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Zunanji zrak - Določevanje številčne koncentracije delcev atmosferskih aerosolov

Ambient air - Determination of the particle number concentration of atmospheric aerosol

Außenluft - Bestimmung der Partikelanzahlkonzentration des atmosphärischen Aerosols

Air ambient Détermination de la concentration en nombre de particules de l'aérosol atmosphérique

Ta slovenski standard je istoveten z: EN 16976:2024

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Ambient air - Determination of the particle number concentration of atmospheric aerosol

Air ambiant - Détermination de la concentration en nombre de particules de l'aérosol atmosphérique

Außenluft - Bestimmung der Partikelanzahlkonzentration des atmosphärischen Aerosols

This European Standard was approved by CEN on 19 May 2024.

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European foreword

This document (EN 16976:2024) has been prepared by Technical Committee CEN/TC 264 "Air quality", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2024, and conflicting national standards shall be withdrawn at the latest by December 2024.

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

This document supersedes CEN/TS 16976:2016.

In comparison with the previous edition, the following technical modifications have been made:

- 1: The lower limit of the measured particle size range is set to be 10 nm and thus identical to MPSS (Mobility Particle Size Spectrometers) measurements (see CEN/TS 17434). In air quality monitoring networks where MPSS will be used for determining the particle size distribution a CPC may be used for QA purposes for the MPSS data.
- 3: The parameter "calibration factor" has been introduced and defined. The terms and definitions for the various flow rates have been revised and rearranged.
- 5.1.2: Aerosol diffusion dryer based on silica is excluded, because diffusion losses are too high with this type of dryer.
- 6.2: Coincidence correction shall be applied. No other correction factors shall be applied unless a correction for the analysed flow rate is necessary.
- 6.3: All tests are carried out only at one temperature (between 20 °C and 30 °C).
- 6.4: Table 1: Criteria for several performance characteristics have been changed, the performance characteristic "calibration factor" has been included.
- 6.5: Some of the test procedures have been revised, a test procedure for the calibration factor has been added.
- 7.2: Two dilution factors are necessary: one for reducing the concentration, an additional one for drying.
- 7.5: The method of using tracer gas for the determination of the dilution factor of a dilution system has been removed. General criteria for dilution systems have been added.
- 9.2: The test "Determination of low size cut-off" has been removed, the "Number concentration check" has been substantially revised.
- The previous Annex C "Data reporting" has been removed.
- Annex D: The ambient particle number concentration values have been updated.
- Annex E: An example of the design of a dilution system and an example for the calculation of the uncertainty of the dilution factor have been added.

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- Annex G: The new Annex “Coincidence correction” has been added.
- Annex H: The new Annex “Results of an experimental comparison of different CPCs” has been added.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

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Introduction

There is a growing awareness of the significance of aerosol particles with diameters of $D < 1 \mu\text{m}$ for human health as well as for their climatic impact. To assess air quality, it appears necessary to supplement gravimetrically determined mass concentrations such as $\text{PM}_{2,5}$ and PM_{10} (see EN 12341) with a measurement of the particle number concentration. Since ultrafine particles with diameters of $D < 0,1 \mu\text{m}$ make an almost insignificant contribution to the mass of atmospheric aerosol particles, they can best be detected with counting measuring methods of sufficient sensitivity.

As particle measurement instrumentation allows determining either the particle number concentration or the particle number size distribution two documents are established:

- one dealing with the determination of the single parameter number concentration (a measure of “total” number concentration, this document)
- one dealing with the determination of number concentration within a limited number of size ranges (CEN/TS 17434).

Clauses 4 and 5 contain general information about the method and the expected properties of the aerosol to be measured.

Clause 6 sets out the performance criteria for CPCs. Specifically, these are the relevant performance characteristics of CPC instruments (without any sampling system), the respective criteria that need to be met, and a description of how the tests are to be carried out. In general, these tests are expected to be carried out by test houses or CPC manufacturers rather than users and could form the basis for type testing of CPCs in future.

Clause 7 sets out the performance criteria and test procedures for the sampling and conditioning system (e.g. dilution). These may be applied by manufacturers of sampling systems, test houses or users (network operators).

Clause 8 sets out requirements for the installation, initial checks and calibrations, and operation of a CPC and sampling system at a monitoring site, including routine maintenance, data processing (including use of QA/QC data) and reporting. In general, these will be the responsibility of users (network operators), though calibrations requiring test aerosols are only to be carried out by suitably qualified laboratories.

Clause 9 sets out Quality Assurance and Quality Control procedures, i.e. the ongoing checks and calibrations that are required on the CPC and sampling system during operation at a monitoring site. It is expected that these will be the responsibility of users (network operators), though calibrations requiring test aerosols are only to be carried out by suitably qualified laboratories. The main sources of measurement uncertainty are described.

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1 Scope

This document specifies a standard method for determining the particle number concentration in ambient air in a range up to about 10^7 cm^{-3} for averaging times equal to or larger than 1 min. The standard method is based on a Condensation Particle Counter (CPC) operated in the counting mode and an appropriate dilution system for concentrations exceeding the counting mode range. It also defines the performance characteristics and the minimum requirements of the instruments to be used. The lower and upper sizes considered within this document are 10 nm and a few micrometres, respectively. This document gives guidance on sampling, operation, data processing and QA/QC procedures including calibration parameters.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 27891:2015, *Aerosol particle number concentration — Calibration of condensation particle counters*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org>

3.1 Aerosol properties

3.1.1

particle

small piece of matter with defined physical boundary

Note 1 to entry: The phase of a particle can be solid, liquid, or between solid and liquid and a mixture of any of the phases.

[SOURCE: ISO 27891:2015, modified]

3.1.2

aerosol

multi-phase system of solid and/or liquid particles suspended in a gas, ranging in particle size from 0,001 μm to 100 μm

3.1.3

number size distribution

frequency distribution of the particle number concentration represented as a function of particle size

3.1.4

particle number concentration

number of particles related to the unit volume of the carrier gas

Note 1 to entry: For the exact particle number concentration indication, information on the gaseous condition (temperature and pressure) or the reference to a standard volume indication is necessary.

[SOURCE: ISO 27891:2015]

3.1.5

Stokes diameter

diameter of a spherical particle which at the same velocity through a medium experiences the same drag force as the particle to be described

3.1.6

Kelvin diameter

diameter of a pure vapour substance drop that would start to grow at the same supersaturation as the particle in question

3.2 Instrument performance

3.2.1

coincidence error

error that occurs with counting measuring methods when two or more particles are counted simultaneously as a single particle

Note 1 to entry: Coincidence error is related to particle number concentration, flow velocity through the sensing zone and size of sensing zone.

3.2.2

detection efficiency

ratio of the particle number concentration determined by the measuring instrument to the reference particle number concentration of the aerosol at the instrument's inlet

Note 1 to entry: The detection efficiency depends on particle size and may depend on particle number concentration.

3.2.3

calibration factor

model- or instrument-specific ratio between the reference FCAE reading and the CPC count rate, both converted to particle number concentration

3.3 Flow rates

3.3.1

actual flow rate

volumetric flow rate of an individual instrument, measured at its inlet under the actual air conditions

3.3.2

nominal flow rate

volumetric flow rate which a specific CPC model is designed for and which is indicated on the instrument specification sheet by the manufacturer

Note 1 to entry: The actual flow rate of individual instruments may differ from the nominal flow due to manufacturing tolerances.

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actual flow rate at the time of calibration documented on a calibration certificate

3.3.4**analysed flow rate**

volumetric flow rate which is used for instrument internal calculation of the particle number concentration

4 Atmospheric aerosol

Atmospheric aerosols are strongly dependent on their local and regional sources. Especially, the size distribution in number and mass, as well as the size-resolved chemical composition are highly variable. Aerosol particles are either emitted directly (primary aerosols) or formed by nucleation and condensation from pre-cursor gases (secondary aerosol). Combustion processes lead to both primary and secondary aerosols.

Mass-wise, the global direct emission of aerosol particles is dominated by sea salt, biological material as well as by desert and volcanic dust. These particles are generally larger than 1 μm . Anthropogenic emissions in this size range play a minor role on a global scale. Submicrometre natural aerosols consist mainly of marine sulfate, biogenic organics, and wildfire carbonaceous particles. Submicrometre anthropogenic aerosols are complex mixtures of primary and secondary particles, consisting mainly of sulfate, nitrate, organics, and elemental carbon.

Particle number concentrations of atmospheric aerosols cover several orders of magnitude. While remote marine or free tropospheric aerosols have number concentrations as low as tens or a few hundred per cubic centimetre, anthropogenically influenced aerosols can contain a few thousand up to one million particles per cubic centimetre. The number concentration of the anthropogenic aerosol over land, especially in urban areas is dominated by particles in the size range smaller than 0,1 μm . Major sources for high number concentrations in this size range are regional new particle formation and local combustion processes. Average background concentrations in an urban area are several thousands of particles per cubic centimetre.

For details see Annex D.

5 Description of the method**5.1 Sampling and conditioning****5.1.1 Sampling**

The measurement of atmospheric aerosols will always necessitate sampling and the transport of the sample to the measuring instrument. Moreover, in certain cases the sample has to be processed in terms of temperature, relative humidity, and particle concentration in order to adapt the aerosol to the measuring instrument's permissible operating conditions.

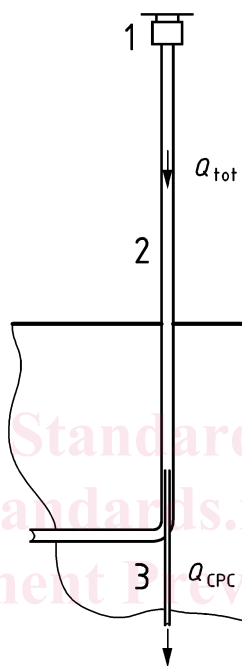
The information given on this issue in this document refers to stationary ambient monitoring sites. For mobile applications (e.g. measurements from aircraft), additional considerations have to be taken into account.

The measuring instruments shall be accommodated in a protected environment in controlled conditions (temperature 20 $^{\circ}\text{C}$ to 30 $^{\circ}\text{C}$, stable within ± 2 $^{\circ}\text{C}$ during 1 day).

The sampling location depends on the measurement task. If the undisturbed atmospheric aerosol is to be measured, air intake should take place 5 m to 10 m above the ground level. Buildings, vegetation, or the topography of the terrain may make an even higher sampling point necessary. The measurement of

aerosols in a regulatory framework can require much lower sampling points (1,5 m to 4 m above the ground) and at a minimum distance from the source (for example, at least 25 m from the boundary of major intersections and not more than 10 m from the kerb for traffic-related measurements), see Directive 2008/50/EC [1]).

The design of the inlet port should permit representative sampling regardless of the direction of the wind for a broad range of wind velocities. However, this is not a critical condition for the small particles measured by the CPC. Steps shall be taken to avoid soiling of the sampling lines by particles larger than 10 μm . For this purpose, a PM_{10} or $\text{PM}_{2,5}$ inlet can be used (see Figure 1). An inlet that removes particles in the measurement range of the CPC (e.g. a commercial PM_1 inlet) shall be avoided.



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Key

- 1 PM sampling inlet
- 2 Primary sampling tube
- 3 Secondary sampling tube

Figure 1 — Basic design of the aerosol inlet port

The sample should ideally be fed via a vertical primary sampling tube without bends to the measuring instruments. Since gas measuring methods have fundamentally different requirements regarding sampling, gas and aerosol sampling should be conducted independently of each other.

To reduce diffusion loss, it is necessary to intake aerosol with the aid of a pump at a primary flow rate (Q_{tot}) much higher than the secondary flow rate (Q_{CPC}). The CPC should sample isoaxially in the central area from this volumetric flow via a secondary sampling tube that is as short as possible. Flow in the primary sampling tube should be laminar in order to prevent additional particle loss due to turbulence. Ideally, a Reynolds number close to $Re = 2\,000$ should be aimed for (see 7.2).

The diffusion losses in the sampling system for the smallest relevant particle size of 10 nm shall be less than 25 % (see 7.2).

The inlet port and lines shall be made of a conductive, corrosion-resistant material with a low surface roughness (e.g. stainless steel) and electrically earthed. This prevents chemical changes to the aerosol

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and particle losses due to electrostatic effects. Flexible tubing of electrically conductive material may also be used for small connections or short distances. The length of flexible tubing should be below 50 cm.

The inlet and the flow-splitter of the sampling system shall be checked regularly to detect obstructions, e.g. by insects, and cleaned, if necessary.

5.1.2 Drying

Aerosols with a high relative humidity (mist in extreme cases) should be dried, as the size of particles of hygroscopic materials is strongly influenced by humidity. The requirement is to keep the relative humidity of the secondary flow at the CPC inlet lower than 40 % (see 7.2). The relative humidity at the inlet of the CPC shall be monitored.

According to 5.1.1, the CPC is operated in a protected environment with controlled temperature conditions. This indoor temperature can differ substantially from the outdoor temperature. With respect to the temperature conditions three cases are to be distinguished:

- In case the indoor temperature is higher than 22 °C no aerosol dryer is needed if the dew point temperature of the aerosol to be sampled never exceeds 10 °C.
- If the aerosol dew point temperature is between 10 °C and the indoor temperature, the secondary flow shall be dried.
- In case that the aerosol dew point temperature is above the indoor temperature, the primary flow shall be dried in the outside section of the primary sampling tube. Additional drying of the secondary flow may be necessary.

There are two recommended methods to dry the aerosol:

- Membrane dryer; preferably used to dry the secondary sampling flow.
- Dilution (see 5.1.3) with dry clean air (particle number concentration less than 1 cm⁻³); preferably used to dry the primary sampling flow. In this case the exact dilution ratio shall be known in order to calculate the correct concentrations.

5.1.3 Dilution

Dilution is applied either to reduce the number concentration of the ambient aerosol to the limits of the CPC's measuring range or to reduce the humidity of the ambient aerosol. In both cases the dilution step may introduce a high uncertainty which shall be estimated and specified in the report. Where dilution is not required this step should be avoided. The minimum requirement with respect to uncertainty of the dilution factor for both cases is given in 7.2.

Preferably the CPC selected to measure at any particular site will have a concentration range in counting mode that covers the expected concentrations. When this is not possible the sample shall be diluted with clean air (particle number concentration less than 1 cm⁻³). In this case the secondary sampling flow is diluted. Operation principles of suitable dilution systems for this purpose are presented in Annex E.

If dilution is applied to dry the aerosol, then the dilution system shall be part of the primary sampling line outside of the air-conditioned environment to avoid water condensation in that part of the sampling system. A dilution system specially designed for that purpose is presented in E.4. Its operating parameters are discussed in detail.