

Specific requirements for measuring instruments for nanoparticles from combustion engines

A Definitions and explanations

Mobility diameter

Diameter of a spherical particle which exhibits the same electrical mobility as the measured particles when measured in a mobility analyser in accordance with ISO 15900:2009¹.

Nanoparticles

Solid, mostly carbonic components in the exhaust gas from combustion engines.

The particles have a mobility diameter in the range from about 20 nm to 300 nm.

The condensing portions are not taken into account.

Particle number concentration

Number of nanoparticles per volume unit. This is specified per cubic centimetre (cm⁻³).

Efficiency E

The efficiency E of the measuring instrument designates the quotient of the displayed particle number concentration and the particle number concentration entering into the measuring instrument.

¹ ISO 15900:2009, Determination of particle size distribution — Differential electrical mobility analysis for aerosol particles. The text of the standard can be obtained from the Swiss Association for Standardisation (SNV), 8400 Winterthur. The standard can also be accessed free of charge at the Federal Office of Metrology, 3003 Bern.

B Measurement requirements

1 Measurement range

- 1.1 The measurement range for the particle number concentration of nanoparticles is at least from $5 \times 10^4 \text{ cm}^{-3}$ to $5 \times 10^6 \text{ cm}^{-3}$.
- 1.2 In case of measured values outside of the measurement range, the measuring instrument must indicate whether the measured value lies below or above the measurement range. If no categorisation is possible, no value may be output.
- 1.3 The particle number concentration is indicated for the current ambient conditions.

2 Nominal operating conditions

The following nominal operating conditions must be fulfilled:

- 2.1 Climatic, mechanical and electromagnetic ambient conditions:
 - Range for ambient temperature from $-10 \text{ }^\circ\text{C}$ to $40 \text{ }^\circ\text{C}$;
 - Range for ambient pressure from 860 hPa to 1060 hPa;
 - Mechanical environment class M3;
 - Electromagnetic environment class E2.
- 2.2 Electrical nominal operating conditions to be specified by the manufacturer:
 - Voltage and frequency range for AC voltage supply;
 - Limits for DC voltage supply.

3 Error limits

The following error limits apply:

- 3.1 Depending on particle size and particle composition, the measuring instrument must uphold an efficiency E over the entire measurement range within the limits specified in Table 1.

Efficiency of measuring instruments for nanoparticles

Table 1

Mobility diameter	Limits of efficiency E
23 nm nanoparticles	$E < 50 \%$
41 nm nanoparticles	$50 \% < E$
80 nm nanoparticles	$70 \% < E < 130 \%$
200 nm nanoparticles	$E < 200 \%$
30 nm droplets of tetracontane (number concentration up to 10^5 cm^{-3})	$E < 5 \%$

4 Permissible effect of disturbance influences

- 4.1 Disturbance influences are considered to be:
- Ultrafine nanoparticles (diameter of less than 20 nm), e.g. from fuel additives for combustion engines;
 - Spray water, corrosive exhaust gas components, dust;
 - Heat in the sample and in the vicinity of the sampling (temperatures up to 300 °C over 5 minutes);
 - Condensates from exhaust gas components
 - Very high particle number concentration (e.g. when measuring on engines without or with a damaged particle filter).
 - Soiling of the sensors in the instrument (e.g. when smoke and condensates are deposited)
- 4.2 Disturbance influences may have an effect only to the extent that:
- The change in the measurement result does not result in a violation of the limits specified in Number 3;
 - The measurement result is output such that it cannot be construed as a valid result.
- 4.3 The user should be warned and an official measurement should be suppressed if an operating parameter (e.g. temperature) is outside of the specified values.

5 Other requirements

- 5.1 The measurement process must be automated in such a way as to eliminate any subjective influences of the user.
- 5.2 In the official measurement in accordance with Number 7, the step response of the measured value from 10 % to 90 % for a rectangular change in the input concentration (for increasing and decreasing concentration) shall last 4.5 s to 5.5 s (response time).
- 5.3 The duration of the exhaust gas inflow during the sampling up to the display of the number concentration shall be less than 10 s (delay interval).
- 5.4 For the type evaluation, electronic output of the measurement data shall be provided in a text file with time stamp and number concentration, and with an acquisition rate of at least 10 Hz. It must be possible to output the file via an interface to an industry-standard computer.
- 5.7 The measuring instrument has to be configured for portable operation outdoors.

6 Measurement stability

- 6.1 The information about the functioning of the measuring instrument shall include, in particular, details about the holder's duty to maintain the instrument, the maintenance work, the intervals for performing such work and verification thereof.
- 6.2 At least the following work steps are part of the maintenance work:
 - Cleaning of the components that come into contact with particles,
 - Checking of the built-in sensors (e.g. for humidity, temperature and pressure) and
 - If necessary, adjustment of the sensors that are relevant for measuring the number of particles.
- 6.3 The measuring instrument must be configured such that the maintenance work is adequate to keep the measurement characteristics within the error limits during the calibration interval.
- 6.4 If an adjustment of the measuring instrument is performed after the maintenance work, re-calibration is required.
- 6.5 METAS shall stipulate the procedure for re-calibration in detail.

7 Official measurement

- 7.1 The term “official measurement” designates the measurement procedure that is regimented for the official exhaust gas measurement.
- 7.2 The official measurement must:
- Be switched on and off by the user;
 - Be performed without interruption;
 - Last a maximum of 5 minutes;
 - Determine the peak value from the measured values;
 - Display at least the following values: Current measured value, peak value and measurement duration after switching on the official measurement in seconds.
- 7.3 At the end of the official measurement, the measuring instrument must document the following content:
- Designation “Official measurement”;
 - Date and time of day of the measurement;
 - Peak value of the number concentration;
 - Duration of the measurement.