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Instruments for measuring vehicle exhaust emissions

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Part 2 - Metrological controls and tests

8 Metrological controls

8.1 ~~Pattern~~Type approval

8.1.1 Documentation
The documentation for an instrument supplied by the manufacturer when applying for ~~pattern~~type 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. in particular the requirement 6.3.x shall be covered;

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~~type 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~~Type evaluation shall be carried out on ~~at least one and normally not more than~~ three units, which represent the definitive ~~pattern~~type. The evaluation shall consist of the tests specified in 8.1.3. In order to accelerate the test procedure, the testing laboratory can carry out different tests simultaneously on different units randomly chosen (by the laboratory) from the 3 presented.

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~~type approval shall conform to those specified in annex A and B (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 and the documentation shall be studied.
In particular, the following aspects shall be evaluated:

a) indication and resolution (5.1, 5.3);

b) measuring range (5.2);

c) if applicable: printing device (5.x);

d) construction (6.1);

e) adjustment facilities (6.2);

f) security of operation (6.3);

g) inscriptions (7.1);

h) operating instructions (7.2);

i) sealing devices (6.3.9); and

j) consequence of malfunctioning of O_2 sensor (6.3.4)

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~~type approval. The verification shall be carried out using suitable testing means and certified ~~calibration~~ reference gases.

8.2.2 Inspection ~~and tests~~

~~8.2.2.1~~
Before starting the tests, the following inspections shall be performed:

a) carry out ~~Initial verification of an instrument includes~~ a visual inspection to determine conformance with the approved ~~pattern~~type.

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

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

8.2.~~2.2~~3 Tests
The tests to determine the errors of the instrument shall be carried out under rated operating conditions.

a) Before starting the tests, ~~After~~ adjust~~ing an~~ the instrument according to the routine adjustment procedure described in the manufacturer's operating instructions.

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, determine the errors at several values over the measuring range.

~~, 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~~ shall be tested for zero reading and span reading using a ~~calibration gas~~reference gas without oxygen (only CO and/or CO_2 and/or HC in N_2) and a ~~calibration gas~~reference gas containing 20,9 % vol O_2.

The ~~calibration gas~~reference 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.

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 and the O_2 channel.

8.3 Subsequent verification

8.3.1 General requirements
An instrument shall undergo subsequent verification only if
- it has successfully undergone initial verification in the past and
- the validity of the verification has elapsed or
- a repair or modification has been performed that might influence the errors of indication.

The verification shall be carried out using suitable testing means and certified reference gases.

The intervals for subsequent verification is subjected to national legislation. This standard/Recommendation however, suggests an interval not exceeding 1 year.

8.3.2 Inspection
Before starting the tests, a visual inspection shall be performed to determine the validity of the previous verification and the presence of all required stamps, seals and documents.

8.3.3 tests for short-term subsequent verification
If the prescribed interval for subsequent verification has not elapsed by more than 1 month, all tests according to 8.2.3, except the warm-up check shall be performed.

8.3.3 tests for long-term subsequent verification
All tests according to 8.2.3 shall be performed if:
a) the prescribed interval for subsequent verification has elapsed by more than 1 month, or

b) when the instruments have been moved to a new location (e.g. change in business address as defined by the responsible legal authority), or

c) when the instrument has undergone repairs other than disassembly of the gas handling system (e.g. a probe or filter element replacement).

~~Instructions about requirements and intervals for subsequent verification and advice about routine testing shall be provided. **(by whom ?)**~~

~~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~~type approval

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

9.1 Check of the ~~calibration~~ error 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~~voltage and frequency 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~~10), 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~~AC mains voltage dips, short interruptions and voltage variations: see clause A.12;

c) bursts ~~from the mains~~ (transients) on AC mains, signal, data, and control lines: see clause A.13;

d) transient conduction in case of a road vehicle battery: see clause A.x

e~~d~~) electrostatic discharges: see clause A.14;

f) Surges on signal, data, control, and power lines; see A.y

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

~~f~~h) ~~-~~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~~type 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~~type 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 - Description of performance tests for ~~pattern~~type approval (normative/mandatory)

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~~reference 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.
Unless otherwise specified in the description of the test, either binary gasses or gas mixtures can be used.

If the instrument is equipped with a lambda indication, the displayed value of lambda is recorded for each test and compared to the value calculated with the formula specified in Annex A of Part 1. In accordance with 5.10, the difference shall not exceed 0,3 %.

A.2 ~~Calibration~~ Linearity 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~~requirement specified in 5.12 shall be ~~carried out~~tested 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 %.
See IEC 60068-2-2, IEC 60068-3-1 and IEC 60068-3-1A.

A.5.2 The ~~calibration gas~~reference 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.

See IEC 60068-2-1, IEC 60068-3-1 and IEC 60068-3-1A

A.6.2 The ~~calibration gas~~reference 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 mixturel	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.
See IEC 60068-2-78 and IEC 60068-3-4.

A.7.2 The ~~calibration gas~~reference 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 (860 hPa to 1060 hPa) 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 (ambient ± 25 hPa) 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~~ Reference gases shall be supplied at the probe at ambient test pressure (to within 750 Pa).

~~At least two~~The 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 at the following pressures:
- ambient pressure;
- extreme high pressure;
- extreme low pressure;
- ambient pressure.

.
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.

See: OIML D 11, clause 10.4.1

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 Voltage and frequency~~Power supply~~ variation~~[1)]~~

In case the instrument can be used with more than one source of power, all relevant tests A.9.1 to A.9.3 shall be carried out independently.

A.9.1 AC mains voltage and frequency
Instruments intended to be powered by AC mains power are subjected to an ~~The a.c. power supply~~AC mains voltage variation test and an AC mains

~~[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.~~

frequency variation test, ~~consists~~ consisting of exposure of the instruments to extreme values of the nominal ~~power supply~~mains 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 mains voltage U_{nom}, V	+ 10 % - 15 %
Nominal mains 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.~~

Voltage of a road vehicle battery

The test consists of exposure of the instrument to the high voltage and the low voltage as specified in table A.x for a period long enough to perform the required measurement.

Table A.x		
Nominal voltage	12 V	24 V
Low voltage	9 V	18 V
High voltage	16 V	32 V

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 (binary gasses):

- 3,5 % vol CO;
- 14 % vol CO_2;
- 1 000 ppm vol HC; and
- ~~water up to saturation~~humidity > 95%.

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 .

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~~33), 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 $m \cdot s^{-2}$;~~

~~- ASD level 10 Hz to 20 Hz: 0,048 $m^2 \cdot s^{-3}$;~~

~~- ASD level 20 Hz to 150 Hz: – 3 dB/octave;~~

~~- number of axes: 3;~~

~~- duration per axis 10 Hz to 150 Hz: 2 min.~~

total frequency range:	10 Hz to 150 Hz;
total RMS level:	1,6 $m \cdot s^{-2}$;
ASD level 10 Hz to 20 Hz:	0,048 $m^2 \cdot s^{-3}$;
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~~ 64~~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~~AC mains voltage dips, short interruptions and voltage variations ~~2)~~

A.12.1 A test generator suitable ~~for reducing~~to reduce for a defined period of time the amplitude of the ~~a.c.~~AC mains voltage is used. It shall be adjusted before being connected to the instrument~~s~~.

~~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.~~

For the voltage dips, all 3 tests shall be applied. The voltage reductions shall be repeated 10 times with an interval of at least 10 seconds.

Table A.x			
Voltage dips	Test a	Reduction	0 %
		Duration	0,5 cycles
	Test b	Reduction	0 %
	Test c	Reduction	70 %
		Duration	50 Hz: 25 cycles; 60 Hz: 30 cycles
Short interruptions		Reduction	0 %
		Duration	50 Hz: 250 cycles; 60 Hz: 300 cycles

See IEC 61000-4-11

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.~~The test consist of exposure to bursts of voltage spikes on power ports, protective earth, and Input/Output signal, data and control ports.

The injection network on the mains shall contain blocking filters to prevent the burst energy being dissipated in the mains.

For the coupling of the bursts into the I/O and communication lines and ports for external battery power, a capacitive coupling clamp as defined in the standard shall be used.

The test shall be performed under the following conditions:

	AC mains power ports and protective earth	Input/Output signal, data and control ports
Test voltage	1 kV	0,5 kV
Repetition rate	5 kHz	

~~2) See footnote to A.9.~~

Polarity of the bursts	Both positive and negative
Duration of the test	≥ 1 minute

See IEC 61000-4-4.

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.x Electrical transient conduction in case of road vehicle battery

A.x.1 Electrical transient conduction along supply lines
The instrument is subjected to the disturbances listed in Table A.x
For more details of the test and the shape of the pulses, the referenced standard shall be consulted.

Table A.x

Pulse	U_n	12 V	24 V
2a	U_s	+ 50 V	+ 50 V
2b	U_s	+ 10 V	+ 20 V
3a	U_s	- 150 V	- 200 V
3b	U_s	+ 100 V	+ 200 V
4	U_s	- 7 V	- 16 V

U_n = Nominal battery voltage
U_s = Pulse voltage

See ISO 7637-2, test level IV

A.x.2 Electrical transient conduction via lines other than supply lines
The instrument is subjected to the disturbances listed in Table A.y
For more details of the test and the shape of the pulses, the referenced standard shall be consulted.

Table A.y

Pulse	U_n	12 V	24 V
a	U_s	- 60 V	- 80 V
b	U_s	+ 40 V	+ 80 V

U_n = Nominal battery voltage
U_s = Pulse voltage

See ISO 7637-3, test level IV

A.x.3 During the test, measurements shall be performed using the recommended volume fractions given in Table A.z

Table A.z

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 For instruments not equipped with a ground terminal, the instrument shall be fully discharged between discharges.

Contact discharge is the preferred test method. Air discharges shall be used where contact discharge cannot be applied.

Direct application:
In the contact discharge mode to be carried out on conductive surfaces, the electrode shall be in contact with the EUT.
In the air discharge mode on insulated surfaces, the electrode is approached to the EUT and the discharge occurs by spark.

Indirect application:
The discharges are applied in the contact mode to coupling planes mounted in the vicinity of the EUT.

The test shall be performed under the following conditions:

Contact discharge	6 kV
Air discharge	8 kV
Number of discharges	≥ 10
Time interval between discharges	≥ 10 s

See IEC 61000-4-2. ~~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 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~~ 2 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.y Surges on signal, data, control and power lines

A.y.1 The test consists of exposure to surges for which the rise time, pulse width, peak values of the output voltage/current on high/low impedance load and minimum time interval between two successive pulses are defined in the referred standard.
At least 3 positive and 3 negative surges shall be applied.
On AC mains supply lines at least 3 positive and 3 negative surges shall be applied synchronously with AC supply voltage in angles 0°, 90°, 180° and 270°.
For this test, supply lines for power by an external battery shall be considered as "signal, data, and control lines".

Table A.y.1			
Signal, data, and control lines	Balanced	line to line	1 kV
		line to earth	2 kV
	Unbalanced	line to line	N.A.
		line to earth	2 kV
AC power lines		line to line	1 kV
		line to earth	2 kV

See IEC 61000-4-5

A.y.2 During the test, measurements shall be performed using the recommended volume fractions given in Table A.y.

Table A.y.2	
Measurand	**Volume fraction of measurand**
CO	0,5 % vol
CO_2	14 % vol
HC	100 ppm vol
O_2	0,5 % vol

A.15 Radio frequency immunity

IEC 61000-4-3 only specifies test levels above 80 MHz. For frequencies in the range below 80 MHz, the test methods for conducted radio frequency disturbances are recommended (test A.15.2).

However, for EUT having no mains or other input port available, the lower limit of the radiation test should be 26 MHz taking into account that the test specified in A.15.2 cannot be applied (refer to Annex H of IEC 61000-4-3). In all other cases both A.15.1 and A.15.2 shall apply.

A.15.1 Radiated, radio frequency, electromagnetic fields

A.15.1.1 Instruments shall be exposed to an electromagnetic field strength as follows:

- frequency range: ~~26~~ 80 MHz to ~~1 000 MHz~~ 2 GHz;
- field strength: 10 V/m;
- modulation: 80 % AM, 1 kHz sine wave.

A.15.1.2 ~~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.~~The EM field can be generated in different facilities, however the use of which is limited by the dimensions of the EUT and the frequency range of the facility.

The frequency ranges to be considered are swept with the modulated signal, pausing to adjust the RF signal level or to switch oscillators and antennas as necessary. Where the frequency range is swept incrementally, the step size shall not exceed 1 % of the preceding frequency value.
The dwell time of the amplitude modulated carrier at each frequency shall not be less than the time necessary for the EUT to be exercised and to respond, but shall in no case be less than 0,5 s.
The sensitive frequencies (e.g. clock frequencies) shall be analyzed separately.

See IEC 61000-4-3.

Note: Usually, these sensitive frequencies can be expected to be the frequencies emitted by the EUT.

A.15.2 Conducted radio frequency fields

If the EUT is composed of several elements, the tests shall be performed at each extremity of the cable if both of the elements are part of the EUT.

A.15.2.1 Instruments shall be exposed as follows to a conducted radio frequency field:

- frequency range: 0.15 MHz to 80 MHz;
- RF amplitude (50 Ω): 10 V (e.m.f.);
- modulation: 80 % AM, 1 kHz sine wave.

A.15.2.2 Radio frequency EM current, simulating the influence of EM fields shall be coupled or injected into the power ports and I/O ports of the EUT using coupling/decoupling devices as defined in the referred standard.

See IEC 61000-4-6

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.

See IEC 61000-4-8

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) stabili~~z~~se 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 deactivated, 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~~reference 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~~reference 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~~reference 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,~~50 % vol

A.19 Low flow

A.19.1 A measurement shall be performed with a ~~calibration gas~~reference 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~~reference gas shall be supplied at the probe at ambient pressure (to within 750 Pa).

A.20.3 While sampling the ~~calibration gas~~reference gas, record the indication, then adjust the leakage rate so that the indication of the ~~calibration gas~~reference 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~~reference 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~~reference 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 gas~~reference 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~~reference 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~~reference 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~~reference gas. To this end, the true value is determined as follows:

$I_{true} = C \times PEF$

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~~reference 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 errors of the instruments are constant both near 100 ppm vol and near 1000 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 - Designation of ~~calibration~~ reference gases and their composition
(normative/mandatory)

B.1 General requirements

B.1.1 The ~~calibration gas~~reference gases shall be supplied either in gas cylinders or by dynamic blending.
Gas mixtures in gas cylinders shall meet the requirements of ISO 6142.

~~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~~ reference 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~~ 3 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~~reference 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~~reference 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 - Procedure for initial verification~~
~~(informative)~~

~~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~~ C - Procedure for subsequent verification
(informative)

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~~ D or in the manufacturer's operating instructions, perform all tests included in the initial verification.

As verification after repair does not include a test for the correct operation of the pressure compensation, the instruments should only be used at about the same altitude as at the location of the verification.

Annex ~~E~~ D - Procedure for routine testing
(informative)

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~~reference 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 - Lambda calculation
(normative/mandatory)
Moved to Part 1

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:

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

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.

F.3 Other formulae

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

Annex G - 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.