Pneumatic conveying

Part 1. Glossary of terms

ICS 01.040.53; 53.040.30

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee MHE/9, Continuous mechanical handling equipment, upon which the following bodies were represented:

Agricultural Engineers' Association
Association of Consulting Engineers
Automated Material Handling Systems Association
British Aggregate Construction Materials Industries
British Coal Corporation
British Rubber Manufacturers' Association Ltd.
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Electrical, Electronic, Telecommunications and Plumbing Union
Electricity Association
Mechanical Handling Engineers' Association
Solids Handling and Processing Association Ltd.

This British Standard, having been prepared under the direction of the Engineering Sector Board, was published under the authority of the Standards Board and comes into effect on
15 November 1996

Amendments issued since publication

Amd. No.	Date	Text affected

The following BSI references relate to the work on this standard:
Committee reference MHE/9
Draft for comment 96/79332 DC

ISBN 0 580 26260 X

Contents

Foreword

This British Standard has been prepared by Technical Committee MHE/9 in order to set out standard terms for use in the pneumatic conveying industry and in a series of standards being prepared on the subject of pneumatic conveying.

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Introduction

Pneumatic conveying is the term used to describe the transport of particulate solids in gas, usually air, through pipes and ducts. The relative concentrations by weight of the solids phase and the gas phase can vary widely. The term solids loading ratio is used to describe the ratio of the mass flow rate of the solids conveyed to the mass flow rate of the gas used for conveying.

A solids-gas phase diagram is a wide ranging graph of pressure gradient versus gas velocity in a pipe containing flowing gas and solids. Because of the difficulty of finding a suitable scale to show all the detail on the same graph it tends to be used only qualitatively as an aid to communication.

Figure 1 shows the relationship between pressure gradient, gas velocity and solids flow rate for a coarse powder. Different modes of flow can be related to specific locations on the diagram. A more complete example of a phase diagram covering a number of flow rates for a coarse powder, showing more detail, is given in figure A1.

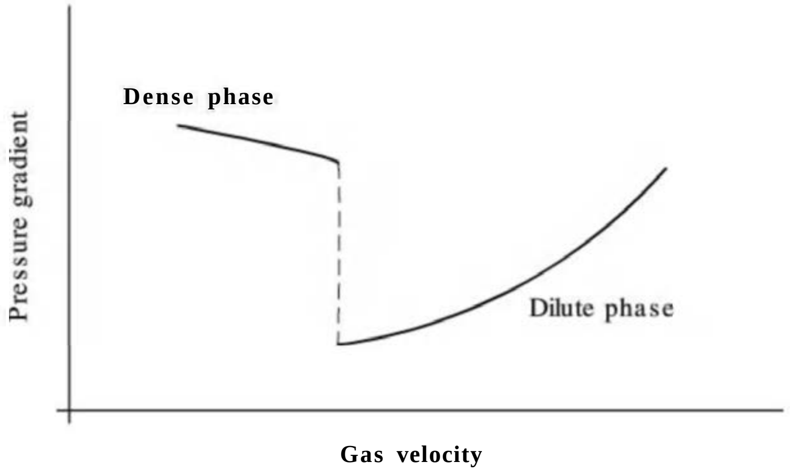


Figure 1. Phase diagram for a particulate solid conveyed at a constant flow rate

Section 1. Air

No.	Term	Definition
1.1 Free air terms		
1101	**free air conditions**	Those conditions at which ***p*** - 101.3 kN/m^2 absolute (standard atmospheric pressure) and ***t*** = 15 °C (standard atmospheric temperature). NOTE. Free air conditions are generally used as the reference conditions for the specification of positive pressure air movers.
1.2 Air flow terms		
1201	**free air velocity**	The velocity of the air at free air conditions.
1202	**superficial gas velocity**	The velocity of the gas, disregarding the volume of solid particles or porous media, at the temperature and pressure conditions under consideration within the pipeline. NOTE. In a pipeline it is the velocity based upon the cross-sectional area; the space occupied by the conveyed product is neglected. For flow through a membrane or across a filter, it is the open duct velocity normal to the surface. Gas velocity is dependent upon both pressure and temperature, and so when conveying gas velocities are evaluated at any point in a system, the local values of pressure and temperature at that point are used.
1203	**minimum conveying air velocity**	The lowest superficial air velocity which can be used to convey a material.
1204	**conveying line inlet gas velocity** pick-up velocity entrainment velocity	The superficial gas velocity at the point where the product is fed into the pipeline. NOTE, hi a single bore pipeline this will be the lowest gas velocity in the conveying line and so it will be greater than the minimum conveying gas velocity required to ensure successful conveying of a product
1205	**conveying line exit gas velocity**	The superficial gas velocity at the end of a conveying line where the product is discharged into the receiving hopper. NOTE, hi a single bore pipeline this will be the highest gas velocity in the conveying line.
1206	**saltation**	The process of deposition of solid particles along the bottom of a horizontal pipeline.
1207	**saltation velocity**	The superficial gas velocity at which solid particles begin to fall from suspension in horizontal How. NOTE 1. Saltation occurs in dilute phase flow when the gas velocity falls below the minimum conveying gas velocity. NOTE 2. The deposited particles may move slowly along the bottom of the pipe but are not generally re-entrained.
1208	**choking**	A process which occurs in vertically upward flow and commences when solid particles near the pipe wall begin to flow downwards. NOTE. Choking in vertical transport is somewhat analogous to saltation in horizontal transport, for both phenomena represent saturation conditions in dilute phase conveying.

No.	Term	Definition
1209	**choking velocity**	The superficial gas velocity at which choking occurs. NOTE 1. For mixed size particles the velocity at which choking occurs is usually lower than the saltation velocity. NOTE 2. An alternative definition for choking velocity takes the superficial velocity at which the entire suspension collapses into slug flow as the choking velocity However not all powders can be made to collapse into slug flow and the given definition is preferred.
1210	**null point**	The position in a system where the pressure is equal to the ambient pressure. NOTE. This is often used in relation to closed loop systems and can identify a natural point of access to the system for monitoring or conditioning.
1211	**specific humidity**	The ratio of the mass of water vapour to the mass of air in a given volume of the mixture. NOTE. Specific humidity gives an indication of the amount of water vapour that is actually contained in the gas.
1212	**relative humidity**	The ratio of the partial pressure of the gas, at a given temperature, to the partial pressure of the gas when saturated, at the same temperature. NOTE 1. Relative humidity gives an indication of how much water vapour the gas is capable of supporting before it becomes fully saturated. Its value is usually expressed as a percentage. NOTE 2. The relative humidity may change throughout a pneumatic conveying system as relative humidity increases with rise in pressure and decreases with rise in temperature.

Section 2. Solids/gas terms

No.	Term	Definition
2001	**solids loading ratio** phase density	The ratio of the mass flow rate of the solids conveyed, to the mass flow rate of the gas used for conveying. NOTE 1. Solids loading ratio is used by pneumatic conveying engineers to describe the nature of the solid/gas flow in a pipeline. Other terms used include phase density, mass ratio, solids to air loading and mass flow ratio. It is a useful dimensionless quantity since its value does not vary with the conveying gas pressure and so it remains constant throughout the pipeline. NOTE 2. Some references may define phase density as a mass volume ratio which should not be confused with the above definition.
2002	**aeration**	The process by which a particulate solid is conditioned by the introduction of gas locally within its mass. NOTE. The objective of aeration is usually to assist movement by reducing interparticle friction or to prevent compaction.
2003	**fluidization**	A mode of contacting solids with gas such that the particulate solids are given fluid-like properties. NOTE. A common example of fluidization occurs where a gas is passed upwards through contained particulate solids with a velocity which just lifts and suspends the particles without carrying them away. If this condition can be achieved, the particles will disengage from each other and the bulk may be stirred or caused to flow like a liquid with relatively little energy expenditure.
2004	**fluidized flow**	The movement of fluidized solids, by pouring or other means, under the influence of gravity or a pressure gradient
2005	**dilute phase conveying** lean phase suspension flow	The conveying of a material in suspension in a flowing gas. NOTE. It is necessary to exceed a minimum value of conveying line inlet gas velocity to produce sufficient drag force on the solid particles to ensure dilute phase conveying. The vast majority of material can be conveyed in this mode.
2006	**dense phase conveying**	Conveying of materials in air at velocities lower than those required for dilute phase conveying. NOTE. The nature of dense phase flow is very varied, for it depends upon the properties of the bulk solid, the phase density of the conveyed material and the conveying air velocity. Typical flows include flow over a deposited layer, which may itself be moving slowly, and flow in discrete or separate slugs of material which may be formed quite naturally. The range of materials which can be totally conveyed in this mode is limited.
2007	**transition region**	An unsteady part of the phase diagram which occurs immediately below the value of air velocity necessary to maintain dilute phase conveying. NOTE. This is not an operating region and may be characterized by a change in type of flow, often with particles forming dunes in horizontal pipelines. The capability for reliable flow at lower velocities depends upon the properties of the product to be conveyed. Some products can only be conveyed in dilute phase and will block the pipeline in the transition region.
2008	**capsule conveying**	Transporting bulk solids loaded into containers through a pipeline with gas as a motive source. NOTE. For large diameters and heavy payloads wheeled capsules coupled in trains are generally employed.

No.	Term	Definition
2009	**air slide conveying**	Fluidizing a bulk solid in a channel with a porous base and causing it to flow normally under the influence of gravity NOTE. Large particles and unit loads can be handled in enclosed ducts with directional jets.

Section 3. Material characterization terms

The characteristics of materials to be conveyed feature prominently in the decisions made at many stages in the design of a conveying system. This section includes some of the more common material properties.

No.	Term	Definition
3001	**cohesive material**	A material in which the particles tend to stick together. NOTE. Problems may be experienced with cohesive materials sticking to hopper walls and pipelines.
3002	**explosive material**	A material which in a finely divided state, when dispersed in air, will propagate flame if ignited. NOTE. There is a wide range of materials which can be classified as explosive including foodstuffs such as sugar, flour, custard powder and cocoa, synthetic materials such as plastics, chemical and pharmaceutical products, metal powders and fuels such as wood and coal. A safe system for handling such powders must be established at the design stage. This is likely to be obtained by adopting one or more of the following approaches. a) Use of inert gas as the conveying fluid. b) Use of automatic explosion suppression equipment. c) Elimination of every possible ignition source. d) Use of explosion venting (to a safe area). e) Containment of explosion pressure within the system.
3003	**damp or wet material**	A material containing a high level of particle surface moisture. NOTE. Most of the handling problems with wet materials occur in feeding them or discharging them from vessels. Fine materials which are wet will tend to coat the pipeline and bends and gradually block the line. (Lump coal having a large proportion of fines can be a particular problem in this respect)
3004	**moisture content**	The mass of water contained in a material with respect to its own mass expressed as a percentage. NOTE. Particle surface moisture content will differ from total moisture content.
3005	**electrostatic material**	A material which tends to accumulate an electrostatic charge during conveying NOTE. All conveying systems should be suitably earthed throughout their length.
3006	**abrasive (erosive) material**	A material which is hard enough (or of a shape) to cause significant wear on system components. NOTE. Erosive wear is likely to occur at all surfaces against which the particles impact. Velocity is one of the major parameters and so the problem may be significantly reduced in a low velocity system.
3007	**friable or degradable material**	A material in which the particles are easily damaged. NOTE. If degradation of the conveyed product is to be minimized, a system in which the material can be conveyed at low velocity should be considered The number and magnitude of particle impact points, particularly against bends in the pipeline, should be reduced as this is one of the mayor causes of the problem.
3008	**hygroscopic (deliquescent) material**	A material which readily takes up moisture. NOTE. For products which are hygroscopic or deliquescent it may be necessary to condition the conveying medium to avoid the introduction of moisture into the conveyed material.

No.	Term	Definition
3009	**low melting point material**	A material that softens or melts at temperatures which may be encountered in a pneumatic conveying system. NOTE. The energy from the impact of particles against bends and pipe walls at high velocity in dilute phase conveying can result in high particle temperatures being generated. The effect is localized to the small area around the point of contact on the particle surface, but can result in that part of the particle melting. The problem is accentuated if the particles slide on the pipe wall. Plastics pellets are prone to melting when conveyed in dilute phase, hi all systems including frozen products the temperature of the product and conveying gas should be considered.
3010	**toxic or hazardous material**	A material capable of causing ir\juiy or ill health, either immediately or in the long term. NOTE. If toxic materials, including radioactive materials, are to be handled, strict control of the working environment is to be maintained so that the possibility of material leakage is eliminated.
3011	**air retentive material**	A material capable of trapping air within its bulk. NOTE. Powders tend to expand and exhibit a lower bulk density when mixed with gas. Some fine powders will retain low bulk density conditions for a substantial time after the mixing gas flow ceases. Other coarse powders revert quickly to the de-aerated condition when the gas flow is no longer present. Powders which retain air tend to behave well in low velocity conveying systems. Care should be exercised in sizing equipment which will handle air retentive materials because of possible wide variations in bulk density.

Section 4. Systems

No.	Term	Definition
4001	**simple pressure system**	Pneumatic conveying operation under pressure by blowing, with discharge into a single gas and material separator which is also a material receiving vessel (see figure 2).
4002	**multi-discharge system**	Pneumatic conveying operation by blowing or suction, with discharge into several gas and material separators which are also material receiving vessels. NOTE. Figure 3 shows a multi-discharge blowing system.
4003	**simple vacuum system**	Pneumatic conveying operation under suction, with discharge into a single gas and material separator which is also a material receiving vessel (see figure 4).
4004	**multi-pick up system**	Pneumatic conveying operation under suction, with multiple feeder units, and with discharge into several gas and material separators and material receiving vessels. NOTE. Figure 5 shows a multi-pick up system
4005	**combined vacuum/pressure system**	Pneumatic conveying operation under suction with discharge into a single gas and material separator and material receiving vessel. The same unit provides a pressure system to one or several gas and material receiving vessels (see figure 6).
4006	**closed loop system**	Pneumatic conveying operation by blowing or suction, with discharge into a gas and material separator and material receiving vessel. The gas is drawn into the gas mover for recycling (see figure 7).

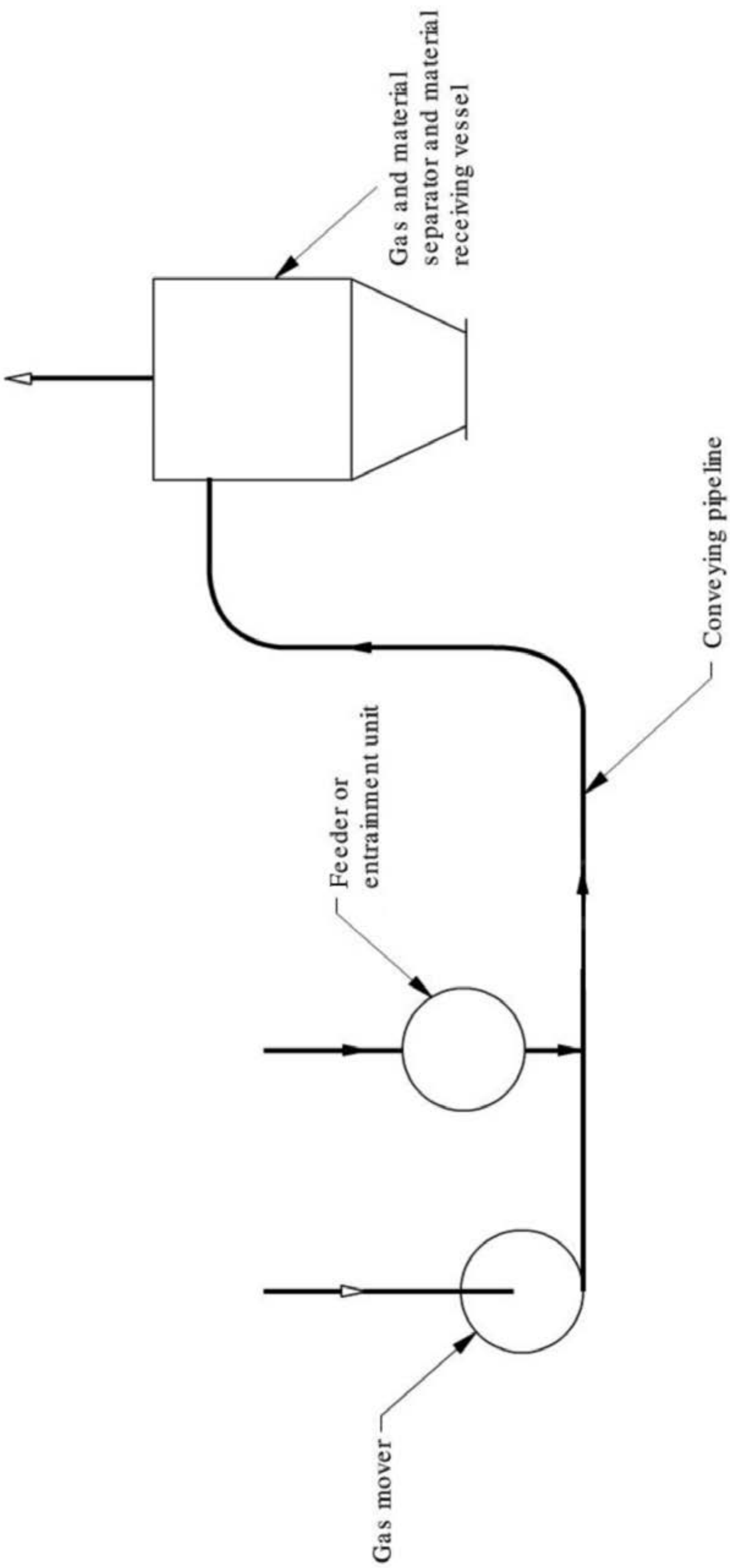


Figure 2. Simple pressure system

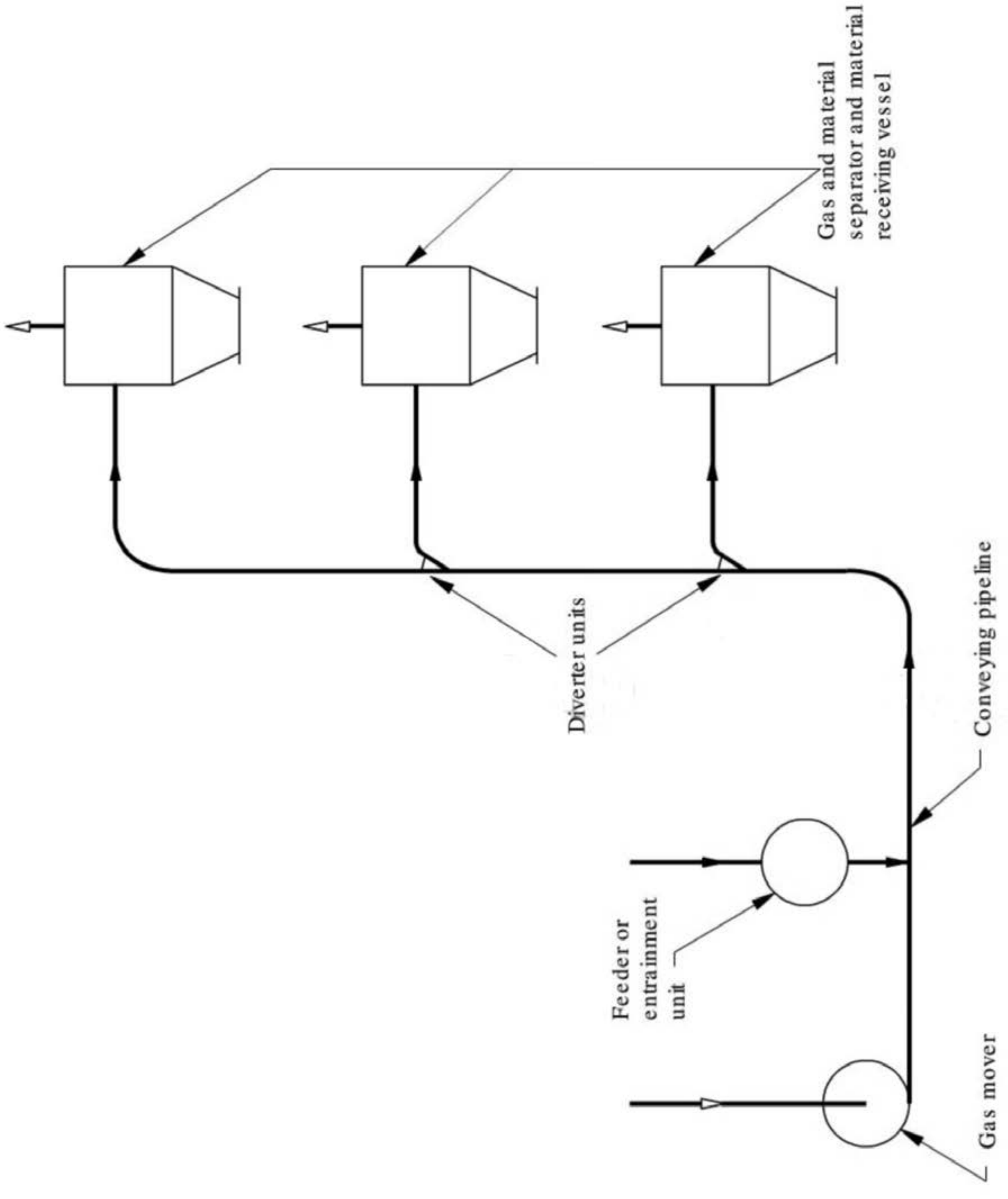


Figure 3. Multi-discharge system

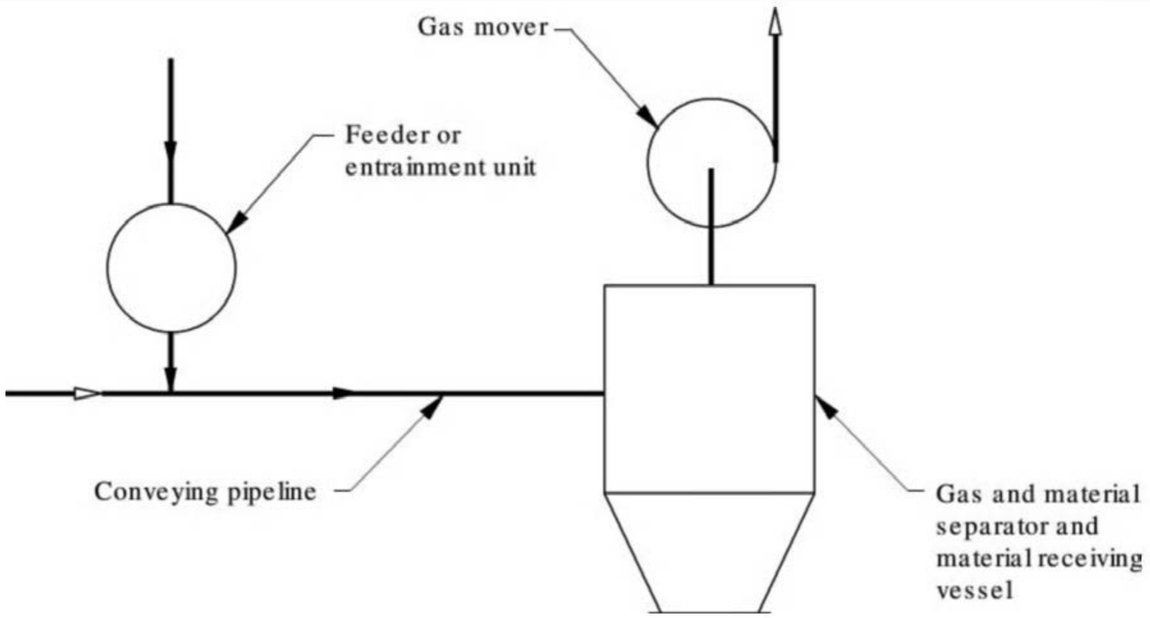


Figure 4. Simple vacuum system

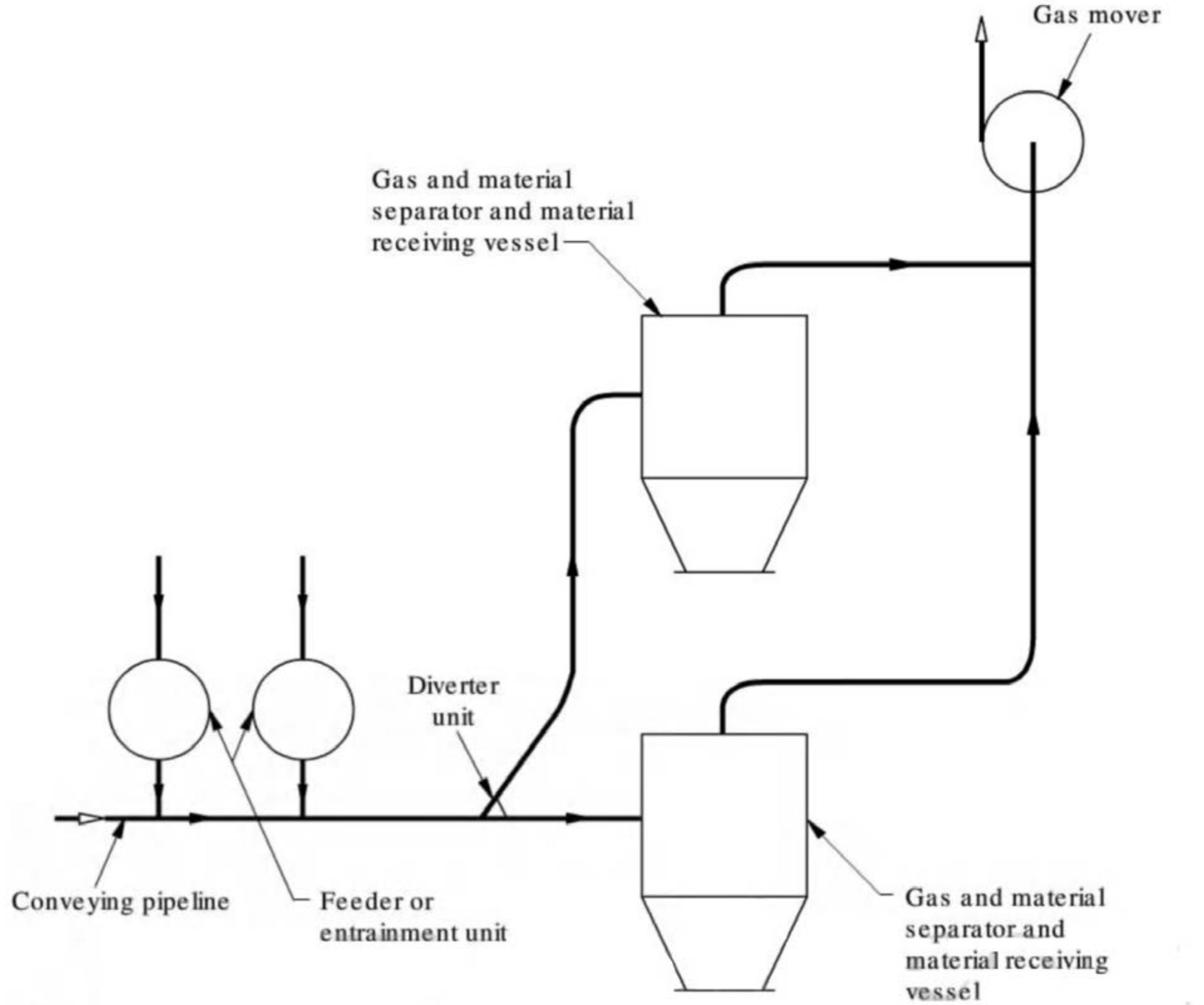


Figure 5. Multi-pick up system

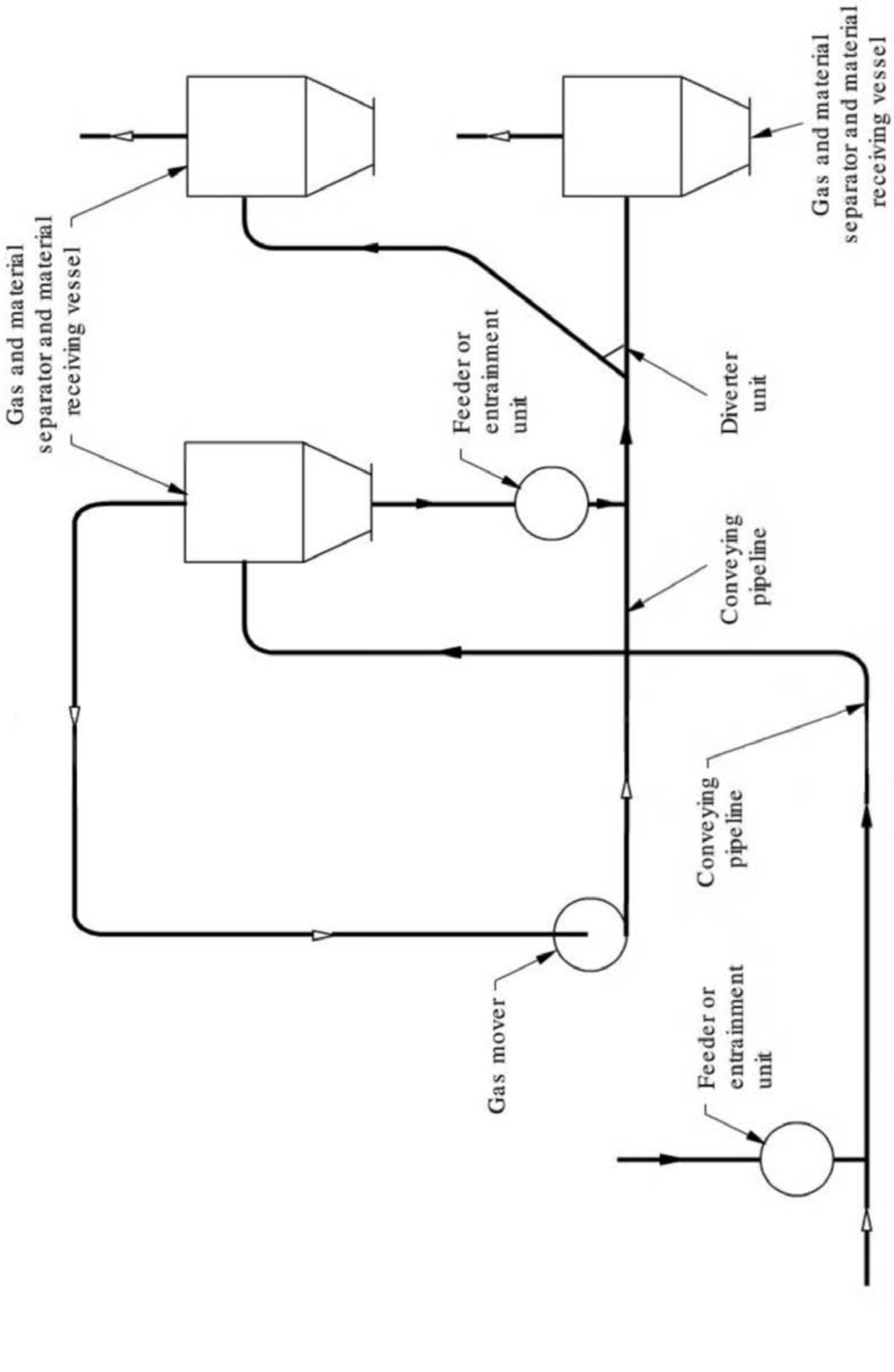


Figure 6. Combined vacuum/pressure system

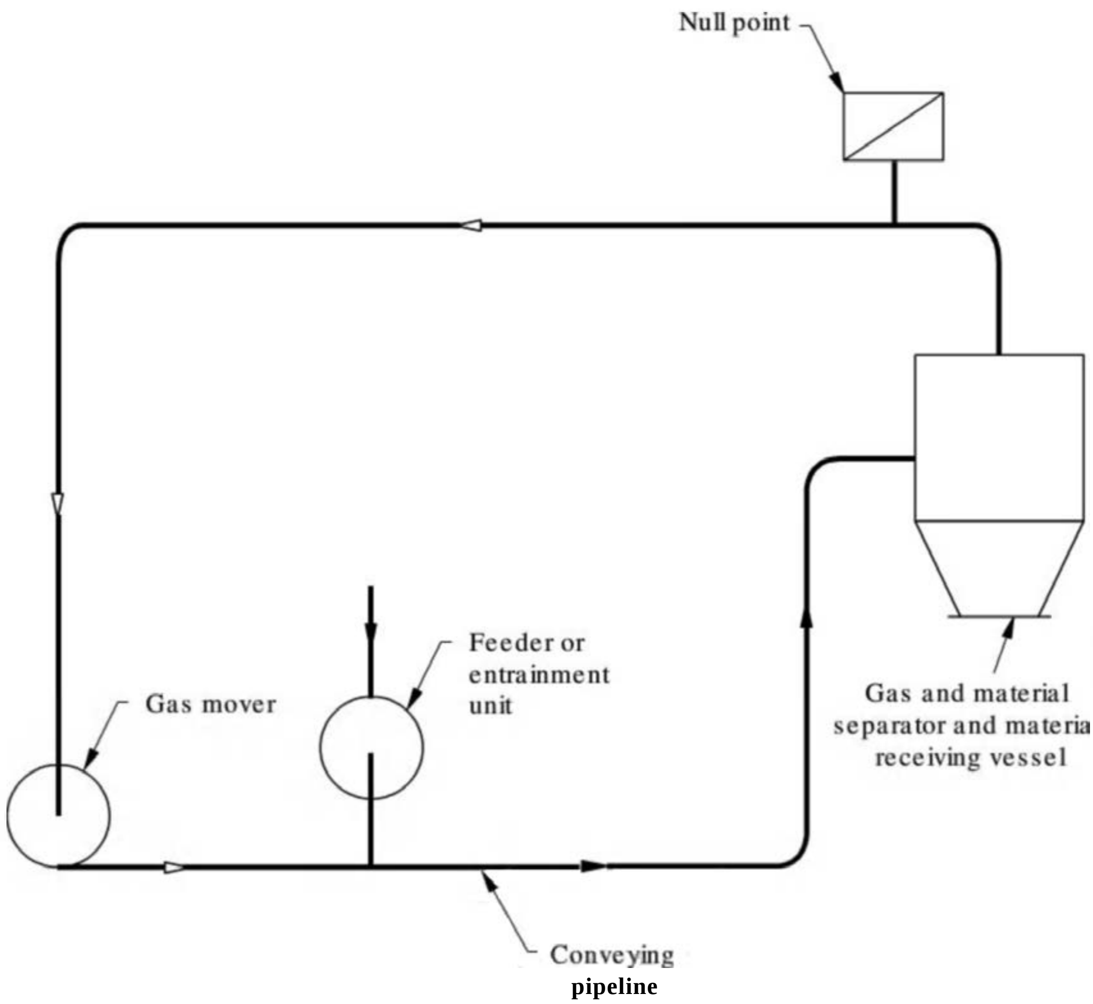


Figure 7. Closed loop-system

Annexes

Annex A (informative)

Main types of flow

For the main types of flow the capability or suitability of a particular type of flow to convey a given bulk solid depends very much upon the properties of the particular bulk solid. In some cases the influence of product properties is well documented, but for others it may be necessary to cany out tests to establish whether it is possible or suitable to use a particular mode of flow.

The phase diagram for a coarse powder in horizontal co-current flow, figure A.1, is divided broadly into two flow regions where the solids concentration is dilute or dense; there is a transition region between the two.

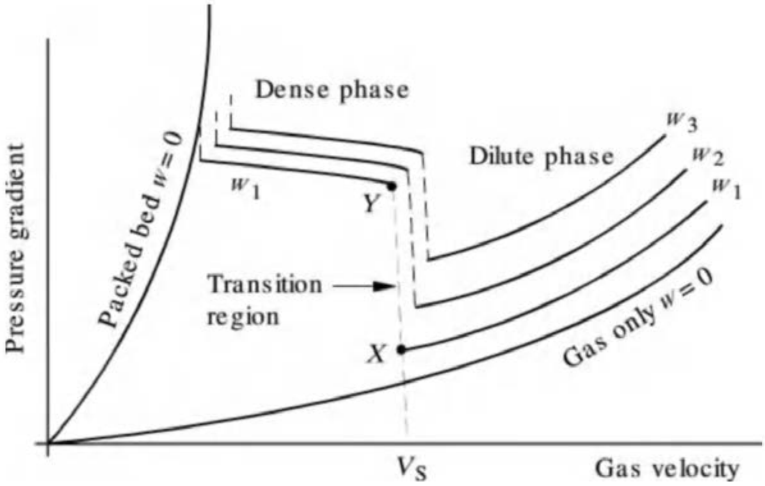
The velocities used in commercial dilute phase conveying systems need to be high enough to ensure that the conveying performance is not unduly sensitive to minor variations in solids mass flow rate or solids properties. Often this means that a range of different solids could be conveyed through a particular pipeline using the same blower system. In dense phase conveying, the solids' properties, and in particular the behaviour of the solids when fluidized, are of great importance in determining the flow characteristics and achievable phase densities. Solids/gas flow in the dense phase region will differ significantly in character from flow in the dilute phase. In general the transition region is counteractive to continuous, stable operation.

The phase diagram relates to continuous flow arising from the movement of particulate solids within a pipe by a gas which has itself been caused to move co-currently by a fan, blower or similar device. Other types of flow are possible. For a constant solids mass flow rate W_1, figure A.1 shows the pressure gradient falling with gas velocity throughout the whole of the dilute phase conveying region. At the saltation point X, particles fall out of suspension and are not re-entrained. In this simple model a layer of solids forms in the bottom of the pipe as the solids feed rate continues at W_1 and the discharge rate falls off. A transition period begins and there is an unsteady state until the pressure is high enough for equilibrium to be re-established at point Y. At this point the solids outflow will again match the solids feed W_1 but at the higher pressure level This marks the end of the transition period and the start of dense phase flow.

Successful operation at any velocity below the saltation velocity may be subject to special design provision to prevent plugging of the conveying pipe. Assuming that the necessary conditions for dense phase flow have been established then the pressure gradient will continue to increase slightly with further reduction in gas velocity and corresponding increase in phase density until a boundary condition is reached. At this boundary condition, gas will flow over and through a static or packed bed without causing movement With any further reductions in gas velocity the pressure gradient will fall progressively to zero.

The phase diagram is used only diagrammatically to illustrate flow concepts. The diagram relates to one location in a pipeline and because of compressibility effects it is possible to have different gas velocities and different flow conditions at other locations within the same pipeline.

The diagram and associated description are idealized in a number of respects. In reality it is likely that different systems would be used for dilute and dense phase conveying. Hence the implication in the description that it is possible to move from the dilute phase through a transitional region to the dense phase in the same system is not strictly accurate. Moreover in the case of some fine powders with good air retention properties, the saltation point is not clearly defined and the transition region barely exists at high solids flow rates.



W = solid mass flowrate and

$W_3 > W_2 > W_1$

V_s = superficial gas velocity at the onset of saltation, i.e. saltation velocity.

Figure A.1 Idealized phase diagram for a coarse powder in horizontal co-current flow

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