



Glossary of Terms in Powder & Bulk Technology

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## 1.3 General Terms

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accuracy	The closeness of the agreement between the result of a measurement and the true value.
aerosol	A dispersion of fine particles (solids or liquids) suspended in a gas.
adsorbed water	Water attracted to the particle surface by physiochemical forces, having properties that may differ from the pore water at the same temperature and pressure due to the altered molecular arrangement. Adsorbed water does not include water that is chemical combined within the particles.
aeration	The action of injecting gas, usually air, to a bulk material to weaken the particulate structure by dilatation. The process induces the material to adopt a fluid or highly agitated state. (See quiescent and boiling bed).
anisotropic	Not of the same composition, structure or condition in all axial directions.
attrition	Unwanted reduction in particle size caused by the collision of particles with other particles or with a surface, resulting in abrasion, causing fines, or fracture that creates 'mother' and 'daughter' particles.
barrel section	The upper, parallel section of a circular storage hopper. See body section.
bed	An assembly of particles in a contained state.

biaxial compression	Compression of a bulk mass by the application of normal stresses in two directions at right angles to each other
biaxial state of stress	State of stress in which one of the three principal stresses is zero
big bag	See FIBC
bin	A bulk storage container, usually of small or medium size. Synonymous with hopper and, to a limited extent, with silo. May be mobile or transportable, See IBC
binder	An additive that coheres a loosely assembled particulate mass.
Bingham plastic	A form of deformation that exhibits Newtonian behaviour once a threshold shear stress is exceeded.
body force	A force, such as gravity, magnetic force or inertia, whose effect is distributed throughout a material body by direct action on each elementary part of the body independent of others.
body section	The upper, parallel part, of largest cross section, of a storage container.
bunker	Generic term for a fixed container for bulk storage. Typically of shallow construction with a large, open top. See hopper, bin.
capillarity	A phenomenon associated with surface tension and angle of contact that leads to the migration of fluids through narrow channels, as the interstitial voids of closely packed particulate beds.
cavitation	The formation of a cavity.
clean room	A room with control of particulate contamination to a defined level.
C/M/R substances Materials	Classified as category 1 or 2 carcinogens, mutagens or toxic to reproduction. (Related to points 29, 30 and 31 pf Annex 1 of Directive 76/769/EEC. (A Consolidated, 100 page, list of materials is given ).
coagulant	An agent causing coagulation.
colloid	A state of matter comprising a system with two or more phases, in which one phase exists as discrete particles of the order of 100 to 100,000 nanometers densely permeating a continuous phase. Physical characteristics related to the enormous surface area of the bulk tend to dominate the behaviour of such materials.
compression index	The slope of the linear portion of the pressure-void ratio curve on a semi-log plot.

compressive stress	A normal stress that tends to shorten the body to which it is applied, in the direction in which it acts. In solids, the effect is termed compaction.
consolidation	The reduction in volume of a bulk particulate mass resulting from the effect of gravity over time, or of a compacting stress. It is useful to consider consolidation as a state, rather than a process of volume reduction, which is better distinguished by the term 'compaction'.
creep	A slow, plastic deformation under stress lower than the failure stress.
critical density	The unit weight of a unit volume of a granular material that will deform in a specific state of stress without change of volume. Below this value of density the bulk will gain strength when subjected to deformation, i.e. it is under-consolidated, and above which it will lose strength when deformed, an over-consolidated condition. Critical density reflects the condition of a material in instantaneous equilibrium during gravity flow.
deliquescent	The ability to absorb moisture from the atmosphere, to the extent that the product dissolves in the absorbed fluid.
dilatant suspension	A material that increases in shear strength with the rate of shear.
dilatation	A condition of expanded particulate structure that may be brought about by such as agitation, aeration or shear. The opposite of compaction.
disintegrant	Materials incorporated within compacts of dry powders or granules to promote separation to the primary particles, on addition to a liquid.
elastic limit	Point on the stress-strain curve beyond which deformation will not fully recover on the removal of stress.
elastic state of equilibrium	State of stress within a stressed mass when the internal resistance to permanent deformation is not fully mobilised.
elastic strain energy	Potential energy stored within a strained solid equal to the work done in deforming the solid from its unstrained condition, less any energy dissipated by inelastic deformation.
elasto-plastic	A deformation that will partially recover on relaxation of the applied stress
emulsion	A dispersion of immiscible liquids.

entrainment pattern	The flow velocity contours that are generated over the cross section of the interface from a hopper outlet by a feeder used to discharge the container.
equivalent surface level	The level that the contents of a hopper would reach if the material were evenly spread across the surface.
failure	A state of dis-equilibrium brought about by stresses exceeding the elastic limit of deformation of a powder compact. (See shear failure, yield).
failure criterion	Specification of the mechanical conditions under which a bulk solid will fail to support the applied stress.
feeder	A device used to discharge a bulk storage container in a controlled manner. Typical equipment for this purpose are screw feeders, belt conveyors, scraper type conveyors, vibratory feeders, table feeders, rotary valves and disc type feeders.
FIBC	A Flexible Intermediate Bulk Container, See IBC.
filter porosity	The ratio (or percentage) of the void volume within the filter material to the total volume of the filter material.
flocc, floc; flocculate	An assemblage of particles which, having been initially dispersed, have become loosely coherent.
fluid	A liquid or gas.
fractions	Portions of the mass that fall into a certain defined category, usually a particle size range.
fume	Cloud of airborne particles, generally visible, that arise from condensing vapours from either a chemical or physical reactions.
Gaussian distribution	(See normal distribution)

	<p>For substances within EU classification as a dangerous substance are ranked in five groups of acute health hazard with respect to corrosive/irritation and organ toxicity. These classes are ranked 1 – 5 ( with 0 for unidentified products).</p> <ul style="list-style-type: none"> <li>- Class 0: No data available relevant to human health hazard</li> <li>- Class 1: Very high risk. (e.g. very acute toxicity).</li> <li>- Class 2: High risk. (e.g. acute toxicity).</li> <li>- Class 3: Moderate risk, (e.g. mild toxicity).</li> <li>- Class 4: Low risk, (e.g. low toxicity).</li> <li>- Class 5: No reasonable concern with regard to health hazard effects</li> </ul>
health hazard ranking	<p>Five sub-chronic/chronic health hazards relating to allergy, neurotoxicity, carcinogenicity, genotoxicity and reproductive toxicity are, ranked A – E, as below:</p> <ul style="list-style-type: none"> <li>- Class 0: No relevant data available</li> <li>- Class A: Severe effects from low exposure</li> <li>- Class B: Severe effects after medium exposure, or mild effects with low exposure</li> <li>- Class C: Severe effect only from extensive exposure, or to limited cases</li> <li>- Class D: Effects limited or applies to isolated cases.</li> <li>- Class E: No reason for concern with regard to health effects.</li> </ul>
HEPA filter	<p>Acronym for High Efficiency Particulate Air filter, for particles in air, having a specified minimum collection efficiency to the D O P test.</p>
heterogeneous material	<p>Material in which a spot sample will have a significantly different value of the characteristics under consideration from the mean value of that characteristic of the bulk material.</p>
homogeneous material	<p>Material in which a spot sample will have the same value of the characteristic under consideration as the mean value of that characteristics for the bulk material.</p>
homogeneous suspension	<p>A suspension in which the particles are uniformly distributed in a liquid.</p>
homogenisation	<ol style="list-style-type: none"> <li>1. (Relating to a fluid based product). Mixing using a high shear rate.</li> <li>2. (Relating to a particulate solid). Re-ordering the particle distribution of a heterogeneous material to the condition of a homogeneous material.</li> </ol>

	<p>1. Generic term for a bulk storage container.</p> <p>2. The converging section of a bulk storage container.</p>
hopper	(The ambiguity of this term demands that, for appropriate clarity, the meaning is clarified within the context in which it is used).
hopper half angle	The inclination of the wall of a symmetrical hopper from the vertical axis.
hopper section	(of bulk storage container) The converging section of a bulk storage container leading to the outlet. See hopper.
Hvorslev surface	<p>The envelope of a family of yield loci on a three dimensional axis of shear stress, normal stress and bulk density. The boundary conditions are:</p> <ul style="list-style-type: none"> <li>- The line of tensile strength on the axis of density.</li> <li>- The critical state line, being the limiting shear strength of a bulk mass against its density.</li> <li>- The envelope of the yield loci at each condition of bulk density.</li> <li>- The bulk density condition at zero shear strength. (Maximum density for fluidity).</li> <li>- The bulk density condition of maximum consolidation.</li> </ul>
hygroscopic	<p>Possessing the tendency to absorb moisture from the atmosphere. In the case of particulate solids this leads to many potential flow problems as the effect of moisture changes the bulk strength and slip characteristics of the bulk, sometimes dramatically with only a small change of water content. Equilibrium atmospheric moisture conditions depend upon the ambient temperature, pressure and relative humidity. Changes in ambient conditions can cause moisture content variations according to the boundary surface contact conditions of the bulk mass. Moisture migration and condensation conditions can give rise to massive imbalances in moisture distribution, leading to caking or surface adhesion problems. (See moisture content).</p>
hysteresis	Incomplete recovery of shape on the relaxation of stress. i.e. A partial elastic recovery inhibited by a degree of permanent deformation.
IBC	Intermediate bulk container.

intensity of variation	The degree to which a variation of a physical property deviates from defined bounds, the average value of a batch or from adjacent product, whichever is significant. (See Scale of scrutiny and Scale of variation).
interstice	The space between particles in a mass. (See preferred term void).
interstitial	Occurring in the space between the particles of composition. Pertaining to axial directional differences. This applies to individual particles, their structure in a bulk arrangement of particles, to stresses and to strains. A sphere is isotropic, whereas elongated particles and flakes are not. Fluids are, whilst wood, by virtue of its grain, is not. Strain, Shear and uniaxial compaction are essentially anisotropic (non-isotropic) processes that produce anisotropic states in the bulk material.
isotropic	The feature is relevant to both the preparation and loading of a sample of bulk material for testing, as the failure conditions depend upon how the bulk will shear. This in turn depends on the orientation of the constituents of the particulate structure in relation to the direction of stresses that produced the specific state of the bulk and the direction of stresses applied to cause the bulk to fail. The isotropy of a particulate structure is essentially disturbed when shear takes place.
Jenike, Andrew	See Appendix II. (Recommended reading).
laminar flow	Flow in which the head loss is proportional to the first power of the velocity. It is characterised by the lack of turbulence.
latex particles	Particles of natural latex or other polymer; usually spherical and of a narrow size range; often used for calibration purposes.
liquefaction	The process whereby a powder bed is transformed from a solid state to a liquid state, usually as a result of the restructuring of particles in a fully saturated bed to a higher packing density arrangement or the introduction of excess fluid. Additional fluid separates the particles, whereas closer particle packing allows the pore pressure of the incompressible fluid to support the applied stresses. Either change relaxes the particle-to particle contact pressure and resulting in a much greater freedom for the particles to shear with little resistance. Fluidisation is an equivalent process with a gas, instead of a liquid, providing the void pressure to reduce the contact pressure between particles.

Log-normal distribution	A distribution which results in a straight line when a cumulatively quantity on a probability axis is plotted against particle size on a logarithmic axis.
measuring range	The range over which an instrument as set-up can give results within a specified uncertainty. (Note: – Some instruments have many measuring ranges).
micrometre (µm)	One millionth part ( $10^{-6}$ ) of a metre.
micron	(See micrometre)
monolith	A block of material; a very large particle.
nanometre (nm)	One thousand millionth part ( $10^{-9}$ ) of a metre.
nano technology	The study of particles in the size region of one nanometre or less. (This is an area of intense interest because of some useful physical characteristics of ultra fine particles, such as their large surface area in relation to mass).
normal distribution	A distribution which results in a straight line when cumulative quantity on a probability axis is plotted against particle size on a linear axis.
normal stress	The stress acting at 90 degrees to the considered plane. (usually that of shear failure).
particle	A discrete piece of matter.
particle adhesion	The tendency for neighbouring particles to hold together by attraction forces, such as surface tension, Van der Waal forces at the molecular level, surface sintering, thermal fusion or by electrostatic forces.
particle, effective	A particle as perceived by a measuring technique that discriminates between the constituent elements of a powder.
particle, primary	The basic particle within a agglomerate or flocculate.
particulate	Consisting of particles.
particulate bed	A particulate solid occupying a given space.



particulate solid	A crowd of particles, the number of particles being sufficient for the statistical mean of any property to be independent of the number of particles present. The mass assumes a behaviour due to their interaction such that the assembly may be considered as a continuum. Particulate solids may be called bulk solids, granular solids or powders although, in certain contexts, these terms have different meanings from one another.
particulate structure	The manner of composition of touching particles in a bed.
period of scrutiny	The time interval over which variations of a given property are significant. A typical example is for defining the time interval over which a weighed sample should be collected to determine the relevant accuracy of a Loss-in-weight feeder output. Typically, for this duty, the period is of the order of 60 seconds. Whereas feedback control can ensure that the average feed rate is relatively accurate, there are circumstances, such as metering the feed into a high-speed mill where the residence time is very short, that place a high premium on the very short-term feed evenness, rather than the precise accuracy, in relation to the mill power demands and consistency of the product produced.
phase	A physical state that constitutes all or part of a material mass, such as a liquid, gas or solid. Particulate solids comprise a minimum of two phases, the solid and the medium occupying the voids. There are three phases if a loose fluid is present in addition to a gas in the void space.
points of co-ordination	The points of contact between particles in a particulate bed.
Poisson's ratio	The ratio between linear strain changes perpendicular to, and in the direction of, a given uniaxial stress change.
porosity, filter	(See filter porosity).
powder	A bulk solid consisting of particles less than 1 mm.
primary consolidation	The reduction of volume that occurs in a dilated powder due to the escape of excess gas from the voids.
relative humidity	The proportion of moisture that can be held in air as a vapour compared with the maximum vapour holding capacity at the given temperature.

The dimensionless number which defines the flow pattern of a fluid surrounding a particle, with

$$Re = v \cdot d \cdot \rho / \eta$$

Reynolds number

where:

- Re is the Reynolds number
- v is the relative velocity
- d is the diameter of spherical particles
- $\rho$  is the density of fluid
- $\eta$  = viscosity

All values being in the same system of units.

rheology The subject of deformation and flow.

rheopectic The behaviour of materials that set or increase in viscosity when shaken or tapped.

risk phrases Legends used in the Countries of the EU to denote category of risk related to dangerous substances and preparations. See Attributes.

Rosin-Rammler distribution A mathematical function to describe particle size distribution (The expression was originally developed for broken coal).

safety See attributes, risk phrases, MSDS, CMR substances, and Directives 99/45/EC, 67/548/EEC (in Appendix of standards).

The amount, volume or mass, that is sufficient to ensure that specific determined qualities of interest in a bulk material sample will satisfy the requirement for purpose. A common use is to define the size of a mixture sample that must be taken, to ensure that the ratio of constituents falls within acceptable bounds for the application. In the case of a mix prepared for making pharmaceutical tablets, this should be no more than that required for an individual tablet to confirm that the amount of active ingredient per dose is within prescribed bounds.

scale of  
scrutiny

A larger sample may be appropriate for a detergent for use in domestic appliances and a different again scale for a solid fuel supply to a power station, where the average calorific value on a large scale is of interest.

Some circumstances demand that more than one scale of scrutiny be considered, for each of which different levels of tolerances can apply. (See Scale of variation, intensity of variation, period of scrutiny).

An analogy may be considered with colour differences in a fabric or sheet, where a small, intense spot is obvious, but a small shade difference at that scale would be un-noticed. However, a similar fine shade difference on a much large scale would be immediately apparent and un-acceptable.

scale of  
variation

The size of region over which a significant variation of an interesting physical property is detected. This may be from defined bounds or from the average in the universal sample. (See scale of scrutiny and Intensity of variation). Note that this term relates to the scale of causal occurrence of a variation, whereas the scale of scrutiny applies to the scale of significance relevant to an application, as with the suitability of the material to subsequent processing or for its ultimate use.

shear  
failure

The permanent disturbance of a particulate structure by the application of a shear stress. Interest may focus on incipient failure and/or sustained failure.

silo

A bulk storage container, usually of large volumetric capacity and tending to have a slender, cylindrical body section with a conical hopper section. May be built in banks and constructed of metal or concrete. Broadly synonymous with hopper and, to a limited extent, with bin and bunker.

solid A state of matter in which the constituent molecules or ions possess no translational motion, but can only vibrate about fixed mean positions. A solid has definite shape and offers resistant to changes in shape and/or volume.

spot sample A sample taken at random from a bulk mass.

state (of a bulk material) The condition of dilatation of a bulk material, as characterised by the packing arrangement of the constituent particles. Material state is normally quantified by its condition of density, although strictly, this does not take account of any anisotropy in the system.

The equation relating the pace of Brownian motion to the diameter of the particle in motion, expressed as:

$$D = kT/3\pi\cdot\eta\cdot d$$

where:

- D is the diffusion coefficient of the particle.
- K is the Boltzmann's constant.
- T is the temperature.

Stokes-Einstein equation

- $\eta$  is the viscosity of the surrounding fluid
- d is the particle diameter (diffusion diameter).

and where D is determined in photo correlation spectroscopy using the equation:

$$k = 4 \pi \cdot n \cdot \sin (\theta/2) / \lambda$$

where

- n is the refractive index of the suspending field
- $\theta$  is the scattering angle
- $\lambda$  is the wavelength of incident light.

The equation which determines the free falling velocity,  $v$ , (terminal velocity), attained by a particle in viscous flow conditions and allows a calculation to be made of the particle size.

$$v = d^2 \cdot g (\rho_s - \rho_f) / 18 \eta \text{ in SI Units}$$

Stoke's law where:

- $v$  is the free-falling velocity.
- $d$  is the Stoke's diameter of particle.
- $g$  is the gravitational acceleration.
- $\rho_s$  is the density of particle.
- $\rho_f$  is the density of fluid.
- $\eta$  is the viscosity.

strain ellipsoid	Representation of strain in the form of an ellipsoid into which a sphere of unit radius deforms and whose axis are the principal axis of strain.
stress	The value of an applied force divided by the area of its application.
stress ellipsoid	The representation of the state of stress in the form of an ellipsoid whose semi-axes are proportional to the magnitude of the principal stresses and lie in the principal directions. The coordinates of a point, P, on this ellipse are proportional to the magnitudes of the respective components of the stress along the planes normal to the direction, OP, where O is the centre of the ellipsoid.
stress history	The sequence of stress conditions that have brought a bulk material to the state in which it now resides.
stress relaxation	The reduction in stress due to creep or the reduction in confinement during flow. See Sigma Two relief.
surfactant	A substance which reduces surface tension.
suspension	A dispersion of particles in a fluid.
tangent modulus	The slope of the tangent to the stress-strain curve at a given stress value. (generally taken at a stress equal to half the compressive strength).
thixotropic suspension	A condition that requires an initiating stress to commence deformation, but then resistance decreases with increased strain.
turbidity	The light scattering properties of particles suspended in a fluid.
ullage	The space in the upper part of a bulk storage container that cannot be filled because of the surface contours formed by the repose conditions acting from the point of fill.

unconfined failure	The failure of a particulate bed that is not supported on a boundary by a confining surface, therefore no normal force or shear force is acting on this surface. Such is the situation at the underside of an arch.
under-consolidated	A state of consolidation and applied stress where shearing causes compaction of the particulate structure in the shear plane.
uniaxial state of stress	State of stress in which two of the principal stresses are zero.
unloading module	Slope of the tangent to the unloading stress-strain curve at a given stress value.
van der Waal forces	Molecular attractive forces between closely aligned fine particles.
viscous flow	Of permeability. A form of flow in which adjacent layers of fluid do not mix except at the molecular level and when the velocity at the particle interface is zero.
void	Space in a particulate bed that is not occupied by particulate matter. This volume may be occupied by air, water or any other liquid or gas in any combination. If the void space is totally occupied by a liquid, the bed is said to be 'fully saturated'.
void pressure	The pressure of the fluid, usually air, in the interstitial voids between the particles in a bed.
void ratio	The ratio of the volume of the void space to the volume of the solid particles in a given particulate mass. At higher normal loads, with a particular condition of preparation, the shear strength will not peak, and continue to increase accompanied by an increase in the density of the sample to a different bulk condition, where it has a greater shear strength. See underconsolidated.
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