7637-2, *Road vehicles — Electrical disturbance by conducting and coupling — Vehicles with nominal 24 V supply voltage.*

[3] 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.

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