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Particle characterization of particulate systems — Vocabulary

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 24, *Particle characterization including sieving*, Subcommittee SC 4, *Particle characterization.*

This second edition cancels and replaces the first edition (ISO 26824:2013), which has been technically revised.

The main changes are as follows:

— All definition clauses have been rearranged as subclauses in Clause 3 and all terms and clauses have been renumbered.

— Latest revisions and documents from ISO/TC 24/SC 4 have been incorporated, as well as harmonization with ISO/TC 229 general definitions.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Since the last revision of this document in 2013, about 24 ISO standards have been published by ISO/TC 24/SC 4 and about 15 projects are currently under construction together with the 5-year revision of the existing standards. Therefore, terms and definitions of each standard, which are relevant for other standards should be collected and adjusted to a uniform nomenclature.

Especially the interdisciplinary application fields of particle and particulate systems characterization - from mining and construction industry, pharmaceutical and food industry, medicine and life sciences, chemical industry, microelectronics and nanotechnology - need transparency and unambiguous terminology. The development of international trade not only of measurement devices for particle characterization, but also of process equipment for the production and treatment of particulate systems need the comparability of quality and performance parameters as well as international health, safety and environmental protection regulations.

The structuring and presentation rules applied to the terminological entries are based on a clause structure, which represents the methods of sample preparation, measurement results presentation and the analysis methods, starting with more general terms in each clause.

The clause headlines address "Terms related to" technical fields, which are understood as a kind of domain with validity of the definitions limited to the indicated field.

The following particle properties are covered in the clauses given in brackets:

— particle size (3.1, 3.4 to 3.10, 3.12 to 3.15)

— particle shape (3.2, 3.8)

— particle number concentration (3.5, 3.9 and 3.12)

— pore size, pore volume (3.3)

— surface area (3.3, 3.10)

— electrical charge in aerosols (3.13)

— zeta potential in liquid dispersion (3.17)

— particle dispersion in liquids (3.16).

Data uncertainty related definitions are given in 3.1 and 3.11

Particle characterization of particulate systems — Vocabulary

1 Scope

This document defines terms that are relevant to the characterization of particles and particulate systems. This document includes such fields as the representation of results of particle size analysis, the descriptive and quantitative representation of particle shape and morphology, sample preparation, specific surface area and porosity characterization and such measurement methods as sedimentation, classification, acoustic methods, laser diffraction, dynamic light scattering, single particle light interaction methods, differential electrical mobility analysis, image analysis and others in a size scale from nanometre to millimetre.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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 Terms related to representation of size and classification analysis data

3.1.1
particle
minute piece of matter with defined physical boundaries

Note 1 to entry: A physical boundary can also be described as an interface.

Note 2 to entry: A particle can move as a unit.

Note 3 to entry: This general particle definition applies to *nano-objects* (3.1.7).

[SOURCE: ISO 26824:2013, 1.1]

3.1.2
agglomerate
collection of weakly or medium strongly bound *particles* (3.1.1) where the resulting external surface area is similar to the sum of the surface areas of the individual components

Note 1 to entry: The forces holding an agglomerate together are weak forces, for example van der Waals forces or simple physical entanglement.

Note 2 to entry: Agglomerates are also termed secondary particles and the original source particles are termed *primary particles* (3.1.4).

[SOURCE: ISO 26824:2013, 1.2]

3.1.3
aggregate
particle (3.1.1) comprising strongly bonded or fused particles where the resulting external surface area is significantly smaller than the sum of surface areas of the individual components

Note 1 to entry: The forces holding an aggregate together are strong forces, for example covalent bonds, or those resulting from sintering or complex physical entanglement or otherwise combined former *primary particles* (3.1.4).

Note 2 to entry: Aggregates are also termed secondary particles and the original source particles are termed *primary particles* (3.1.4).

[SOURCE: ISO 26824:2013, 1.3]

3.1.4
primary particle
original source *particle* (3.1.1) of *agglomerates* (3.1.2) or *aggregates* (3.1.3) or mixtures of the two

Note 1 to entry: *Constituent particles* (3.1.5) of *agglomerates* (3.1.2) or *aggregates* (3.1.3) at a certain actual state can be primary particles, but often the constituents are aggregates.

Note 2 to entry: *Agglomerates* (3.1.2) and *aggregates* (3.1.3) are also termed secondary particles.

[SOURCE: ISO 26824:2013, 1.4]

3.1.5
constituent particle
identifiable, integral component of a larger *particle* (3.1.1)

Note 1 to entry: The constituent particle structures may be *primary particles* (3.1.4) or *aggregates* (3.1.3).

Note 2 to entry: See Figure 1.

Note 3 to entry: Constituent particles are considered as the smallest dispersible units of a large particle.
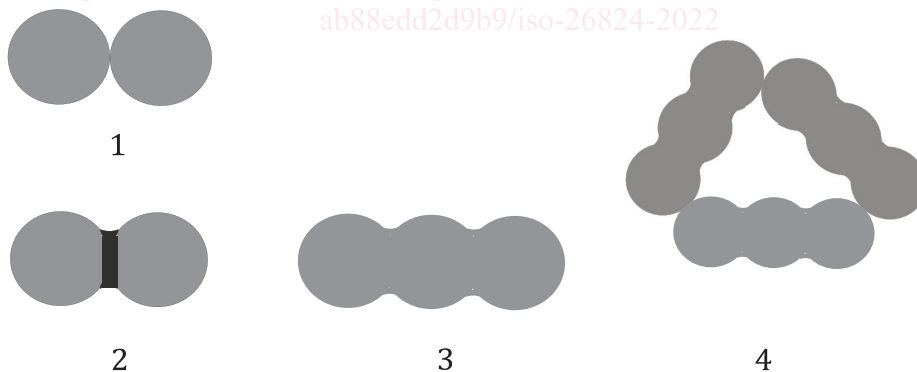
Key

1 agglomerate - constituent particles are identical to primary particles

2 aggregate with covalent bond - constituent particles are identical to primary particles

3 aggregate, produced from initially formed, primary particles (of approximetly 10 or more times smaller size than the widths of the aggregate) which coalesce during the pyrogenic process and sinter into long chains (the visible large circle-like parts never existed as isolated particles before)

4 example of an agglomerate, formed from aggregates (key 3), which are the constituent particles-

Figure 1 — Examples for agglomerates and aggregates of constituent particles and primary particles (not identifiable as such in all cases)

[SOURCE: ISO/TS 80004-2:2015, 3.3, modified — Figure 1 has been added, Note 1 has been modified, Note 2 and 3 have been added]

3.1.6
nanoscale
length range approximately from 1 nm to 100 nm

Note 1 to entry: Properties that are not extrapolations from larger sizes are predominantly exhibited in this length range.

[SOURCE: ISO/TS 80004-1:2015, 2.1]

3.1.7
nano-object
discrete piece of material with one, two or three external dimensions in the *nanoscale* (3.1.6)

Note 1 to entry: The second and third external dimensions are orthogonal to the first dimension and to each other.

[SOURCE: ISO/TS 80004-1:2015, 2.5]

3.1.8
nanomaterial
material with any external dimension in the *nanoscale* (3.1.6) or having internal structure or surface structure in the nanoscale

[SOURCE: ISO/TS 80004-1:2015, 2.4]

3.1.9
particle size
x
d
linear dimension of a *particle* (3.1.1) determined by a specified measurement method and under specified measurement conditions

Note 1 to entry: Different methods of analysis are based on the measurement of different physical properties. Independent of the particle property actually measured, the particle size is reported as a linear dimension, e.g. as the *equivalent spherical diameter* (3.1.10).

Note 2 to entry: Examples of size descriptors are those based at the opening of a sieve or a statistical diameter, e.g. the Feret diameter, measured by image analysis.

Note 3 to entry: In ISO 9276 the symbol '*x*' is used to denote the particle size. However, it is recognised that the symbol '*d*' is also widely used to designate these values. Therefore the symbol '*x*' may be replaced by '*d*'. [ISO 9276-1:1998, 3.1]

[SOURCE: ISO 9276-1:1998, 4.2, modified – text reformated]

3.1.10
equivalent diameter
equivalent spherical diameter
diameter of a sphere that produces a response by a given particle-sizing method, that is equivalent to the response produced by the *particle* (3.1.1) being measured

Note 1 to entry: The physical property to which the equivalent diameter refers is indicated using a suitable subscript [ISO 9276-1:1998].

Note 2 to entry: For discrete-particle-counting, light-scattering instruments, an equivalent optical diameter is used.

Note 3 to entry: Other material constants like density of the particle are used for the calculation of the equivalent diameter like Stokes diameter or sedimentation equivalent diameter. The material constants, used for the calculation, should be reported additionally.

Note 4 to entry: For inertial instruments, the aerodynamic diameter is used. Aerodynamic diameter is the diameter of a sphere of density 1 000 kg m^{-3} that has the same settling velocity as the irregular particle.

[SOURCE: ISO/TS 80004-6:2021, 4.1.5]

3.1.11
type of quantity
r
specification of the quantity of a distribution, a *cumulative* (3.1.13) or a *density* measure (3.1.14).

Note 1 to entry: The type is indicated by the general subscript, *r*, or by the appropriate value of *r* as follows:

number: $r = 0$

length: $r = 1$

area: $r = 2$

volume or mass: $r = 3$

[SOURCE: ISO 9276-1:1998, 4.3]

3.1.12
particle size distribution
distribution of *particles* (3.1.1) as a function of *particle size* (3.1.9)

Note 1 to entry: Particle size distribution may be expressed as *cumulative distribution* (3.1.13) or a *distribution density* (3.1.14) (distribution of the fraction of material in a size class, divided by the width of that class).

[SOURCE: ISO/TS 80004-6:2013, 3.1.2]

3.1.13
cumulative distribution
$Q_r(x)$
distribution of the fraction of material smaller (undersize) than given *particle sizes* (3.1.9)

Note 1 to entry: If the cumulative distribution, $Q_r(x)$, is calculated from histogram data, only individual points $Q_{r,i} = Q_r(x_i)$ are obtained. Each individual point of the distribution, $Q_r(x_i)$, defines the relative amount of particles smaller than or equal to x_i. The continuous curve is calculated by suitable interpolation algorithms. The normalized cumulative distribution extends between 0 and 1, i.e. 0 and 100 %.

$$Q_{\mathrm{r},i} = \sum_{v=1}^{i} \Delta Q_{\mathrm{r},v} = \sum_{v=1}^{i} \overline{q}_{\mathrm{r},v} \Delta x_v \ \text{ with } 1 \le v \le i \le n.$$

where

i (subscript) number of the size class with upper limit x_i

v (integer, see subscript i)

n total number of size classes

$Q_{r,v}$ relative amount of particles in size class with upper limit x_v

Note 2 to entry: When plotted on a graph paper with a logarithmic abscissa the cumulative values, $Q_{r,i}$, i.e. the ordinates of a cumulative distribution, do not change. However, the course of the cumulative distribution curve changes but the relative amounts smaller than a certain particle size remain the same. Therefore, the following equation holds:

$$Q_r(x) = Q_r (\ln x)$$

Note 3 to entry: The cumulative oversize distribution is given by $1 - Q_r(x)$.

[SOURCE: ISO 9276-1:1998, 5.2]

3.1.14
distribution density
$q_r(x)$
distribution of the fraction of material in a size class, divided by the width of that class

Note 1 to entry: Under the presupposition that the *cumulative distribution* (3.1.13), $Q_r(x)$, is differentiable, the continuous distribution density, $q_r(x)$, is obtained from

$$q_r(x) = \frac{dQ_r(x)}{dx}$$

Conversely, the *cumulative distribution* (3.1.13), $Q_r(x)$, is obtained from the distribution density, $q_r(x)$, by integration:

$$Q_r(x_i) = \int_{x_{min}}^{x_i} q_r(x)\,dx$$

Note 2 to entry: The more common term "density distribution" can be misunderstood in the context of sedimentation methods, so an alternative has been adopted.

Note 3 to entry: Differential distribution is also called in statistics "density of a probability or frequency"

[SOURCE: ISO 9276-1:1998, 5.3, modified – "density distribution" replaced with "distribution density"]

3.1.15
distribution density on a logarithmic abscissa
$q^*_r(x)$
distribution density (3.1.14), transformed for a logarithmic abscissa

Note 1 to entry: The density values of a histogram, $q^*_{r,i} = {}^- q^*_r(x_{i-1}, x_i)$, can be recalculated using the following equation which indicates that the corresponding areas underneath the distribution density curve remain constant. In particular, the total area is equal to 1 or 100 %, independent of any transformation of the abscissa.

$$q^*_r(\xi_{i-1}, \xi_i)\,\Delta\xi_i = \overline{q}_r(x_{i-1}, x_i)\,\Delta x_i \text{ where } \xi \text{ is any function of } x.$$

Thus the following transformation can be carried out to obtain the distribution density on a logarithmic abscissa

$$q^*_r(x_i) = q_{r,i} \cdot x_i \text{ or } \overline{q}^*_r(\ln x_{i-1}, \ln x_i) = \frac{\overline{q}_r(x_{i-1}, x_i)\,\Delta x_i}{\ln x_i - \ln x_{i-1}} = \frac{\overline{q}_{r,i}\,\Delta x_i}{\ln(x_i / x_{i-1})} = \frac{\Delta Q_{r,i}}{\ln(x_i / x_{i-1})}$$

Note 2 to entry: This equation also holds if the natural logarithm is replaced by the logarithm to base 10.

[SOURCE: ISO 9276-1:1998, 6.2]

3.1.16
histogram
graphical representation of a *distribution density $q_r(x)$* (3.1.14), comprising a successive series of rectangular columns with the height of mean distribution density, $\overline{q}_{r,i}(x)$, and the width of Δx_i, the area of each represents the relative quantity $\Delta Q_{r,i}(x)$, where

$$\Delta Q_{r,i} = \Delta Q_r(x_{i-1}, x_i) = \overline{q}_r(x_{i-1}, x_i)\,\Delta x \text{ or } \overline{q}_{r,i} = \overline{q}_r(x_{i-1}, x_i) = \frac{\Delta Q_r(x_{i-1}, x_i)}{\Delta x_i} = \frac{\Delta Q_{r,i}}{\Delta x_i}$$

Note 1 to entry: The sum of all the relative quantities, $\Delta Q_{r,i}$ forms the area beneath the histogram $q_r(x)$, normalized to 100 % or 1 (condition of normalization). Therefore, following equation holds:

$$\sum_{i=1}^{n} \Delta Q_{r,i} = \sum_{i=1}^{n} \overline{q}_{r,i} \Delta x_i = 1 = 100 \ \%$$

[SOURCE: ISO 9276-1:1998, 5.1]

3.1.17
concentration distribution density
distribution of the concentration of material in a size class, divided by the width of that class

Note 1 to entry: In aerosol measurement e. g. the distribution density of the particle number concentration is represented as a function of the particle size.

Note 2 to entry: The concentration distribution density can be calculated from the *distribution density* (3.1.14) function of the *particle size* (3.1.9) by multiplication with the overall sizes measured concentration.

3.1.18
analytical cut size
x_a
cut size with the coarse and the fine material containing equal quantities of misplaced material

Note 1 to entry: Since the relative mass of the fine material as determined by the classification process, is taken to be equal to the relative mass of the undersize material in the feed, that is $Q_{3,s}(x)$, an analytical cut size x corresponding to this definition has to be found.

[SOURCE: ISO 9276-4:2001, 4.3.2]

3.1.19
equiprobable cut size
x_e
cut size, which represents the median of the *grade efficiency* (3.1.20) curve $T(x_e) = 0,5$

Note 1 to entry: The weighted distribution density curves of the fine and the coarse fraction intersect at the equiprobable cut size x_e. Independently from other *particle sizes* (3.1.9), particles of this size have the equal probability to be classified into the fine and into the coarse fraction.

[SOURCE: ISO 9276-4:2001, 3.3.2]

3.1.20
grade efficiency
$T(x)$
grade efficiency (Tromp's curve, Partial classification efficiency) represents for a certain *particle size* (3.1.9) x the ratio of the amount of material present in the coarse material, to the amount of the same size initially present in the feed material.

[SOURCE: ISO 9276-4:2001, 4.4]

Note 1 to entry: In the dust collection field this efficiency is called as Partial separation efficiency.

3.1.21
reference material
RM
material, sufficiently homogeneous and stable with respect to one or more specified properties, which has been established to be fit for its intended use in a measurement process

Note 1 to entry: RM is a generic term.

Note 2 to entry: Properties can be quantitative or qualitative, e.g. identity of substances or species.

Note 3 to entry: Uses may include the calibration of a measurement system, assessment of a measurement procedure, assigning values to other materials, and quality control.

Note 4 to entry: ISO/IEC Guide 99:2007 has an analogous definition but restricts the term "measurement" to apply to quantitative values. However, ISO/IEC Guide 99:2007, 5.13, Note 3 (VIM), specifically includes qualitative properties, called "nominal properties".

[SOURCE: ISO Guide 35:2017, 3.1]

3.1.22
certified reference material
CRM
reference material (3.1.21) characterised by a metrologically valid procedure for one or more specified properties, accompanied by an RM certificate that provides the value of the specified property, its associated uncertainty, and a statement of metrological traceability

Note 1 to entry: The concept of value includes a nominal property or a qualitative attribute such as identity or sequence. Uncertainties for such attributes may be expressed as probabilities or levels of confidence.

Note 2 to entry: Metrologically valid procedures for the production and certification of RMs are given in, among others, ISO 17034 and ISO Guide 35.

Note 3 to entry: ISO Guide 31 gives guidance on the contents of RM certificates.

Note 4 to entry: ISO/IEC Guide 99:2007, 5.14 has an analogous definition.

[SOURCE: ISO Guide 35:2017, 3.2]

3.1.23
accuracy
closeness of agreement between a test result or measurement result and the *true value* (3.1.26)

Note 1 to entry: In practice, the accepted reference value is substituted for the *true value* (3.1.26).

Note 2 to entry: The term "accuracy", when applied to a set of test or measurement results, involves a combination of random components and a common systematic error or bias component.

Note 3 to entry: Accuracy refers to a combination of *trueness* (3.1.25) and *precision* (3.1.24).

[SOURCE: ISO 3534-2:2006, 3.3.1]

3.1.24
precision
closeness of agreement between independent test/measurement results obtained under stipulated conditions

Note 1 to entry: Precision depends only on the distribution of random errors and does not relate to the *true value* (3.1.26) or the specified value.

Note 2 to entry: The measure of precision is usually expressed in terms of imprecision and computed as a standard deviation of the test results or measurement results. Less precision is reflected by a larger standard deviation.

Note 3 to entry: Quantitative measures of precision depend critically on the stipulated conditions. *Repeatability conditions* (3.1.28) and reproducibility conditions are particular sets of extreme stipulated conditions.

[SOURCE: ISO 3534-2:2006, 3.3.4]

3.1.25
trueness
closeness of agreement between the expectation of a test result or a measurement result and a *true value* (3.1.26)

Note 1 to entry: The measure of trueness is usually expressed in terms of bias.

Note 2 to entry: Trueness is sometimes referred to as "accuracy of the mean". This usage is not recommended.

Note 3 to entry: In practice, the accepted reference value is substituted for the true value.

[SOURCE: ISO 3534-2:2006, 3.3.3]

3.1.26
true value
value which characterizes a quantity or quantitative characteristic perfectly defined in the conditions which exist when that quantity or quantitative characteristic is considered

Note 1 to entry: The true value of a quantity or quantitative characteristic is a theoretical concept and, in general, cannot be known exactly.

Note 2 to entry: For an explanation of the term "quantity", refer to ISO 3534-2:2006, Note 1 of 3.2.1.

[SOURCE: ISO 3534-2:2006, 3.2.5]

3.1.27
repeatability
precision under *repeatability conditions* (3.1.28)

Note 1 to entry: Repeatability can be expressed quantitatively in terms of the dispersion characteristics of the results.

[SOURCE: ISO 13320:2020, 3.1.20]

3.1.28
repeatability conditions
observation conditions where independent test/measurement results are obtained with the same method on identical test/measurement items in the same test or measuring facility by the same operator using the same equipment within short intervals of time

Note 1 to entry: Repeatability conditions include the following:

— the same measurement procedure or test procedure;

— the same operator;

— the same measuring or test equipment used under the same conditions;

— the same location;

— repetition over a short period of time.

[SOURCE: ISO 3534-2:2006, 3.3.6]

3.1.29
method repeatability
closeness of agreement between multiple measurement results of a given property in different aliquots of a sample, executed by the same operator using the same instrument under identical conditions within a short period of time

Note 1 to entry: The variability includes the variabilities of sub sampling technique, of the sampled material together and of the instrument.

[SOURCE: ISO 13320:2020, 3.1.22]

3.2 Terms related to representation of particle shape

3.2.1
particle shape
external geometric form of a *particle* ([3.1.1](#))

Note 1 to entry: Macroshape is a description of the overall form of a *particle* ([3.1.1](#)) defined in terms of the geometrical proportions of the particle. In general, simple geometrical descriptors calculated from size measurements made on the particle silhouette are used.

Note 2 to entry: Mesoshape description provides information about details of the particle shape and/or surface structure that are in a size range not much smaller than the particle proportions.

Note 3 to entry: Microshape determines the roughness of shape boundaries using fractal dimension or higher-order Fourier coefficients for surface-textural analysis.

[SOURCE: ISO/TS 80004-6: 2021, 4.1.3, modified — Notes 1 to 3 have been added from ISO 9276-6:2008, 5.2]

3.2.2
Legendre ellipse of inertia
ellipse with its centre at the particle's centroid and with the same geometrical moments of inertia, up to the second order, as the original particle area

Note 1 to entry: The ellipse can be characterized by its major and minor diameters, the position of its centre of gravity and its orientation.

Note 2 to entry: Macroshape descriptor, geometrical descriptor

[SOURCE: ISO 9276-6:2008, 8.1.2]

3.2.3
geodesic length and thickness
x_{LG} and x_E
approximations for very long and concave *particles* ([3.1.1](#)), such as fibres, calculated from the projection area A and perimeter P:

$$A = x_E \cdot x_{LG} \quad P = 2\left(x_E + x_{LG}\right)$$

Note 1 to entry: Macroshape descriptor, geometrical descriptor

[SOURCE: ISO 9276-6:2008, 8.1.2]

3.2.4
ellipse ratio
ratio of the lengths of the axes of the *Legendre ellipse of inertia* ([3.2.3](#))

Note 1 to entry: Macroshape descriptor, proportion descriptor

[SOURCE: ISO 9276-6:2008, 8.1.3]

3.2.5
Feret diameter
x_F
distance between two parallel tangents on opposite sides of the image of a *particle* ([3.1.1](#))

[SOURCE: ISO 13322-1:2014, 3.1.5]

3.2.6
aspect ratio
ratio of the minimum *Feret diameter* to the maximum *Feret diameter* ([3.2.5](#))

Note 1 to entry: For not very elongated particles (approximately smaller than 1:3)