TECHNICAL GUIDE ON INSTRUMENTS FOR MEASURING VEHICLE EXHAUST PARTICULATE NUMBER EMISSIONS

Part 2: Metrological controls and performance tests

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Technical guide on instruments for measuring vehicle exhaust particulate number emissions

Part 2: Metrological controls and performance tests

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Prepared by:

Grupo de trabajo para la elaboración de métodos de medición de número de partículas en motores de combustión interna – CALAC+

Technical Secretary:

Freddy Koch, Programa CALAC+

John Ramiro Agudelo, Docente investigador – Universidad de Antioquia Colombia

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Members of the Working Group for the elaboration of methods of measurement of PN in internal combustion engines - CALAC+

México

Antonio Galván	Sedema
Sara Mercado	Sedema
Sergio Zirath Hernández Villaseñor	Sedema
Daniela Muñoz	Semovi
Rodrigo Díaz González	Semovi
Carolina García Cañón	Estado de México
Rocío Rojas	Estado de México
Biol. Francisco Javier Barrera Martínez	Estado de México
Dr. Luis Gerardo Ruiz	Inecc
Abraham Ortínez	Inecc
Claudia Octaviano	Inecc
Andrés Aguilar	Inecc
Rodrigo Perrusquía Máximo	Semarnat
Luis Felipe Acevedo Portilla	Semarnat
Daniel López Vicuña	Semarnat
Sergio Israel Mendoza Aguirre	Semarnat
Juan Manuel Flores Moreno	Semarnat
Adán Espejo Preciado	Jalisco
Dr. Víctor Hugo Páramo Figueroa	CAMe
Ramiro Barrios	CAMe
Arón Jazcilevich Diamant	UNAM
Enrique Rico Arzate	IPN
Isabel Kreiner	ITESM
Jose Ignacio Huertas	Inst. Tec. Monterrey

Chile

Nancy Manríquez	Ministerio del Medio Ambiente, MMA
Alfonso Cádiz	Ministerio de Transportes y Telecomunicaciones, MTT
Rodrigo Tapia	Directorio de Transporte Público Metropolitano, DTPM
Aliosha Reinoso	GEASUR
Robert Fraser	PUREXHAUST
Nicolas Fraser	PUREXHAUST
Rigoberto Bahamonde	Opus Inspection

Colombia

Mayra Lancheros	Ministerio de Ambiente y Desarrollo Sostenible
Johana Jiménez	Ministerio de Ambiente y Desarrollo Sostenible
Mauricio Gaitán	Ministerio de Ambiente y Desarrollo Sostenible
Hugo Sáenz	Secretaría Distrital de Ambiente
Jaime Rueda	Secretaría Distrital de Ambiente
Luis Galindo	Secretaría Distrital de Ambiente
Rafael Chaparro	Secretaría Distrital de Ambiente
John Ramiro Agudelo	Universidad de Antioquia
Maria Luisa Botero	Universidad de Antioquia
Edilia Arboleda	Área Metropolitana del Valle de Aburra AMVA
Gloria Ramirez	Área Metropolitana del Valle de Aburra AMVA
Ana Orrego	Área Metropolitana del Valle de Aburra AMVA

Perú

Rosa Azpilcueta	ATU
Claudia Ato	ATU
Luis Bravo	MINAM
Luis Antonio Ibañez	MINAM
Aldo Florez	MINAM
Milagros Morales	MTC
Ivan Maita	MTC
Orlando Dávila Vizconde	MTC Políticas
Iván Maita Gomez	MTC
María del Carmen Sánchez Orozco	MTC
Julien Noel	UTEC
Sthy Warren Flores Daorta	UTEC
Jose Cesar Ramos Saravia	UTEC

Ecuador and other Regions

Roberto Custode	Consultor independiente
Eduard Fernández	CITA
Pascal Bukenhoudt	CITA
David Miller	3DATX
Mike Dio	3DATX

CALAC+

Adrián Montalvo	Jefe de Proyecto
Freddy Koch	Coordinador Componente 1
Santiago Morales	Coordinador Componente 2
Gina Lombardi	Asesora en comunicación
Carol Arenas	Coordinadora Chile
Guisselle Castillo	Coordinadora Perú
Marco Balam	Coordinador México
Andrés Díaz	Coordinador Colombia

Content

1. Introduction 6
2. Metrological controls 7
3. Performance tests for type evaluation 11
4. Standards and reference documents 22
5. Contact information 23
6. References 23
7. Annex 24

1. Introduction

This guide is the second part of Technical Guide No. 2 entitled: "Technical guide on instruments for measuring vehicle exhaust particulate number emissions", which is intended to set out recommendations for equipment measuring volumetric particle concentration used for PTIs and roadside inspections. Guide No. 2 is divided into two parts, namely:

Part 1: Metrological and technical requirements, and

Part 2: Metrological controls and performance tests

The basic working documents on which this guide has been developed were those proposed by NMi (The Netherlands): Proposal Particulate Number Counter. Instruments for measuring vehicle exhaust particulate number emissions. Part 1: Metrological and technical requirements. 2019-10-16, Part 2: Metrological controls and performance tests.

This second part of Technical Guide No. 2 specifies the applicable metrological controls and performance tests for exhaust particle counting instruments. Legal metrological control can consist of type evaluation, initial and subsequent verification, and metrological supervision. This Part 2 of the Guide provides general guidelines for each of these steps.

2. Metrological controls

2.1 Responsibility for compliance with requirements

2.1.1 Notwithstanding the kind of legal metrological control in a country, the manufacturer (or its formal representative) has the full responsibility that the instruments comply with the requirements of Part 1 of Guide No. 2 at the moment, they are delivered to the user.

2.1.2 After assignment, the owner of the instrument has the responsibility that the instrument is well maintained and complies with the requirements in Part 1 of Guide No. 2 as long as the instrument is in use. The operational presence of the instrument at the owner's premises is considered as "in use".

2.2 Reference PN sample

A reference PN sample is generated by a particle (aerosol) generator with a reference instrument, which measures the reference value of the sample because the generator usually can only approximate a particle concentration.

The particles should be close to soot. Other particles (such as salt or oil) may be used provided that correlation is available. The applied aerosols are considered to be thermally stable.

The reference instrument shall establish and maintain metrological traceability of its measurement results by means of an unbroken and documented chain of calibrations, each contributing to the measurement uncertainty and linking them to the appropriate reference.

The particle size distribution can be monodisperse or polydisperse.
For the error curve a polydisperse aerosol should be used in order to achieve high concentrations. For the counting efficiency a monodisperse aerosol shall be used.

2.3 Uncertainty of the reference

2.3.1 Each test comprises measurements applying harmonized test setups for the verification of compliance with requirements. Measurement uncertainty is an attribute of each measurement.

2.3.2 The uncertainty associated with the test method shall be taken into account in the decision on the applicability of the test method.

When a test is conducted, the expanded uncertainty of the reference used for the determination of the errors on indications shall be less than or equal to one-third of the maximum permissible error (MPE).

2.3.3 The estimation of expanded uncertainty is calculated according to the Guide to the expression of uncertainty in measurement, Reference [1], by applying a coverage probability which corresponds to the application of a coverage factor k = 2 for a normal distribution and which comprises approximately 95 % of the measurement results.

2.4 Type evaluation

2.4.1 Documentation

When applying for type evaluation, the documentation supplied by the manufacturer for an instrument 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) General information about the software;

e) The operating instructions that shall be provided to the user.

Along with the application for type evaluation, the manufacturer shall provide any data or other information that may support the assertion that the design and construction of the instrument comply with the requirements of this Guide.

2.4.2 General requirements

Type evaluation shall be carried out on at least one unit, which represents the definitive type. The evaluation shall consist of the tests specified in clause 2 and checking the requirements for which no test is available by inspection and/or functional checks.

Specified nominal concentrations have a tolerance of ± 20 per cent, unless otherwise specified, provided by a particle generator with reference instrument.

2.4.3 Inspection and tests

The inspection and testing of instruments is intended to verify compliance with the requirements of clauses 5, 6 and 7 of Part 1 of this Guide.

As a rule, tests should be carried out on the complete instrument according to its specifications, without (software) modifications.

2.4.3.1 An instrument shall be given a visual inspection to obtain a general appraisal of its design, construction and conformity to the documentation submitted for type examination.

In particular, the requirements of Part 1 of this Guide not covered by tests shall be evaluated.

2.4.3.2 The equipment under test (EUT) shall be submitted to the performance tests specified in clause 2 to determine its correct functioning.

2.4.3.3 A measurement concerns the end result of a cycle as performed by the instrument in its normal operation mode. The length of the cycle time may depend on applicable legislation. For the type evaluation the shortest cycle as defined by the manufacturer should be used. For verification, the cycle for the applicable legislation should be used.

2.5 Initial verification

2.5.1 General requirements

A new instrument shall undergo initial verification only after type evaluation. The verification shall be carried out using suitable testing means and a particle generator with reference instrument.

2.5.2 Inspection

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

a) A visual inspection to determine conformance with the approved type;
b) A check of the power supply voltage and frequency at the location of use to determine compliance with the specifications on the measuring instrument´s label.

2.5.3 Tests

The tests to determine the errors of the instrument shall be carried out under rated operating conditions.

a) Before starting the tests, adjust the instrument according to the routine adjustment procedure described in the manufacturer's operating instructions.
b) Check the air-tightness of the system by performing a leak check as described in the manufacturer's operating instructions.
c) Check the activation of the low gas flow device, an also for the low flow lockout, by restricting the gas flow supplied to the probe while sampling ambient air.
d) After the instrument has warmed up, determine the error curve according to clause 2.1 with the reference samples defined in 2.5.4.
   The errors observed shall be within the maximum permissible error (MPE) for each measurement.
e) Check the response time.

2.5.4 Reference PN samples to be used for the initial verification

Initial verification shall be performed with five reference samples including the minimum

and maximum of the measuring range and the point where the MPE changes from absolute to relative (100,000 particles/cm^3) and two intermediate values. Nominal values +/- 30% provided by the generator with reference instrument.

2.6 Subsequent verification

2.6.1 General requirements

The subsequent verification shall be carried out using suitable test means (Part 3) and a particle generator with the reference PN instrument.

The interval for subsequent verification is subject to national or regional legislation. The suggested interval is 1 year.

2.6.2 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.

2.6.3 Body in charge of Subsequent Verification

It is suggested that the subsequent verification be carried out by the metrological body of each country.

2.6.4 Tests for subsequent verification

The tests to determine the errors of the instrument shall be carried out under rated operating conditions.

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

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

c) Check for the activation of the low gas flow device, and also for the low flow lockout, by restricting the gas flow supplied to the probe while sampling ambient air.

d) After the instrument has warmed up, determine the error curve according to clause 2.1 with the reference samples defined in 2.6.4.
The observed errors shall be within the MPE for each measurement.

2.6.5 Reference PN samples to be used for subsequent verification

Subsequent verification shall be performed with at least three reference samples including near to zero, 100 000 particles/cm^3 and 1 000 000 particles/cm^3. Nominal values +/- 50% provided by the generator with the reference instrument.

3. Performance tests for type evaluation

Prior to the type evaluation tests and when specified in the manufacturer's operating instructions provided under 3.1.1, the instrument shall be adjusted according to these instructions.

Except for the parameter being tested, the reference conditions specified in Part 1, 7.6.1, apply.

3.1 Verification of the error curve (linearity)

This test shall be carried out under reference conditions.

The errors of the instrument shall be determined for at least 10 concentrations within the measuring range, including the minimum and maximum of the measuring range and the point where the MPE changes from absolute to relative (100 000 particles/cm^3) and seven intermediate values.

The measurements shall be performed successively. During this test, the errors shall not exceed the maximum permissible error.

3.2 Stability with time or drift

This test shall be conducted for a period of 12 hours following the warm-up time. Measurements shall be performed at least every hour using a nominal concentration of 100 000 particles/cm^3.

During this test, the errors shall not exceed half the maximum permissible error.

3.3 Repeatability

The requirement specified in Part 1, 7.11 shall be tested at a nominal concentration of 100 000 particles/cm^3. Between each measurement, ambient air is offered to the instrument.

3.4 Effect of influence quantities

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

An acceptable alternative for the reference instrument may be a second EUT maintained at reference conditions. In this case, the difference in indication of the two EUTs at reference conditions shall be corrected.

For each influence quantity test:

Test procedure	At each of the value(s) of the influence quantity: Adjust the EUT as close to zero indication as practicable prior to the test. The EUT shall not be readjusted at any time during the test. After stabilization, apply at least five concentrations including the minimum and maximum of the measuring range and the point where the MPE changes from absolute to relative (100 000 particles/cm^3) and two intermediate values and record: a) date and time; b) temperature; c) relative humidity; d) measurands; e) indications; f) errors; g) functional performance.
Precondition	Normal electrical power supplied and "on" for a time period equal to or greater than the warm-up time specified by the manufacturer.
Condition of the EUT	Power is to be "on" for the duration of the test.
Acceptance criteria	All functions shall operate as designed. All errors shall be within the maximum permissible error.

3.4.1 Temperature

Applicable standard	IEC 60068-2-1, IEC 60068-2-2, IEC 60068-3-1
Stabilization	2 hours at each temperature under "free air" conditions.
Temperature sequence	Reference temperature; Specified low temperature; Specified high temperature; Reference temperature.

3.4.2 Damp heat, steady state (non-condensing)

Applicable standard	IEC 60068-2-78
Condition of the EUT	The EUT shall be handled such that no condensation of water occurs on it.
Test	The EUT is kept at 40 °C, 85 % relative humidity (RH) for 2 days (48 h). At the end of this period and still under these conditions, apply the test procedure.

Notes	This test is applicable if intended for closed location.

3.4.3 Cyclic damp heat (condensing)

Applicable standard	IEC 60068-2-30, IEC 60068-3-4
Condition of the EUT	Condensation of water is expected to occur.
Test	Exposure to a cyclic temperature variation between 25 °C and the appropriate upper temperature while maintaining the relative humidity above 95 % during the temperature change and low temperature phases and at or above 93 % relative humidity in the upper temperature phases. The 24-hour cycle comprises of: - temperature rise for 3 hours, - temperature maintained at the upper value until 12 hours from the start of the cycle, - temperature lowered to lower temperature level within a period of time of 3 to 6 hours, the declination (rate of fall) during the first hour and a half being such that the lower temperature level would be reached in a 3 hour period, - temperature maintained at the lower level until the 24-hour period is completed. The stabilizing period before and recovery after the cyclic exposure shall be such that all parts of the EUT are approximately at their final temperature. Test sequence: 1. Measurements during rise of the temperature 2. Measurements during high temperature 3. Measurements during the lower temperature level
Notes	This test is applicable if intended for open location.

3.4.4 Atmospheric pressure

Applicable standard	No applicable standard known
Test	Exposure of the EUT to the specified upper and lower atmospheric pressure limits.

3.4.5 Voltage and frequency variation

Applicable standard	IEC 61000-2-1, IEC 61000-2-2-2 and IEC 61000-4-1	
Test	Exposure of the EUT to the specified upper and lower voltages and frequencies.	
Test level	Mains voltage	$U_{nom\text{-}high}$ + 10% $U_{nom\text{-}low}$ – 15%

	Network frequency	$f_{\text{nom-high}} + 2\%$ $f_{\text{nom-low}} - 2\%$
Note	The values of U_{nom} and f_{nom} are those marked on the EUT. If no range is specified, the low and high values are equal.	

3.4.6 Road vehicle battery voltage variation

Applicable standard	ISO 16750-2	
Test	Exposure of the EUT to the specified voltages.	
Test level	U_{nom} = 12 V	U_{nom} = 24 V
Lower limit	9 V	16 V
Upper limit	16 V	32 V

3.4.7 (Internal) battery voltage variation

Applicable standard	No applicable standard known
Test	Exposure of the EUT to voltages within the specified limits and below the specified lower limit. Reduce the power voltage until the EUT clearly ceases to function properly according to the specifications and metrological requirements. Also check also just above this voltage.
Note	If an alternative power source (standard power supply with sufficient current capacity) is used in bench testing to simulate the battery, it is important that the internal impedance of the specified type of battery is also simulated.

3.4.8 Particle size

Applicable standard	No applicable standard known
Test	Exposure of the EUT to particles with different sizes to check the counting efficiency is within the specified limits. The test is performed with one nominal concentration smaller than or equal to 100 000 particles/cm^3. Determine the (reference) indication with polydisperse aerosol with particle size distribution of 80 nm. Determine the indication with a monodisperse particle size distribution at the particle sizes specified in Part 1, 7.6.3. Check that the indications comply with the requirements in Part 1, 7.6.3.

Note	Due to limited capabilities to generate monodisperse particle size distributions, the nominal concentration may be down to 30 000 particles/cm^3.

3.5 Disturbances

An acceptable alternative for the reference instrument can be a second EUT kept at reference conditions. In this case, the difference in indication of the two EUTs shall be corrected.

For each disturbance test:

Test procedure	At each of the value(s) of the disturbance: Adjust the EUT as close to zero indication as practicable prior the test. The EBP shall not be readjusted at any time during the test. After stabilization, apply 1 concentration at the point where the MPE changes from absolute to relative (100 000 particles/cm^3) and record: a) date and time; b) temperature; c) relative humidity; d) measurands; e) indications; f) errors; g) functional performance.
Precondition	The EUT shall not be re-adjusted at any time during the test except to reset if a significant fault has been indicated.
Condition of the EUT	Power is to be "on" for the duration of the test unless otherwise specified.
Acceptance criteria	Either significant faults do not occur, or significant faults are detected and acted upon by means of a checking facility.

3.5.1 Mechanical shock and vibrations

3.5.1.1 Mechanical shock

Applicable standard	IEC 60068-2-31
Condition of the EUT	Power is to be “off” for the duration of the test.

Test	The EUT, standing in its normal position of use on a rigid surface, is tilted along one bottom edge and is subsequently allowed to fall freely back on to the test surface. The height of fall is the distance between the opposite bottom edge and the test surface. However, the angle between the bottom and the test surface shall not exceed 30°. After the shocks, the EUT shall be switched on and, after a stabilization time equal to or greater than the warm-up time specified by the manufacturer, apply the test procedure.
Test level	Height of fall 50 mm, 1 fall on each bottom edge

3.5.1.2 Vibration

Applicable standard	IEC 60068-2-47, IEC 60068-2-64, IEC 60068-3-8
Condition of the EUT	Power is to be "off" for the duration of the test.
Test	After having been switched off (or the electrical power being disconnected), the following vibration level shall be applied in 3 mutually perpendicular axes during 2 minutes per axis, the EUT being mounted on a rigid fixture by its normal mounting means so that the gravitational force acts in the same direction as it would be in normal use. After the vibrations, the EUT shall be switched on and, after a stabilization time equal to or greater than the warm-up time specified by the manufacturer, apply the test procedure.
Test level	Total frequency range: 10 Hz to 150 Hz Total RMS level: 1.6 $m.s^{-2}$ ASD level 10 Hz- 20 Hz : 0.05 $m^2.s^{-3}$ ASD level 20 Hz- 150 Hz : - 3 dB/octave

3.5.2 Mains voltage dips, short interruptions and reductions

Applicable standard	IEC 61000-4-11, IEC 61000-6-1, IEC 61000-6-2			
Test	A test generator suitable to reduce the amplitude of the AC mains voltage for the required period of time is to be used. The performance of the test generator shall be verified before connecting the EUT. The mains voltage reduction tests shall be repeated 10 times with intervals of at least 10 s between the tests.			
		Test level		Unit
Voltage dips	Test a	Reduction	100	%
		Duration	0.5	cycles
	Test b	Reduction	100	%
		Duration	1	cycles
	Test c	Reduction	30	%
		Duration	25/30	cycles
Short interruptions		Reduction	100	%
		Duration	250/300	cycles

3.5.3 AC mains harmonics

Applicable standard	IEC 61000-2-2-2, IEC/TR 61000-2-5, IEC 61000-4-13

Test	Harmonic voltages at test levels from 3 % and higher, up to the ninth harmonic, shall be applied using a phase shift of both 0° and 180° with respect to the positive zero-crossing of the fundamental. The test shall be performed up to the 40th harmonic.		
Test level	Harmonics	Harmonic order *n*	% of $U_{nom\text{-}high}$
	Odd, non-multiples of 3	5	
		11, 13	
		17, 19, 23, 25	
		29	5
		31, 35, 37	
	Odd, multiples of 3		
		21, 27, 33, 39	
	Even		5
		6 - 40	1,5
Note	The value of $U_{nom\text{-}high}$ is that marked on the EUT.		

3.5.4 Bursts (transients) in the AC mains lines

Applicable standard	IEC 61000-4-4		
Test	Both positive and negative polarity of the bursts shall be applied. The duration of the test shall not be less than 1 minute for each amplitude and polarity. The injection network on the mains shall contain blocking filters to prevent the burst energy being dissipated in the mains.		
Test level	Amplitude (peak value)		kV
	Repetition rate	5	kHz

3.5.5 Bursts (transients) on signal, data and control lines

Applicable standard	IEC 61000-4-4		
Test	Both positive and negative polarity of the bursts shall be applied. The duration of the test shall not be less than 1 minute for each amplitude and polarity. A capacitive coupling clamp as defined in the standard shall be used for the coupling the bursts into the lines.		
Test level	Amplitude (peak value)	1	kV
	Repetition rate	5	kHz

3.5.6 Surges on AC mains power lines

Applicable standard	IEC 61000-4-5

Test	At least 3 positive and 3 negative surges shall be applied. The surges shall be synchronized with the AC supply frequency and shall be repeated such that the injection of surges on all the 4 phase shifts: 0°, 90°, 180° and 270° with the mains frequency is covered.		
Test level	Line to line	1	kV
	Line to ground		kV

3.5.7 Surges on signal, data and control power lines

Applicable standard	IEC 61000-4-5		
Test	At least 3 positive and 3 negative surges shall be applied. The surges shall be synchronized with the AC supply frequency and shall be repeated such that the injection of surges on all the 4 phase shifts: 0°, 90°, 180° and 270° with the mains frequency is covered.		
Test level	Line to line	1	kV
	Line to ground		kV
Note:	Line to line does not apply to shielded and symmetrical lines.		

3.5.8 Electrostatic discharges

Applicable standard	IEC 61000-4-2		
Test	At least 10 discharges per preselected discharge location shall be applied. The time interval between successive discharges shall be at least 1 second. An EUT not equipped with a grounding connection shall be fully discharged between discharges. Direct application: In the contact discharge mode to be carried out on conductive surfaces, the electrode shall be in contact with the EUT before activation of the discharge. On insulated surfaces only the air discharge mode can be applied. The EUT is approached by the charged electrode until a spark discharge occurs. Indirect application: The discharges are applied in the contact mode only on coupling planes mounted in the vicinity of the EUT.		
Test level *	Contact discharge		kV
	Air discharge	8	kV
Note:	In this case, "level" means "up to and including" the specified level (i.e., the test shall also be performed at the specified lower levels in the standard).		

3.5.9.2 Radiated RF electromagnetic fields

Applicable standard	IEC 61000-4-3, IEC 61000-4-20

Test	The EUT is exposed to electromagnetic fields with the required field strength and the field uniformity as defined in the referenced standard. The level of field strength specified refers to the field generated by the unmodulated carrier wave. The EUT shall be exposed to the modulated wave field. The frequency sweep shall be done only pausing to adjust the RF signal level or to switch RF-generators, amplifiers and antennas if 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. Adequate EM fields can be generated in facilities of different type and setup, the use of which is limited by the dimensions of the EUT and the frequency range of the facility. The expected most critical frequencies (e.g., clock frequencies) shall be analyzed separately. [b]
Test level	Radiated 10 V/m, 80 (26)[a] MHz - 6 GHz, modulated 80 % AM, 1 kHz sine wave
Notes	[a] For an EUT without any cabling, the lower frequency limit is 26 MHz. [b] These frequencies can be expected to correspond to the EU emitted EM field frequencies.

3.5.10 Mains frequency magnetic fields

Applicable standard	IEC 61000-4-8		
Test level	Continuous field	100	A/m
	Short duration (1 s to 3 s)		A/m

3.5.11 Instruments powered by a road vehicle battery

3.5.11.1 Electrical transient conduction along supply lines

Applicable standard	ISO 7637-2	
Test	Exposure of the EUT to the specified pulses along supply lines.	
Test level for pulse	U_{nom} = 12 V	U_{nom} = 24 V
2a	+112 V	+112 V

2b	+10 V	+20 V
3a	-220 V	-300 V
3b	+150 V	+300 V

3.5.11.2 Electrical transient conduction via lines other than supply lines

Applicable standard	ISO 7637-3	
Test	Exposure of the EUT to the specified pulses along other than supply lines.	
Test level for pulse	U_{nom} = 12 V	U_{nom} = 24 V
a	-60 V	-80 V
b	+40 V	+80 V

3.5.11.3 Load dump

Applicable standard	ISO 16750-2			
Test	Exposure of the EUT to 2 variants of pulse B on supply lines.			
Test level	U_{nom} = 12 V		U_{nom} = 24 V	
U_s	79 V	101 V	151 V	202 V
U_s*	35 V		58 V	
R_i	0.5 Ω	4 Ω	1 Ω	8 Ω
t_d	40 ms	400 ms	100 ms	350 ms
T_3	10 ms			

3.6 Tests for conformity to other technical and metrological requirements

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

3.6.1 Removal of volatile particles from the sample

The instrument should remove volatile particles from the sample and the remaining solid particle concentration of the sample should be determined (Part 1, 8.2.18). The instrument must remove > 95 % of 30 nm tetracontane ($CH_3(CH_2)_{38}CH_3$) monodisperse aerosol, with an inlet concentration of ≥ 10 000/cm^3, by means of heating and reduction of partial pressures of the tetracontane.

The tetracontane is added to ambient air. The increase of the indication with tetracontane shall be not greater than 5 % of the actual tetracontane concentration.

The tetracontane concentration may be measured by a (modified) reference instrument.

The alternative method is to generate a high concentration (for example, 500 000 particles/cm^3) and check that the indication to be at most 5 % of this concentration.

3.6.2 Warm-up time

At 5 °C (or at the specified low temperature), the warm-up time test to verify compliance with section 7.9 shall consist of the following steps:

a) Stabilize the instrument at 5 °C (or the specified low temperature);

b) Let the instrument warm up;

c) Immediately after the automatic warm-up lockout has been deactivated, perform a measurement (with any necessary internal adjustment being performed prior to this measurement), using a reference PN sample with nominal concentration of 100 000 particles/cm^3;

d) At time intervals of 2 min, 5 min and 15 min after warm-up, perform a measurement with the same reference PN sample as in step c).

The difference between any of the four measured values in (c) and (d) shall not exceed the maximum permissible error.

3.6.3 Response time

A measurement shall be taken to determine the time required for an instrument to respond to a reference PN sample with a nominal concentration of 100 000 particles/cm^3 after sampling ambient air supplied at the probe. A means shall be employed for instantly changing from sampling ambient air to sampling reference PN sample through the probe. The gases shall be supplied at the probe at ambient pressure (to within 8 hPa). The response time shall not exceed the appropriate values specified in Part 1, section 7.8. of this Guide.

3.6.4 Low flow

A measurement shall be performed with a reference PN sample with a nominal concentration of 100 000 particles/cm^3 that is initially supplied to the gas handling system with 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 Part 1, section 8.2.6 of this Guide.

3.6.5 Leakage

An adjustable leak shall be artificially introduced into the gas handling system where a leak of an appropriate orifice size will have the greatest effect on the measurement. With this artificial leak closed, a reference PN sample with a nominal concentration of 100 000 particles/cm^3 shall be supplied at the probe at ambient pressure.

While sampling the reference PN sample, record the indication and then adjust the leakage

rate so that the indication of the reference PN sample differs from the value indicated previously (without the leak) by an amount equal to that required in Part 1, section 8.2.7 of this Guide. Without disturbing the artificial leak, remove the reference PN sample supplied at the probe and conduct the leak test procedure as described in the manufacturer's operating instructions.

3.6.6 Water condensation

The prevention of condensation shall be checked as follows:

Expose the instrument to water saturated ambient air supplied to the gas handling system and to the reference. The instrument shall remain within MPE or detect the occurrence of condensation.

3.7 Practical test

The instrument shall be tested with at least three vehicles, two with diesel engine and one with a petrol engine. The engines shall be at normal operating temperature. Each vehicle shall be used for five measurements. The indication of the instrument shall be compared with the indication of the reference instrument. The errors shall comply with the maximum permissible error.

3.8 Source of power for type evaluation

If applicable, 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, por example, a battery or portable generator, the instrument shall undergo relevant type tests with each source of power with which it is intended to operate.

Each test specified shall be started and completed without changing or recharging the power source.

4. Standards and reference documents

Subsequent amendments or revisions to the dated reference do not apply to the reference cited below. However, those interested in this Guide are encouraged to look into the possibility of applying more recent editions of the normative document listed below.

1] Guide to the expression of uncertainty in measurement (GUM), (1995): Joint publication by the BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, and OIML.

For further references, see Part 1, clause 2 of CALAC+ Technical Guide No. 2.

5. Contact information

Freddy Koch, Programa CALAC+

freddy.koch@swisscontact.org

Adrián Montalvo, Programa CALAC+

adrian.montalvo@swisscontact.org

John Ramiro Agudelo, Universidad de Antioquia

john.agudelo1@udea.edu.co

6. References

NMi proposal for Particule Number Counter version 2019-10-16. Instruments for measuring vehicle exhaust particulate number emissions. Part 2: Metrological controls and performance tests.

Kadijk, G., Elstgeest, M., Van der Mark, P. J., Ligterink, N. (2020). Follow-up research into the PN limit value and the measurement method for checking particulate filters with a particle number counter. TNO report. TNO 2020 R10006.

List of abbreviations

EUT: Equipment Under Test

MPE: Maximum Permissible Error

NMi: Netherlands Measurement Institute (Nederlands Meetinstituut)

PTI: Periodic Technical Inspection

RF: Radio Frequency

RH: Relative Humidity

PN: Particle Number

7. Annex

Routine testing procedure

(informative)

A routine test of the instrument shall consist, as a minimum, of the following:

a. Perform a check of the internal adjustment after start-up and warm-up of the instrument;
b. Perform a leakage check at least once a day. Repair any leaks and perform a satisfactory leak check before testing any vehicle;
c. Use a HEPA filter for zeroing;
d. Check if the fresh ambient air reading is plausible.

CALAC

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Implemented by:

swisscontact

calac@swisscontact.org.pe
www.programacalac.com
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Twitter: @Calacplus

Calle José Gálvez 692, Piso 7, Miraflores
Lima 15074 – Perú
Teléfonos: +511 2641707, 2642547
Fax: +511 2643212
www.swisscontact.org