TECHNICAL SPECIFICATION

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Dispersibility of solid particles into a liquid

Dispersibilité de particules solides dans un liquide

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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*.

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

Dispersing particles is crucial for many end-use product properties such as colour, sensorial quality, polishing, film homogeneity, conductivity, therapeutic efficacy, opacity of paints and inks, as well as UV protection in cosmetics. Dispersions are evaluated over the life-cycle of a product, beginning in the design stage, through production and for the end product. Additionally, some type of dispersion process is a prerequisite for many routine particle characterization methods. Finally, the state of dispersion is an important issue for risk evaluation of fine particles and for classification of nano-enabled products[37].

However, the ease with which a particulate material is dispersed in a liquid phase to meet established or desired criteria, commonly referred to as dispersibility, is not well defined; and its common usage varies widely across different fields and applications. Most existing definitions are application or product specific. Therefore, the need exists for a document that summarizes the common practice, and which also clearly defines dispersibility in a generic manner that is not application dependent. This document addresses that stated need.

The definition for dispersibility is established based on a survey of existing standards of national and international organisations as well as standardized procedures of industry in different application fields. With respect to the final product in different applications, the state of dispersion can be characterized according to the uniformity of the dispersed phase over the entire volume and according to the mean particle size or size distribution with respect to application specific criteria.

This document does not address intermediate- or long-term alterations including aging of a suspension following processing, nor does it address secondary destabilization phenomena. Stability and shelf life are considered in specific standards such as ISO/TR 13097 and ISO/TR 18811.

Dispersibility of solid particles into a liquid

1 Scope

This document establishes a generally applicable (i.e. not application specific) definition for dispersibility. It identifies significant characteristics for evaluating dispersibility and lists examples of methods used to characterize dispersibility in various applications.

This document applies to processes that disperse powders into a liquid continuous phase while reducing the size of agglomerates or flocs down to the intended level, that homogenize an existing dispersed solid phase of a suspension or the mixture of two suspensions, or that exchange the original continuous phase in a suspension for another. Specific methods to disperse particles and to characterize the state of dispersion and/or homogeneity are only referenced, if necessary, for context.

This document is applicable to nano- and micro-sized particles across a range of product applications.

2 Normative references

There are no normative references in this document.

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 http://www.electropedia.org/

3.1
agglomerate
loosely coherent assembly of *particles* (3.12) and/or *aggregates* (3.2) held together by weak physical interactions, with a total surface area virtually equal to the sum of the surface areas of the *constituent particles* (3.13)

Note 1 to entry: The transitive verb “agglomerate” means “to gather into a cluster”, and the process by which the cluster or assembly is formed is generally called “agglomeration”.

Note 2 to entry: Agglomeration can be a reversible process.

3.2
aggregate
assemblage of *particles* (3.12) into rigidly joined structures

Note 1 to entry: Formation of aggregates is usually an irreversible process.

Note 2 to entry: The forces holding an aggregate together are strong, for example covalent bonds or those resulting from sintering or complex physical entanglement.

Note 3 to entry: In common use, the terms aggregate and agglomerate (also aggregation and agglomeration) are sometimes applied interchangeably, but this practice is deprecated since the terms are not synonymous.

Note 4 to entry: The transitive verb “aggregate” means “to gather into a mass or whole”, and the process by which the structure is formed is generally called “aggregation”.

[SOURCE: ISO/TR 13097:2013, 2.2, modified — The term has been changed from "aggregation" to "aggregate"; notes 1 and 3 to entry has been updated; note 4 to entry has been added.]

3.3
comminution
operation of reducing *particle* (3.12) size by crushing, grinding or pulverisation

[SOURCE: ISO 12743:2021, 3.14]

3.4
dispersing agent
dispersant
substance capable of promoting the formation of a *dispersion* (3.7)

[SOURCE: ISO 862:1984, 82, modified — The admitted term "dispersant" has been added.]

3.5
disperse
distribute *particles* (3.12) homogeneously throughout a continuous phase, often by means of reducing the size of *agglomerates* (3.1)

3.6
dispersibility
qualitative or quantitative characteristic or property of a particulate source material assessing the ease with which said material can be *dispersed* (3.5) within a continuous phase

Note 1 to entry: Spatially uniform distribution (*homogeneity* (3.11)) of the dispersed phase is considered an integral part of the desired end point.

Note 2 to entry: *Particle* (3.12) size or particle size distribution is often used as an end point relative to defined criteria specific to the application.

Note 3 to entry: Dispersibility refers to a specific *dispersion* (3.7) process and specific process time.

Note 4 to entry: *Dispersion stability* (3.8), though a related phenomenon, should not be confused with dispersibility.

3.7
dispersion
multi-phase system in which discontinuities of any state (solid, liquid or gas) are homogeneously distributed in a continuous phase of a different composition or state

Note 1 to entry: If solid *particles* (3.12) are *dispersed* (3.5) in a liquid, the dispersion is referred to as a suspension. If the dispersion consists of two or more immiscible liquid phases, it is termed an emulsion.

Note 2 to entry: This term can also refer to the act or process of producing a dispersion, but in this context the term “dispersion process” shall be used.

[SOURCE: ISO/TR 13097: 2013, 2.5, modified — The words "in general, microscopic" have been removed from the begining of the definition; "discontinous phase" has been remove from the within the parentheses; "dispersed" has been replaced by "homogeneously distributed"; note 1 to entry has been updated; note 2 to entry has been added.]

3.8
dispersion stability
ability to resist change or variation in the initial properties (state) of a *dispersion* (3.7) over time, in other words, the quality of a dispersion in being free from alterations over a given time scale

Note 1 to entry: In this context, for instance agglomeration or segregation represents a loss of dispersion stability.

[SOURCE: ISO/TR 13097:2013, 2.6, modified — In note 1 to entry, "creaming" has been replaced by "segregation".]

3.9
energy density
amount of energy per unit volume of sample applied to a material

3.10
floc
ensemble of *particles* (3.12) that form a loosely coherent structure with high void fraction

Note 1 to entry: Flocs are held together by weak particle-particle attraction or by the osmotic pressure of a continuous phase containing polymers not adsorbing to *dispersed* (3.5) particles (loss of configurational entropy of polymers, depletion flocculation).

Note 2 to entry: The term floc may be used to denote an *agglomerate* (3.1) produced by addition of a flocculating agent (e.g., a polyelectrolyte), but flocs can also form spontaneously.

3.11
homogeneity
degree to which a property or a constituent is uniformly distributed throughout a quantity of material

[SOURCE: IUPAC Gold Book[38]]

3.12
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.

[SOURCE: ISO 14644-5:2004, 3.1.7, modified — The original note to entry has been replaced by 2 new notes to entry.]

3.13
constituent particle
identifiable, integral component of a larger *particle* (3.12)

[SOURCE: ISO/TS 80004-2:2015, 3.3, modified — Note 1 to entry has been removed.]

3.14
primary particle
original source *particle* (3.12) of *agglomerates* (3.1) or *aggregates* (3.2) or mixtures of the two

Note 1 to entry: Although a primary particle is often a *constituent particle* (3.13), a constituent particle is not necessarily a primary particle.

[SOURCE: ISO 26824:2013, 1.4, modified — The 2 original notes to entry have been replaced by a new note to entry.]

3.15
sedimentation
settling (separation) of the *dispersed* (3.5) phase due to the higher density of the dispersed *particles* (3.12) compared to the continuous phase

Note 1 to entry: The accumulation of the dispersed phase at the bottom of the container is evidence that sedimentation has taken place.

Note 2 to entry: Particles with a lower density compared to the continuous phase float rather than sink.

Note 3 to entry: Sedimentation leads to a loss of *homogeneity* (3.11).

[SOURCE: ISO/TR 13097:2013, 2.13, modified — The second sentence in the definition has been moved to note 1 to entry; the original note 1 to entry has been removed; notes 2 and 3 to entry have been added.]

3.16
surfactant
substance that lowers the interfacial energy of a material in contact with a liquid

Note 1 to entry: This term is a contraction of surface-active agent.

[SOURCE: ISO 18115-1:2013, 4.464, modified — The words "or the surface energy of that liquid" have been removed at the end of the definition; the 2 original notes to entry have been replaced by a new note to entry.]

4 Basic aspects of dispersion process

Dispersing particulate matter into a liquid continuous phase in the context of processing is a common method to produce suspension-based products in many industrial fields and to prepare samples for analysis (e.g. particle size analysis). In this document, the term "dispersion process" is used in the context of processing (dispersing a material)[1)]. A dispersion process may start from dry source material or a pre-existing suspension. Dispersions can be created by mixing particles into a liquid to achieve a uniform distribution throughout the entire volume, and additionally tailoring the size or size distribution by mechanical or chemical means. Comminution, the size reduction of aggregates or primary particles by milling, for example, is not considered here. Furthermore, the dispersion process results in a multiphase system and not a solution.

The performance of a dispersion process, and therefore the quality/state of the final suspension, depends on the source materials, the liquid continuous phase, the type and conditions of processing, and is application-dependent and often quantified by reference specifications or criteria.

There are numerous textbooks, scientific papers, national and international standards, etc., dealing with different aspects of dispersing particles and characterization of achieved results (see ISO 8780-1, ISO 14887, ISO/TS 27687[2)] and References [39] to [43]). Relevant ISO documents are included in the Bibliography and Annex A.

Various terms are introduced to compare or to quantify the success of the dispersion process, such as "dispersibility", "level of dispersion", "ease of dispersion", "dispersibility index", "degree of dispersity", "re-dispersibility", focussing often on a specific, mostly application driven aspect. These broad views and discussions reflect the practical need to characterize the suspension with regard to different sample preparation or manufacturing processes, as well as the supplied raw materials of different suppliers or batches from the same supplier. On the other hand, comparison or evaluation of the outcome is difficult due to the use of different terms and definitions. To arrive at a generic definition for material "dispersibility", it is appropriate to define the starting point of a (liquid-based) dispersion process.

To disperse powder, the process starts with powder consisting of particles, aggregates and/or agglomerates and has the following objectives (see ISO 14887):

— wet the powder (source material) with the liquid (continuous phase);

— obtain a uniform distribution of mass throughout the liquid volume (primarily for mixing, not size reduction);

— decrease (reduce) the size of agglomerates of the source material to the application specific criteria for size or size distribution, or down to constituent particles or primary particles if desired.

In practice, these procedures are often combined intentionally with additional appropriate measures to prevent the occurrence of spatial inhomogeneities in volume concentration (e.g. due to separation or sedimentation) and any re-association of dispersed particles impacting the specified size or size distribution, respectively. These latter phenomena concern the stability of the dispersion state (ISO/

1) In literature the term "dispersion" and its derivatives (disperse, dispersed, dispersing) can be used both as an active verb (as in "to disperse" something) and in reference to the material itself (as in "a colloidal dispersion").

2) Withdrawn.

TR 13097 and ISO/TR 18811) with respect to time, which is beyond the scope of this document. ISO/TR 13097 provides guidelines to characterize dispersion stability.

To disperse pre-existing suspensions, the process starts with a liquid suspension of the source material that has degraded over time due to destabilization phenomena or requires, for its ultimate purpose, an exchange or alteration of the continuous phase or further processing to achieve product-specific criteria. In this case the objective may be one or more of the following:

— re-disperse agglomerated particles and sediments of a destabilized (e.g. aged) suspension;

— disperse the particles into a different liquid matrix or formulation (e.g. exchange of solvents);

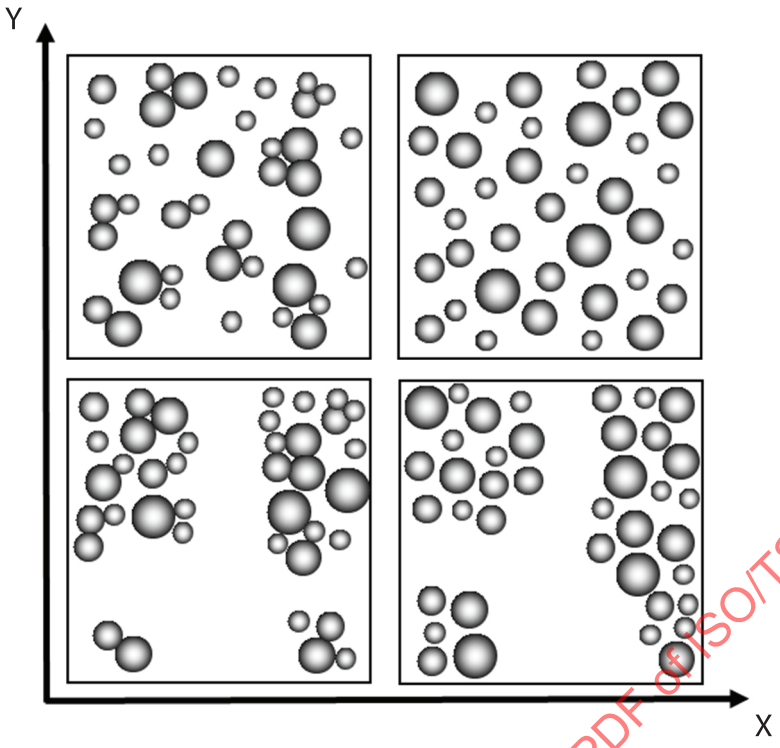
— disperse two or more different types of source material to form a single suspension;

— reduce the size of agglomerated particles to the required size or size distribution for a specific application or end-use.

According to the above description, dispersion processes may be theoretically divided into distributive and disruptive processes, as depicted in Figure 1. These processes often occur in parallel.

Distributive processing involves the mixing of particles throughout the continuous phase volume, often called homogenisation, to obtain uniformly distributed particles throughout the entire suspension volume. This process may not involve size reduction, if the energy input is insufficient to break apart existing agglomerates. In this case, the cohesive forces between particles are stronger than the applied disruptive forces.

Disruptive processing involves the reduction in size of the source material (such as agglomerates, flocs) and is often called dispersive processing, deagglomeration or simply dispersion. Success is attained when the disruptive forces necessary to separate an agglomerate's constituent particles overcome the attractive forces between them. It should be noted that achievement of product specified fineness (endpoint of disruptive processing) does not necessarily correspond with attainment of constituent particles, nor does it necessarily mean that a uniform spatial distribution has been achieved.



Key

X level of disruptive process

Y level of distributive process

Figure 1 — Schematic illustration of distributive and disruptive processes[40]

Three independent factors influence the success of the distributive or disruptive process:

a) the inherent chemical and physical properties of the source materials, for example, dry or wet, particle size and size distribution, shape, brittleness or state of agglomeration;

b) the interaction between the particle surface and the continuous phase; this factor depends, for instance, on wettability, electrostatic interactions, depletion forces, van der Waals forces, polarity interaction, and hydrogen bonding;

c) the dispersion process itself; time, energy, intensity and mechanism (mechanical principle) have an influence on the success of the distributive or disruptive process.

Therefore, to describe dispersibility all three factors shall be considered (multidimensional approach). Each of these independent factors can be characterized by a number of different attributes and quantified by suitable metrics.

5 Definition of dispersibility

5.1 Dispersibility definitions in existing standards

The concept of dispersibility has been used across a wide range of applications and industries for a substantial period of time; however, its interpretation and usage vary widely even among existing international and national standards. Therefore, a survey of existing standards and published references was conducted in order to identify commonalities and differences.

Annex A consists of an annotated listing of relevant standards. According to those standards, dispersibility can refer to the ease with which one can incorporate a powder into a suspension or

achieve deagglomeration (breaking or peptization of agglomerates or flocs into constituent particles). The process of dispersion frequently results in both outcomes, as in the use of ultrasonication. In ISO/TR 13329 (pertaining to nanotechnology), dispersibility is defined as the level of dispersion when it has become constant under defined conditions, a definition adapted from ISO 8780-1. In the latter context, the "level of dispersion" is understood as the extent to which particles have been separated and stabilized by milling in a binder system under defined conditions (taken from ISO 8780-1).

As described in brief above (for details refer to Annex A), there is a broad variety of descriptions that are often very specific, but, on the other hand, also connected with general product behaviour (quality). Summing up the existing definitions and common usage, dispersibility is related to:

— ease of the dispersion process, e.g. energy input, process time, necessary equipment;

— quality of the dispersed end-product, e.g. stability, tinting strength, gloss development, rheological behaviour, opacity/appearance;

— geometrical particle characteristics, e.g. fineness or coarseness, target particle size, target size distribution, specific surface area, particle shape;

— assessment of characteristics of processing outcome, dispersion hardness[46],[47] filtering, sieving, amount of dry matter that can be dispersed, suspension viscosity.

Stability of the processed suspension or end product, strictly speaking, shall be distinguished from "dispersibility", despite the fact that they are interconnected in practice. Dispersibility is related to the dispersion process, while stability is the capacity for such a suspension to maintain its state over a specified period of time. Although beyond the scope of the present document, it can be necessary to apply additional process steps or stabilizing agents (dispersing agents, surfactants) to ensure long term stability of the suspension state (e.g. against agglomeration, flocculation) or to prevent loss of spatial uniformity (e.g. sediment formation by particle sedimentation) of the dispersed phase over time.

5.2 Generic definition of dispersibility

Based on literature sources and other considerations discussed above, dispersibility is defined generically as stated in 3.6.

Dispersibility of a specific source material in a specific liquid application therefore depends upon:

— mass or volume ratio of particulate material to continuous phase;

— density of the particle(s);

— wettability of dry powders;

— primary or constituent particle size and initial state of agglomeration;

— surface/interfacial properties of the dispersed material;

— properties of the continuous phase in which the material is dispersed;

— specified product fineness to be achieved (i.e., the "endpoint" of deagglomeration, which does not necessarily correspond to the primary particle size);

— type and conditions of the dispersion process (e.g. ultrasonication, high pressure or rotor-stator-equipment, pH, temperature);

— energy density applied to the material.

6 Methods to characterize dispersibility of solid particles into a liquid

There are different points of departure for a dispersion process and correspondingly distinctive meanings of dispersibility. Specific topics of characterization methods are dealt with in numerous standards and, in more detail, listed in Annex A.

When the raw particulate material is a powder, "dispersibility" is often used to indicate the ease of bringing a powder into a dispersion by achieving uniform spatial particle distribution and, if aimed, "deagglomeration". In this context, dispersibility can be quantified as the "percentage by mass of the dry matter of the sample that can be dispersed in water", determined by the procedure specified" (ISO/TS 17758). It is also common in this case to characterize dispersibility based on the capacity to achieve a specified particle size or size distribution via deagglomeration of the powder.

On the other hand, if the raw material is already in suspension, the task consists of transferring the dispersed particles into another continuous phase or matrix, of reducing the particle size or achieving a necessary size distribution, of mixing one type of dispersed material with a different type, or of re-dispersing separated or re-associated particles (e.g. in an aged dispersion). In this context, dispersibility is characterized primarily by the degree of uniformity and/or the particle size that can be achieved in the suspension.

Homogeneity (uniformity) can be assessed using methods based on imaging the entire sample or optical scanning, for instance. Metrics based on particle size can utilize a wide range of sizing methods. Indirectly, suspension viscosity, opacity, or other property measurands that relate to the degree to which size has been reduced can also be used as proxies for dispersibility.

Alternatively, some standards focus on the assessment of product quality to define dispersibility. For example, ISO 105-Z04 states that dispersibility is the degree to which particles can be broken down to some minimum size such that they will pass through the interstices of a reference filter media. A similar definition is given for instant dried milk relating dispersibility of a powder in water to its ability to break down into particles passing through a 150 µm sieve. Dispersion hardness is another description to characterize the amount of work required to achieve the tinting strength of a coloured pigment[24] (EN 13900-2). There is a well-known, strong power-law correlation between the mean particle size and the applied energy density of the dispersion technique[44],[45] The obtained exponent of energy density is used as a measure of dispersibility.

For any experimental assessment of dispersibility, particular attention shall be paid to sampling, sample preparation, if necessary, and the time of analysis following sample preparation, which shall be conducted during or immediately after processing. Measurement methods that require dilution, mixing, stirring, sonication or any other mechanical or chemical treatment of samples are deprecated since they may induce changes in the dispersion state.

Annex A
(informative)

A compilation of national and international standards

A.1 General

This annex is a list of available standards that address definitions and measurement procedures of dispersibility within specific applications. Some of these standards are not directly relevant to the scope of this document, but they are included as examples of alternative methods of characterising dispersibility and related quantities.

A.2 ISO documents

ISO 105-Z04	
Textiles — Tests for colour fastness — Part Z04: Dispersibility of disperse dyes	
Scope	Describes a method for determining the dispersibility
Objective of dispersibility	Degree and kinetics of dispersing disperse dye in aqueous media
Definition of dispersibility	Dispersibility = degree to which particles can be broken down to some minimum size such that they will pass through the interstices of a reference filter paper
Quantification of dispersibility	i) Dispersion at 70 °C in aqueous solution (acidic or alkaline) with magnetic stirrer for a defined time ii) Filtration through filter paper (8 µm and 25 µm) iii) Evaluation of filtration time or visible filter-residue
Relevance for this document	Hardly relevant; dye is supposed to dissolve in water; the test essentially evaluates the kinetics of the dissolution process

ISO 105-Z11	
Textiles — Tests for colour fastness — Part Z11: Evaluation of speckiness of colorant dispersions	
Scope	Describes a test method to determine speckiness primarily of disperse dye, vat dye and pigment dispersions
Objective of dispersibility	Instead of dispersibility or state of dispersion, the test quantifies “speckiness”, which is considered due to coarse agglomerates or undissolved particles
Definition of dispersibility	No definition of dispersibility
Quantification of dispersibility	Visual examination of speckiness of filter cloth which was coloured by the dye solution / pigment dispersion; test samples are prepared by thorough mixing and/or turbulent shear flow
Relevance for this document	Minor relevance; the test does not discuss dispersibility or ease of dispersion, but focusses on the homogeneity of cloth colouring, which is affected by several factors, including the disruption of pigment aggregates and the distribution of particulate and dissolved matter; yet, good quality means homogenous distribution and small particle size

ISO 6387	
Surface active agents — Determination of the power to disperse Calcium soap — Acidimetric method (Modified Schönfeldt method)	
Scope	Determination of the minimum quantity of dispersing agent (surface active agent) required to maintain at least 95 % of the Calcium soap present in complete dispersion for one hour
Objective of dispersibility	Power to disperse calcium soap
Definition of dispersibility	Power to disperse calcium soap = The quantity of soap, expressed in grams, which may be completely dispersed by 1 g of dispersing agent (surface active agent)
Quantification of dispersibility:	Titrating of HCl in an equilibrated surfactant solution of calcium soap, observing colour change at pH 4.9
Relevance for this document	Not relevant

ISO 8780-1	
Pigments and extenders — Methods of dispersion for assessment of dispersion characteristics — Part 1: Introduction	
Scope	Introduction to the various methods for dispersing pigments and extenders in a particular binder system for the purpose of assessing the dispersion characteristics
Objective of dispersibility	Related to state/level of dispersion under defined conditions
Definition of dispersibility	Level of dispersion = the extent to which pigment particles have been separated and stabilized by milling in a binder system under defined conditions Ease of dispersion = a measure of the rate at which a pigment achieves a given level of dispersion during its milling in a binder system The ease of dispersion may be assessed in terms of, for example, tinting strength (see ISO 8781-1), fineness of grind (see ISO 8781-2), gloss (see ISO 8781-3) Dispersibility = The level of dispersion (see above) when it has become constant under the defined conditions NOTE: The dispersibility of a pigment depends on the binder system in which it is dispersed, the method of dispersion and the mill base composition.
Quantification of dispersibility	Not provided → the ISO 8781 series
Relevance for this document	Very relevant, yet this standard defines a difference between ease of dispersion (referring to a change of state) and dispersibility (characterising a final state); note that the corresponding standards for assessing dispersion characteristics, ISO 8781-2 and ISO 8781-3, eliminate this difference by i) stating a equivalency between ease of change and dispersibility and ii) implicitly abandoning the idea of constant level of dispersion (the ultimate stage is only defined by the colour reference)

ISO 8780-2
Pigments and extenders — Methods of dispersion for assessment of dispersion characteristics — Part 2: Dispersion using an oscillatory shaking machine
ISO 8780-3

Pigments and extenders — Methods of dispersion for assessment of dispersion characteristics — Part 3: Dispersion using a high-speed impeller mill	
ISO 8780-4	
Pigments and extenders — Methods of dispersion for assessment of dispersion characteristics — Part 4: Dispersion using a bead mill	
ISO 8780-5	
Pigments and extenders — Methods of dispersion for assessment of dispersion characteristics — Part 5: Dispersion using an automatic muller	
ISO 8780-6	
Pigments and extenders — Methods of dispersion for assessment of dispersion characteristics — Part 6: Dispersion using a triple-roll mill	
Relevance for this document	Minor relevance, these standards only describe different methods of dispersing pigments and extenders

ISO 8781-1	
Pigments and extenders — Methods of assessment of dispersion characteristics — Part 1: Assessment from the change in tinting strength of coloured pigments	
Scope	Assessment of the dispersion characteristics of pigments
Objective of dispersibility	Determine the ease of dispersion of a pigment
Definition of dispersibility	No definition, but a procedure to evaluate the ease of dispersion of a pigment based on reflectance measurements
Quantification of dispersibility	Percental increase in tinting strength (from photometric reflectance, ISO 787-24) of coloured pigments between two agreed dispersion stages, dispersion procedures according to the ISO 8780 series
Relevance for this document	Very relevant, with a focus on the disruptive processes when dispersing pigments

ISO 8781-2	
Pigments and extenders — Methods of assessment of dispersion characteristics — Part 1: Assessment from the change in fineness of grind	
Scope	Assessment of the dispersion characteristics of pigments
Objective of dispersibility	Determine the ease of which ultimate fineness of grind is achieved; with "ultimate fineness = degree of fineness which is better or equal or better to that agreed"
Definition of dispersibility	No definition, but "if the ultimate fineness of grind can be attained easily, the pigment is considered to be readily dispersible."
Quantification of dispersibility	Ultimate fineness from maximum particle size with Hegman grindometer (ISO 1524), dispersion stages in geometric progression (of energy, time, no. of revolutions etc.), dispersion procedures according to the ISO 8780 series
Relevance for this document	Highly relevant, quantification of disruptive processes only; method and description reveal a profound understanding of dispersion processes (without much ado)

ISO 8781-3	
Pigments and extenders — Methods of assessment of dispersion characteristics — Part 1: Assessment from the change in gloss	
Scope	Assessment of the dispersion characteristics of pigments
Objective of dispersibility	Determine the ease of dispersion of a pigment
Definition of dispersibility	No definition, but "if the ultimate specular gloss can be attained easily, the pigment is considered to be readily dispersible."
Quantification of dispersibility	Ultimate fineness measured with a glossmeter (ISO 2813), dispersion procedures according to the ISO 8780 series
Relevance for this document	Relevant, focus of disruptive processes; however: coating properties are also affected by dispersion stability (as explicitly stated in the standard)

ISO 11345	
Rubber — Assessment of carbon black and carbon black/silica dispersion — Rapid comparative methods	
Scope	Specifies qualitative visual methods for the rapid and comparative assessment of the degree of macrodispersions of carbon black and/or carbon black/silica into rubber
Objective of dispersibility	n.a.
Definition of dispersibility	None
Quantification of dispersibility	Not given
Relevance for this document	Minor relevance; the standard describes test to evaluate the degree of dispersion for products, it does not evaluate the solids' propensity to be dispersed in rubber

ISO 14887	
Sample preparation — Dispersing procedures for powders in liquids	
Scope	Assistance in preparing "good dispersions" from powder/liquid combination in the context of particle size analysis→ procedures for wetting and deagglomerating, guidance in selecting dispersion media and dispersing agents as well as evaluating stability against reagglomeration
Objective of dispersibility	n.a.
Definition of dispersibility	None
Quantification of dispersibility	Not given
Relevance for this document	No relevance for defining dispersibility; yet helpful for understanding the relevant microprocesses, material-specific effects and available techniques

ISO 18451-1	
Pigments, dyestuffs and extenders — Terminology — Part 1: General terms	
Scope	
Objective of dispersibility	Assessing the ease of dispersion of pigments and fillers
Definition of dispersibility	Dispersibility = property of a pigment or extender characterized by its ability to be wetted, separated and distributed in a medium NOTE 1: The dispersibility depends on its wettability and on the number and strength of the adhering areas between the components of the agglomerates. NOTE 2: As a measure of the dispersibility under specified dispersion conditions, e.g. the speed of the tinting strength development and/or the decrease of the fineness of grind can be taken.
Quantification of dispersibility	Not given
Relevance for this document	Highly relevant, classic view on dispersion (wetting, deagglomerating, distributing); medium is not defined (intended media are liquids, elastomers, plastics; important: viscous, viscoelastic, plastic behaviour during dispersion process)

ISO 18553	
Method for the assessment of the degree of pigment or carbon black dispersion in polyolefin pipes, fittings and compounds	
Scope	Describes a method with two procedures for the assessment of dispersed pigment or carbon black in polyolefin --> agglomerate size and degree of dispersion
Objective of dispersibility	Quality control of thermoplastics (how well are pigment & carbon black particles dispersed in polymer matrix)
Definition of dispersibility	None
Quantification of dispersibility	Microscopic determination of particle and agglomerate size; and grading of particles and agglomerates (particle number per image weighted by size)
Relevance for this document	Irrelevant for dispersibility

ISO 23900-1	
Pigments and extenders — Methods of dispersion and assessment of dispersibility in plastics — Part 1: General introduction	
Scope	Introduction to the various methods for dispersing pigments and extenders in plastic materials for the purpose of assessing the dispersing characteristics and colouristic properties
Objective of dispersibility	Related to state/level of dispersion under defined conditions

Definition of dispersibility	Ease of dispersion = measure of the rate at which or the degree to which a pigment or extender achieves a given level of dispersion when dispersed in a plastics material Dispersibility = ease and extent to which pigments or extenders can, by wetting, elimination of air and by mechanical disagglomeration, be distributed homogeneously in a plastics material under standardized conditions of processing NOTE: Dispersibility is generally assessed in terms of colour strength development, colouristic properties and frequency and size of agglomerates.
Quantification of dispersibility	Not provided → subsequent parts of the ISO 23900 series
Relevance for this document	Highly relevant; the definition refers to all relevant subprocesses of dispersing a solid material in any type of condensed matter (wetting, deagglomeration/disruption, distribution); in contrast to ISO 8780-1, dispersibility is not connected to a (constant) level of dispersion, but reflects the ease to change this level; whereas the significance of ease of dispersion remains (it is bound to predefined state of product quality)

ISO 23900-2	
Pigments and extenders — Methods of dispersion and assessment of dispersibility in plastics — Part 2: Determination of colouristic properties and ease of dispersion in plasticized polyvinyl chloride by two-roll milling	
ISO 23900-3	
Pigments and extenders — Methods of dispersion and assessment of dispersibility in plastics — Part 3: Determination of colouristic properties and ease of dispersion of black and colour pigments in polyethylene by two-roll milling	
ISO 23900-4	
Pigments and extenders — Methods of dispersion and assessment of dispersibility in plastics — Part 4: Determination of colouristic properties and ease of dispersion of white pigments in polyethylene by two-roll milling	
Scope	Methods of determining the colouristic properties of a test pigment relative to a standard, and the ease of dispersion
Objective of dispersibility	Ease of dispersion; change in colouristic properties due to milling under specified conditions
Definition of dispersibility	Refer to ISO 23900-1
Quantification of dispersibility	Via the increase in colour/tinting strength due to milling (starting with a pre-milled plastic-sample)
Relevance for this document	Relevant; the standards describe methods to quantify the ease of dispersion

ISO 23900-5	
Pigments and extenders — Methods of dispersion and assessment of dispersibility in plastics — Part 4: Determination by filter pressure value test	
Scope	Method of assessing the degree of dispersion of a colorant in a thermoplastic polymer
Objective of dispersibility	Indirect assessment of state of dispersion in molten plastics via pressure drop at a filter

Definition of dispersibility	Refer to ISO 23900-1
Quantification of dispersibility	Via filter pressure value (FPV)
Relevance for this document	Minor relevance; highly specific for plastics

ISO 23900-6	
Pigments and extenders — Methods of dispersion and assessment of dispersibility in plastics — Part 4: Determination by film test	
Scope	Method of assessing the degree of dispersion of a colorant and/or extender in a thermoplastic polymer
Objective of dispersibility	indirect assessment of state of dispersion in molten plastics via visual homogeneity of illuminated films
Definition of dispersibility	Refer to ISO 23900-1
Quantification of dispersibility	Via photographic detection of specks in thin films (i.e. due to coarse particles ≥ 42 µm); particle numbers → number concentrations
Relevance for this document	Relevant; relates dispersibility (title) with the fractional number concentration of coarse particles

ISO/TS 16176 (withdrawn in 2018)	
Rubber compounding ingredients — Carbon black — Determination of the aggregate-size distribution at ultimate dispersion	
Scope	Specifies a method for determining the size distribution of aggregates of carbon black dispersed into a liquid by high-power ultrasonic means
Objective of dispersibility	
Definition of dispersibility	
Quantification of dispersibility	Size distribution of carbon black aggregates by centrifugal photosedimentation technique
Relevance for this document	

ISO/TS 17758	
Instant dried milk — Determination of the dispersibility and wettability	
Scope	Specifies a method for determining wettability and dispersibility of instant dried milk in water
Objective of dispersibility	To quantify how instantaneously instant milk powder "dissolves" in water
Definition of dispersibility	No definition, but an equation to calculate dispersibility from measurement data

Quantification of dispersibility	Via mass percentage of milk powder ("instant dried milk"), which is not dispersed below a defined mesh size (150 µm) after manually stirring the whole powder in water for approximately 1 min
Relevance for this document	Hardly relevant in the context of our standard, distributive and disruptive processes are not as important as size and structure (compactness, porosity) of milk powder agglomerates and their wettability

ISO/TR 13014 (ISO/TR 13014:2012/Cor 1:2012 replaces dispensability by dispersibility in the definition)	
Nanotechnologies — Guidance on physico-chemical characterization of engineered nanoscale materials for toxicologic assessment	
Scope	Guidance for the physico-chemical characterization of manufactured nanoobject prior to toxicological assessment (including terms and definitions)
Objective of dispersibility	Dispersibility as an extrinsic phys-chem property of nanomaterials (extrinsic = how does it interact with the surrounding environment)
Definition of dispersibility	a) Under terms and definitions dispersibility = level of dispersion when it has become constant under the defined conditions NOTE 1 Dispersion is defined as a suspension of discrete particles. NOTE 2 Adapted from ISO 8780-1 and ISO 1213-1. b) In text body dispersibility = The degree to which a particulate material (the dispersed phase) can be uniformly distributed in another material (the dispersing medium or continuous phase) and resulting dispersion remains stable (for example one hour or one minute) PLUS: "for very fine particles, including nano-objects, stable suspensions (colloids or aerosols) can be formed, which have indefinite stability
Quantification of dispersibility:	a) Maximum mass or concentration of the dispersed phase present in a unit mass of the dispersing medium / a unit volume of the dispersion at specified temperature and pressure b) "[mostly] based on particle size"
Relevance for this document	Not relevant the standard reveals an unclear terminology and concept of dispersion and dispersibility; in the first definition, dispersibility is seen as "level of a disperse system"; the second definition mixes dispersibility with stability and implies by its context that "distributing material" includes disruptive processes; moreover, the quantification refers neither to the degree of spatial distribution nor to the degree of deagglomeration

A.3 ASTM documents

ASTM B821-10 (2016)	
Standard Guide for Liquid Dispersion of Metal Powders and Related Compounds for Particle Size Analysis	
Scope	Standard for dispersing metal powders and related compounds in liquids for subsequent use in particle size analysis

Objective of dispersibility	Preparation of samples for particle size analysis
Definition of dispersibility	Lack of obvious inhomogeneity or agglomeration
Quantification of dispersibility	Determine whether the powder is dispersed in the liquid by examining it carefully in a beaker during and after stirring. If the powder appears to be distributed uniformly throughout the liquid and does not flocculate within a few seconds after the discontinuation of stirring, particle size analysis can then be performed and the results evaluated
Relevance for this document	Moderate relevance; the concept of stability, which is separate from dispersibility, is an essential part of the method

ASTM D1210-05 (2014)	
Standard Test Method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage	
Scope	Grinding of pigment systems
Objective of dispersibility	Measurement of the pigment in a pigment-vehicle system such as liquid coatings and their intermediates
Definition of dispersibility	Undispersed particles are detected as visible patterns breaking the surface of the sample, and their size is estimated by the corresponding depth of the gage channel
Quantification of dispersibility	Degree of dispersion (commonly referred to as “fineness of grind” by Hegman-Type Gage is determined by the position of speckles observed on the gage after drawing the test material towards the shallow end of the tapered channel
Relevance for this document	Moderate; illustrates the reduction of agglomerates to their constituent particles

ASTM D2067-97(2013)	
Standard Test Method for Coarse Particles in Printing Ink Dispersions	
Scope	To determine the weight concentration of coarse particles in printing ink dispersions by sieve retention
Objective of dispersibility	Determination of coarse particles in printing ink dispersions
Definition of dispersibility	The coarse particle fraction retained on a 325 mesh (45 µm) screen
Quantification of dispersibility	Sample is diluted to roughly 1/5 its initial volume, then shaken for 30 minutes prior to screening. The fraction of coarse particles is calculated by dividing the net weight of the dried residue on the screen by the weight of the original sample
Relevance for this document	Moderate; demonstrates that the dispersion process and amount of time must be specified

ASTM D4441-15	
Standard Specification for Aqueous Dispersions of Polytetrafluoroethylene	
Scope	Aqueous dispersions of polytetrafluoroethylene (PTFE) resins containing not more than 1 % by weight of other fluoromonomers.
Objective of dispersibility	Test to determine the amount of coagulated polymer in aqueous dispersions of polytetrafluoroethylene (PTFE) resins

Definition of dispersibility	The amount of coagulated polymer is the weight fraction trapped on a 177 µm screen.
Quantification of dispersibility	Dispersion (1 kg) is filtered through a 80 Mesh (177 µm) screen, and the retained solids are dried and weighed. The net weight is divided by the estimated weight of solids in the dispersion
Relevance for this document	Not relevant

ASTM E1945-02 (2016)	
Standard Test Method for Percent Dispersibility	
Scope	Dry pesticide formulations dispersed in water
Objective of dispersibility	Provides test method to measure amount of dry pesticide dispersed in water
Definition of dispersibility	A fixed amount (2,5 g) of powder is added to a mixing cylinder, which is then filled to a volume of 250 mL with standard water. After mixing for 2 minutes and settling for 1 minute, 225 mL of liquid is drawn from the top of the cylinder, and the remaining suspension is dried. The residue weight will determine percent dispersibility
Quantification of dispersibility	Dispersibility is calculated from the relative difference between the sample weight and the dried residue weight
Relevance for this document	None; this test does not distinguish between solubility and dispersibility

ASTM E2651–19	
Standard Guide for Powder Particle Size Analysis	
Scope	This guide describes sampling, preparation (dispersion process), and analysis of powders for off-line determination of particle size distribution analysis of powder
Objective of dispersibility	Describes a general dispersion procedure used for particle size analysis
Definition of dispersibility	Lack of obvious inhomogeneity or agglomeration
Quantification of dispersibility	Determine whether the powder is dispersed in the liquid by examining it carefully in a beaker during and after stirring. If the powder appears to be distributed uniformly throughout the liquid and does not flocculate within a few seconds after the discontinuation of stirring, particle size analysis can then be performed and the results evaluated. The use of optical microscopy is recommended to directly observe the state of dispersion
Relevance for this document	Low; dispersion is assessed qualitatively, and there is no discussion of the importance of the defining the dispersion process (e.g. power input) and time (e.g. how long sonication is applied)