Prof. Ing. Dario Pozzetto

Department of Engineering and Architecture – University of Trieste

Via Valerio, 10 –34127 Trieste – Tel: 040.558.3805 / 7982 Fax: 040.558.3812

E-mail: pozzetto@units.it

INDUSTRIAL PLANTS

Chapter twenty-tree:

Pneumatic conveyors

DOUBLE DEGREE MASTER IN

"PRODUCTION ENGINEERING AND MANAGEMENT"

SEAT OF PORDENONE

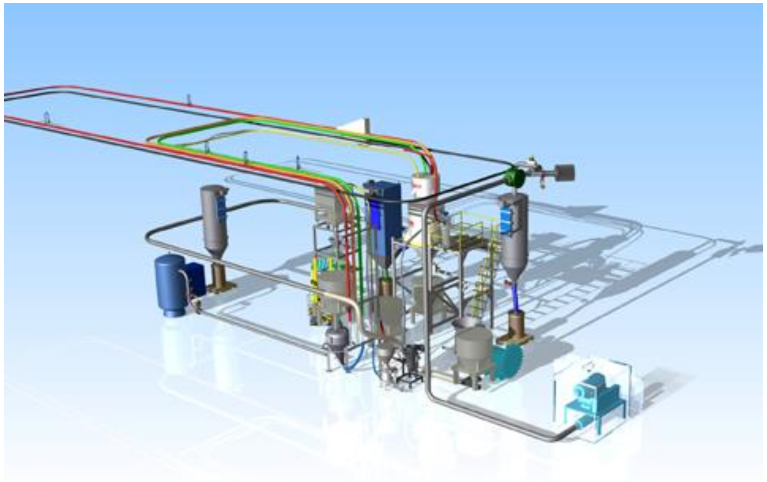
UNIVERSITY OF TRIESTE

Generality

The **pneumatic conveyors** assure the transfer of solid substances in powder or granular small size inside pipes, generally circular cross-section, according to a path, even very tortuous, by means of air current of adequate speed. Consists of the introduction of the material to be transported in the pipes traversed by a current of air suitable to push, to thin and drag it to the predetermined destination.

It can carry pneumatically: bulk materials (density between 300 and 8000 kg/m^3), cylindrical containers (pneumatic post) and gaseous products.

We refer to the pneumatic conveying of bulk materials, including many fine products or powdery or with limited sizes and not too irregular (grain, cement, wood chips, waste, plastics, chemicals, dust etc.)



Generality

The pneumatic conveying systems can be used over distances not too long (maximum to 3 km), due to the compressibility of the carrier medium, since the air expands with the pressure drop, reaching excessive speed and therefore high losses, with wear of the material and of the pipe.

The data significant of the air are:

- density: 1,2 kg/m^3 at 293 K and 1,01 bar
- viscosity: 18,1 · 10^{-6} N s/m^2
- kinematic viscosity: 15,1 · 10^{-6} m^2/s at 293 K and 1,01 bar

Generality

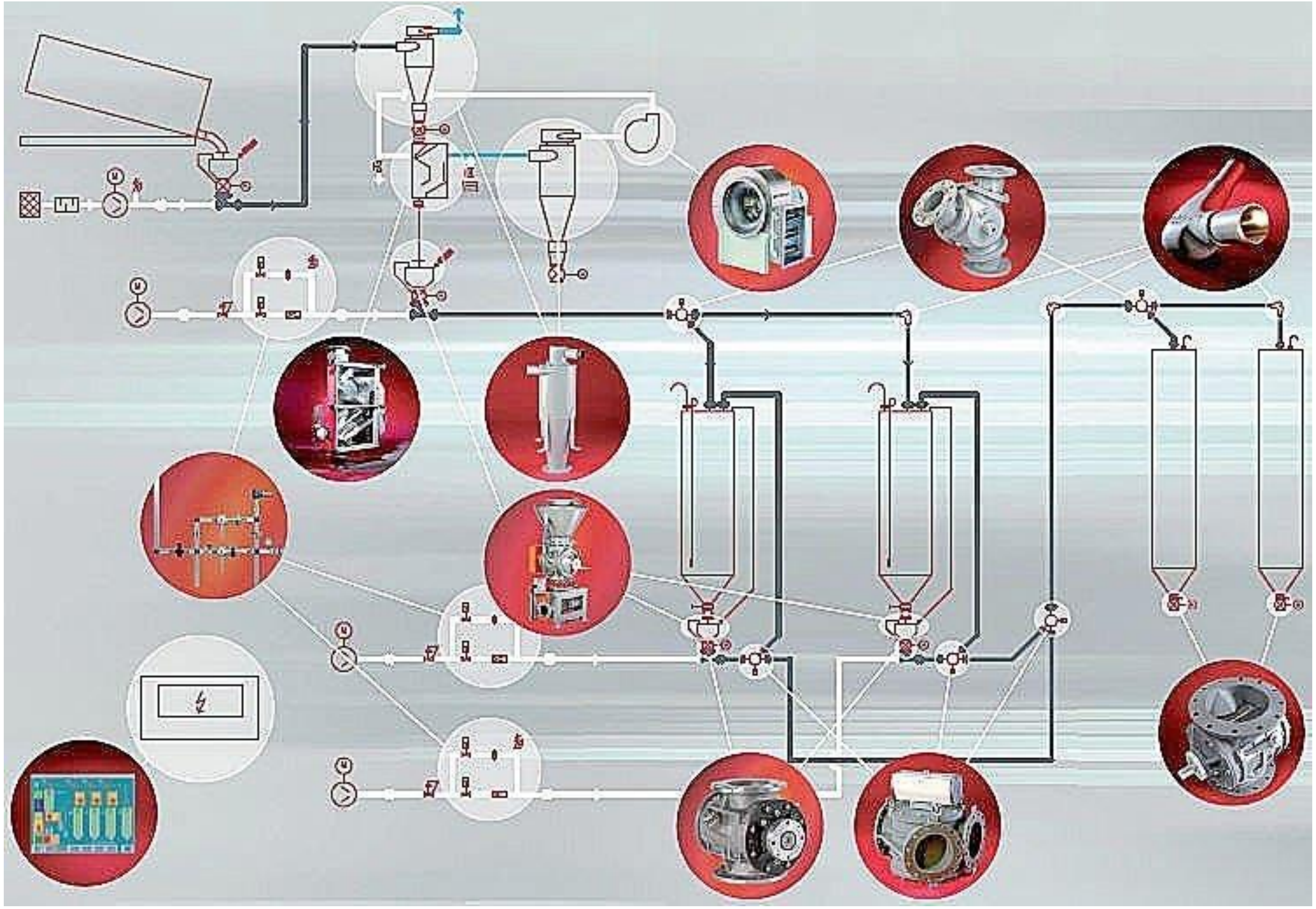
Pneumatic conveying for foundry sands

Generality

The basic components of pneumatic conveying systems are:

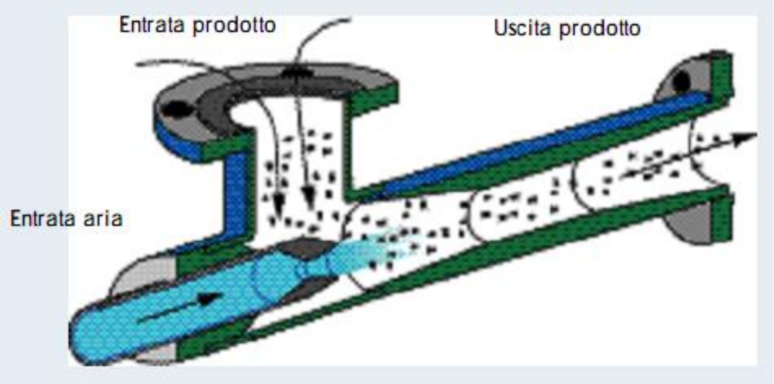
- **working machine** (centrifugal fan, compressor, pneumatic power unit etc.) that allows to overcome the load losses that are generated during operation;
- an **air filtration system**, if necessary, and **one input of the same in the circuit**;
- a **system for feeding and dosing** of the solid material in granular or powder;
- a **series of pipes** which form the transport circuit and connecting the feed point to the exhaust;
- a **silo for storage** of the material to be conveyed or transported;
- a **system of separation** of the solid material from the air of conveying;
- a **filtration system** before being expelled air.

Generality



Pneumatic conveying in dilute phase

Generality



Operating principle of an ejector

Rotary valve

Ejector

Generality

The **advantages** achieved with pneumatic conveying systems are identifiable:

- lack of mechanisms along the path;
- possibility to have tortuous and complex paths with a small footprint;
- possibility to automate the installation;
- ease of aspiration of the material from the piles even of difficult to access.

Generality

The **disadvantages** achieved with pneumatic conveying systems are identifiable:

- high energy consumption for transportation;
- formation of large agglomerates due to the presence of moisture in the solid material to be transported, up to obstruction of the passage section;
- possible damage of the material during transport especially in installations in depression-pressure in which the material is in contact with the blades of the working machine;
- impossibility in issuing the air exempt of the powders of small particle size, despite the adoption of systems of high efficiency filtration.

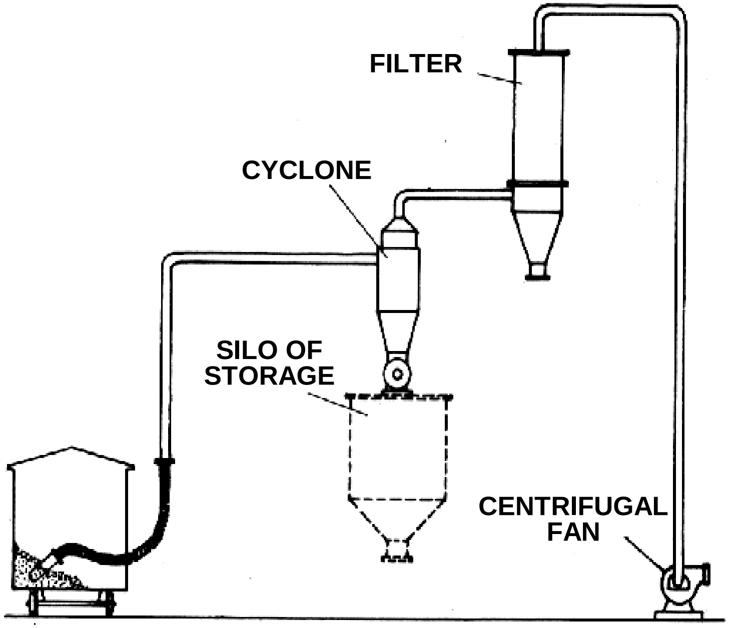
Generality

According to the production characteristics, the pneumatic conveyors are divided according to:

a) arrangement of the elements constituting the transportation:

- **plants in depression or vacuum**

  They are suitable for the transport of the material from several points (silos) to a single station (vehicle to be loaded). In this type of transport the circuit is in depression because the machine is placed at the end of the circuit.



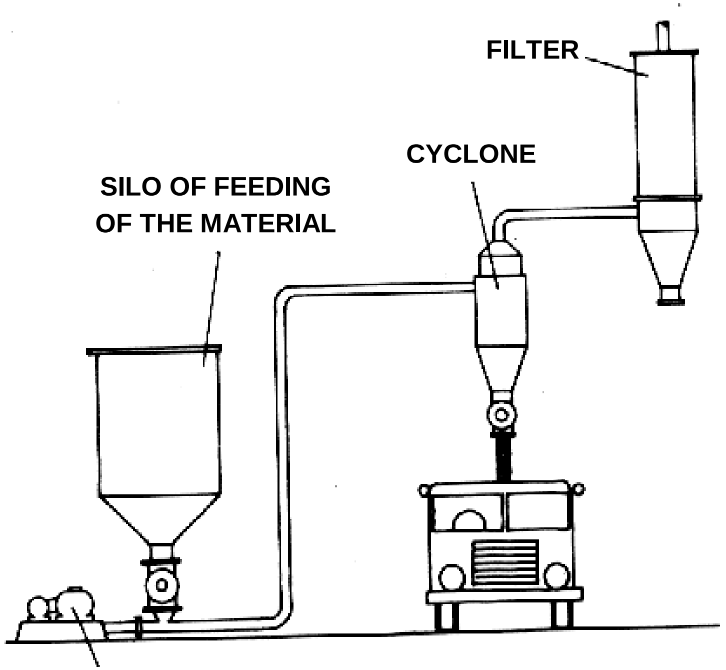
Generality

According to the production characteristics, the pneumatic conveyors are divided according to:

a) arrangement of the elements constituting the transportation:

- **plants in pressure**

  They are suitable for the transport of material from a central place (vehicle by download or storage silo) to multiple unloading stations (deposits or users).



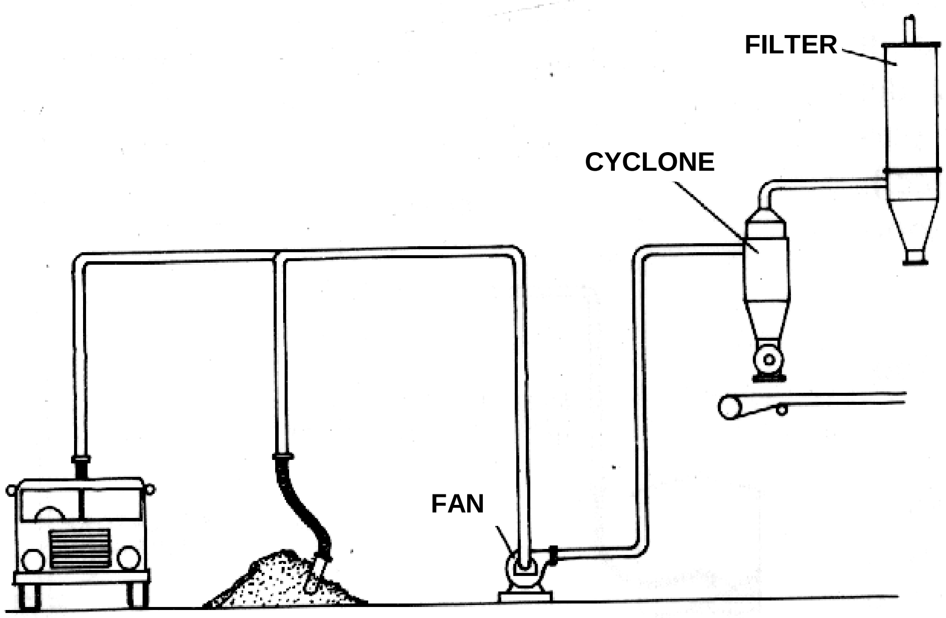
Generality

According to the production characteristics, the pneumatic conveyors are divided according to:

a) arrangement of the elements constituting the transportation:

- **plants in mixed installation**

  They are suitable for the transport of the material from several points (silos) to more unloading stations



Generality

According to the production characteristics, the pneumatic conveyors are divided according to:

b) position of the path of the pneumatic conveying

The position is of considerable importance, because depending on the direction of flow of the carrier medium and the direction of the force of gravity, will generate a series of forces that determine the flow of mixtures at more phase.

A distinction is therefore:

- vertical conveyor plants;
- horizontal conveyor plants;
- mixed conveyor plants, which are inevitable in the presence of curves.

Generality

According to the production characteristics, the pneumatic conveyors are divided according to:

c) of the level of pressure

- **plants at low pressure**

  The low pressure (0.01 - 0.3 bar) is generally obtained by means of centrifugal fans and allows you to transport the material to modest distances (less than 100 m)

- **plants at medium pressure**

  The plants at medium pressure (0.3 - 0.8 bar) are suitable for variable distances between 100 and 500 m; the pressure is obtained by centrifugal fans or rotary compressors

- **plants at high pressure**

  The plants at high pressure (over 0.8 bar) are used for the transport of materials in large distances (greater than 500 meters, up to the maximum of 1 km), the pressure is obtained by means of compressors Roots or screw, centrifugal or to piston, depending on the required flow

Generality

According to the production characteristics, the pneumatic conveyors are divided according to:

c) of the level of pressure

In other conditions being equal, the choice of the type of plant, depending on the pressure, is made taking into account the particle size and the specific weight of the materials.

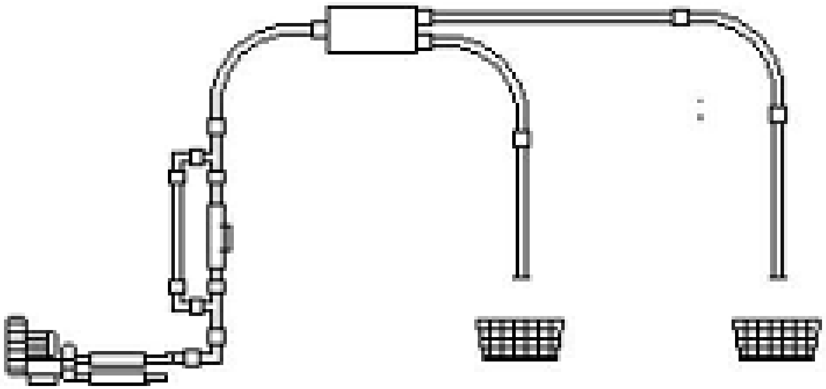
For large distances, it may provide more blowers in series, of limited prevalence, and distributed along the circuit.

Generality

According to the production characteristics, the pneumatic conveyors are divided according to:

d) of the special applications (plant of pneumatic tube)

Often used for the transport of letters, documents, money, test tubes, packages or bulk materials, which can not be transported pneumatically, are used containers calibrated, that fill the entire section of the pipe.



Generality

According to the production characteristics, the pneumatic conveyors are divided according to:

d) of the special applications (plant of pneumatic tube)

The system is composed of sending and receiving stations and intercommunicating, connected by a network of pipes. The goods is inserted in special containers that are transported within the line by a flow of air, generated by an working machine.

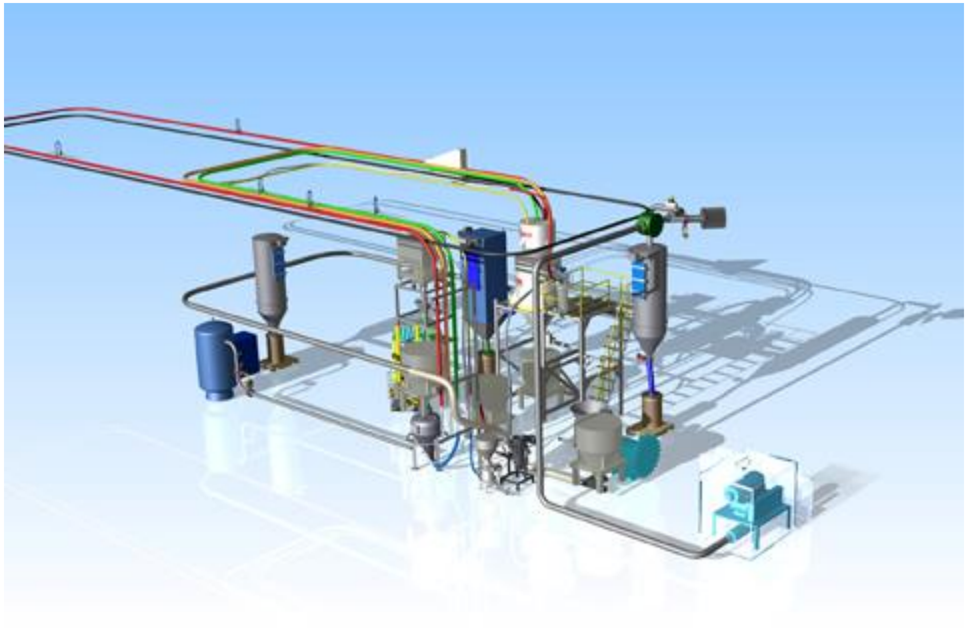
Functional characteristics

The main factors that influence the potentiality of transport are due to technical and economic requirements and design, such:

- physical properties of the material to be transported (type, size, density, air permeability and retention etc.;
- points and systems for loading and unloading of the transported material;
- type of functioning (continuous or discontinuous);
- development horizontal and vertical of the transport circuit;
- nominal diameter of the conveying line;
- difference in pressure between the suction and discharge of the material;
- mode of transport in the circuit.

Functional characteristics

To be able to carry a solid material into a pneumatic conveyor, the driving forces of the carrier fluid acting on the solid particles must be of the same order of magnitude of the forces seeking to retain them. It is to overcome the weight, friction and inertia of the solid particles, but the trend of the forces depends on the position of the conveying line.



Functional characteristics

a) transport in vertical

In this case the driving forces of the flow of carrier medium, such as:

- the flow resistance W defined by the relation:

$$W = c_w \cdot A_s \cdot \frac{\rho_f}{2} \cdot (v - c)$$

with:

c_w = coefficient of resistance, depending on the number of critical Reynolds;

A_s = cross section area of the body wrapped in the flow perpendicular to the direction of the current;

ρ_f = density of carrier fluid;

v-c = relative velocity between carrier fluid and that of the solid material.

Functional characteristics

a) transport in vertical

In this case the driving forces of the flow of carrier medium, such as:

- the pressing force on the solid particles defined by:

$$V_s \cdot \frac{dp}{dl}$$

with:

V_s = volume of the solid particle;

dp/dl = pressure gradient in the axial direction.

Functional characteristics

a) transport in vertical

In this case the driving forces of the flow of carrier medium, such as:

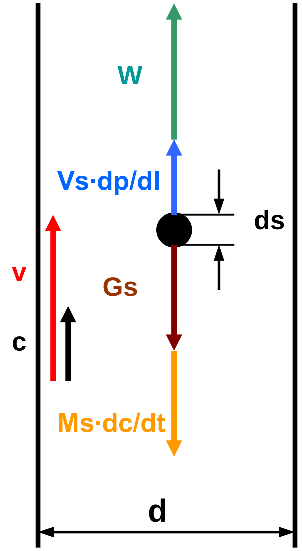
The two forces must be opposite and equal to the weight of the solid particles G_s and to the force of inertia of the solid particles defined by:

$$M_s \cdot \frac{dc}{dt}$$

with:

M_s = volume of the solid particle;

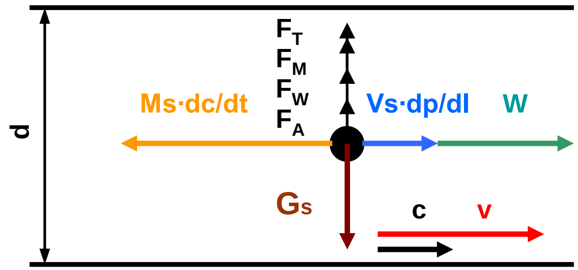
dc/dt = acceleration of the solid.



b) transport in horizontal

While in the vertical transport is observed a balance axial forces, in the case of horizontal transport must be considered the balance of the axial forces and possibly that of the transverse forces.

In the axial direction, with the horizontal transport there must be a balance between the drive components of the flow force (resistance to flow of solid particles W and the pressing force of the particles Vs · dp/dl and the force of inertia of the particles Ms · dc/dt, which considers the friction of solid particles).



b) transport in horizontal

Transversely to the direction of flow to guarantee the transport in suspension, there must be a balance between the weight of particles G_S and the components of the forces that are bearing the compressive force due to the pressure gradient transverse F_A defined by the relation:

$$F_A = V_S \cdot \frac{dp}{dy}$$

that in the pneumatic transport is negligible and that constitutes the thrust of Archimedes. In the vicinity of the is wall occur of the cutting forces F_W which are conditioned by the influx asymmetric profile of the speed and rotation superimposed on the particles. They are of the order of 10-20% of the weight of the particles.

The cutting force due to the rotation of the particles F_M (force of Magnus) can occur at areas that are very distant from the wall. Finally the 40-50% of the weight of the particles are supported by the transverse forces F_T, which are influenced by the turbulence of the fluid.

Functional characteristics

The state of transport, which may have in different conditions, can take different forms and depends on the physical properties of the material to be transported, the carrier medium and the type of conveying line, the quantities of the two media used in transport and the geometry of the transport circuit (diameter, length etc.).

Functional characteristics

As for the states of vertical pneumatic conveying, five configurations can be considered:

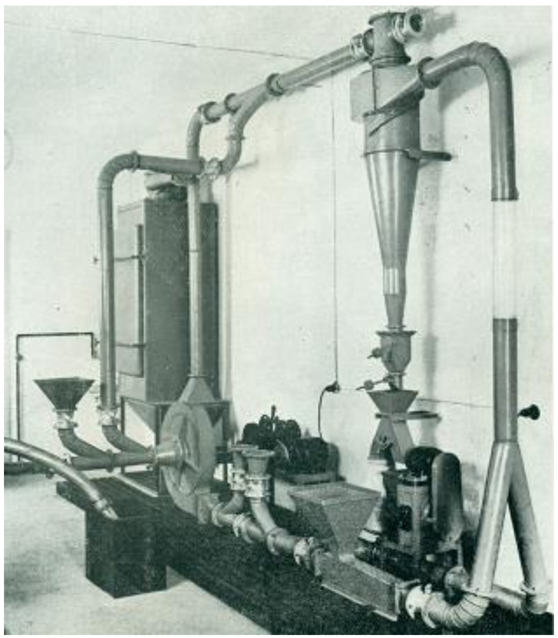
1) transport a flight

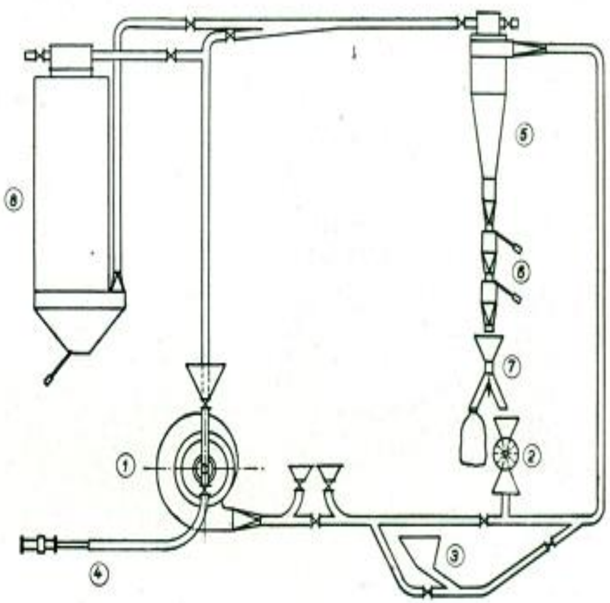
Is the characteristic transport with the speed of the mean load-bearing much greater than the speed of fall of the individual grains and with reduced percentage of the solid, such that the mixture ratio $\mu \leq 10$. In this case the solid particles are sufficiently spaced apart so that not is disturb each other. The turbulence of the current is so high as to allow to distribute any type of particle in the cross section in a uniform manner. The flow can be regarded as almost stationary (a).

Functional characteristics

As for the states of vertical pneumatic conveying, five configurations can be considered:

1) transport a flight





Experimental facility for pneumatic transport

1 - centrifugal fan, 2 - rotary charger, 3 - hopper at induction , 4 - sucking head of suction , 5 - cyclone separator, 6 - discharger to balance, 7 - hopper for collecting and discharging two-way, 8 - bag filter

Functional characteristics

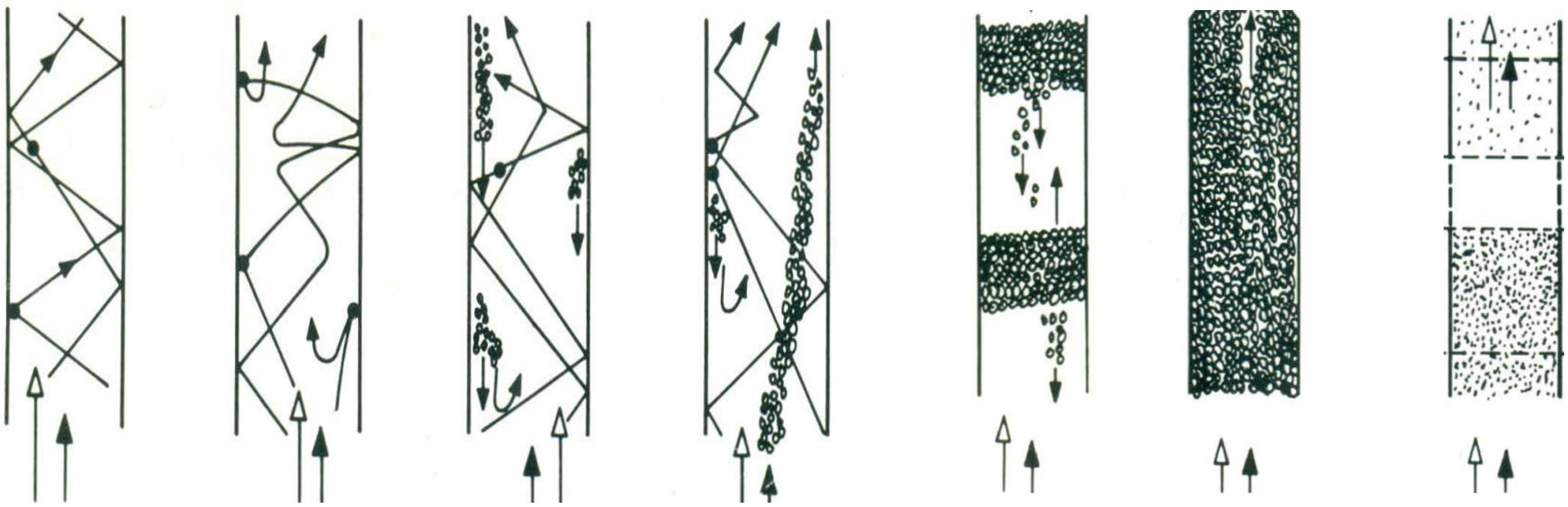
As for the states of vertical pneumatic conveying, five configurations can be considered:

1) transport a flight

With lower velocity of the current with a ratio of mixture increasing (μ<30), the particles are transported regularly by the forces of flow in the central current, but in the vicinity of the wall is has a suspension or a fall of the solid particles, but not group together and for the most part are entered in the central current and are transported upwards. It has a homogeneous distribution of the particles (b).

Functional characteristics

As for the states of vertical pneumatic conveying, five configurations can be considered:



(a) (b) (c) (d) (e) (f) (g)

Functional characteristics

As for the states of vertical pneumatic conveying, five configurations can be considered:

2) transport a balls and transport a rivulets

If the speed of flow of the carrier medium is reduced, approaching that of the fall of the single particle W_{SO} and if the ratios of mixture (by volume or amount of lost air required to carry the unit of solid material by volume or by weight) are next to 30, the solid particles overlap and influence in the behavior of resistance (admixture and transport is defined as "balls"). In this case, the solid can be transported in the average of the time towards the other, since the agglomerations are dissolved and the solid particles are transported individually, even if the behavior results in stationary (c).

While the transport to balls occurs vertically with large particles, in the same conditions as the fine particles tend to agglomerate into a rivulet (d).

Functional characteristics

As for the states of vertical pneumatic conveying, five configurations can be considered:

3) transport a tampons

When the speed of the mean load-bearing is lower than that of fall of individual particles, they are formed of the agglomerations to tampon between the solid particles. Provided there is sufficient pressure for the transport, the swabs are transported integers. The transport is stationary (e) and the mixture ratio is greater than 30.

With this type of transport, the static pressure assumes a significant part in driving force.

Functional characteristics

As for the states of vertical pneumatic conveying, five configurations can be considered:

4) transport at thrust

If the entire pipe is full of solid material to coarse-grained and with piping straight and short, it has a transport at small speeds.

Not to go to the state "a tampon", when the means load-bearing in the passage through the pile breaks down, at the end of the piping should be applied to a diaphragm to increase the resistance.

The solid material is transported, compacted and agglomerated with no internal motion of the particles. The blend ratio is much greater than at 30 (f).

Functional characteristics

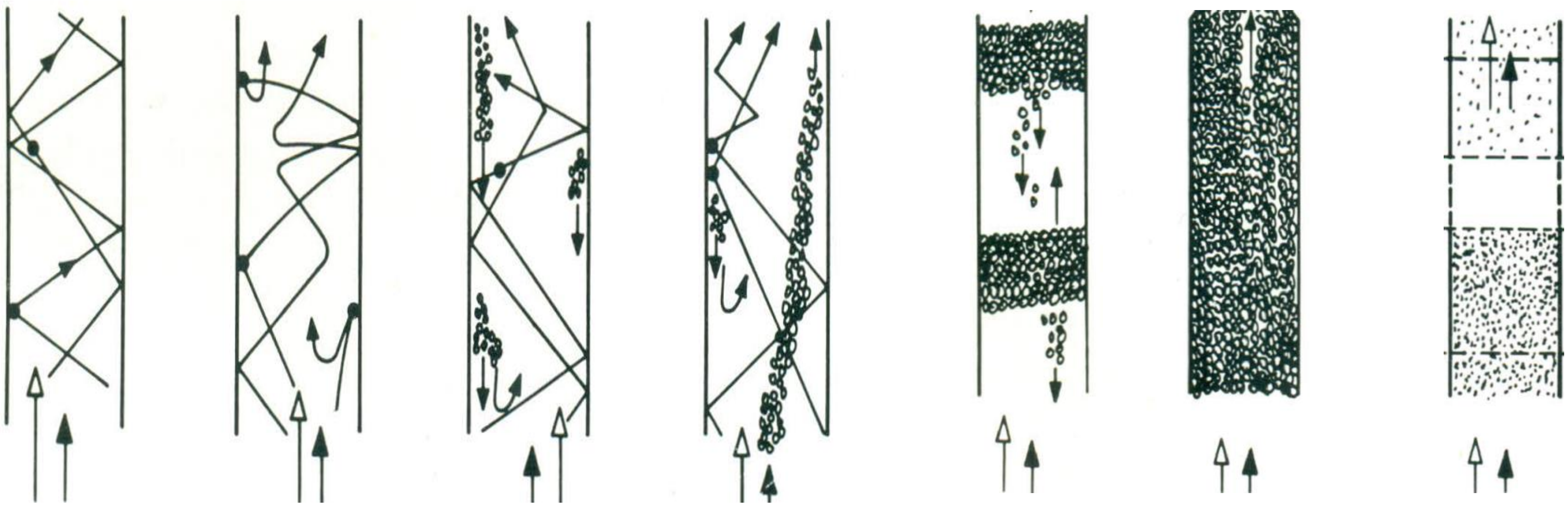
As for the states of vertical pneumatic conveying, five configurations can be considered:

5) transport at flow

Is the transport of a fluidized solid material, which behaves like a liquid. The mean load-bearing at high pressure, obtained in a tank in pressure, flows on the solid material in a turbulent stage that allows for the carriage. Is a transport almost stationary with mixing ratios much higher than 30 (g).

Functional characteristics

As for the states of vertical pneumatic conveying, five configurations can be considered:



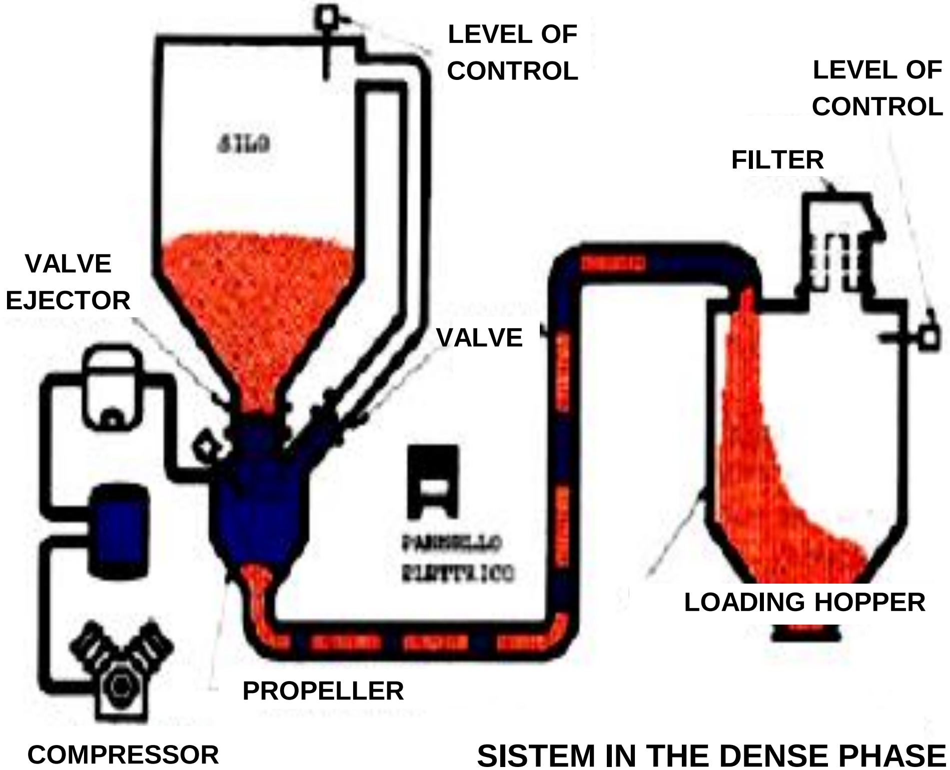
(a) (b) (c) (d) (e) (f) (g)

Functional characteristics

Pneumatic conveyor to push
Propeller with the pipe of departure and a part of the supply circuit

Functional characteristics

These types of transport are carried out with the plants to thrust constituted by a feed hopper, a propeller, a silo of arrival with a filter for the cleaning of the air exhausted and by a series of pipes.



SISTEM IN THE DENSE PHASE

Functional characteristics

With regard to the states of the horizontal pneumatic transport, in which the weight force of the material is manifested by effect of admixture when the speed of the carrier medium decreases, can be considered six configurations:

1) trasport a flight

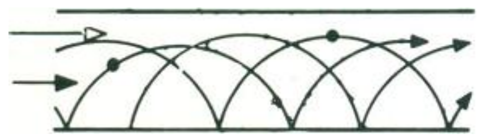
Is characteristic of a homogeneous distribution of the material in the cross section and with mixing ratios of less than 10, with very fine particles that may be transported in homogeneous suspension (transport in suspension) (a).

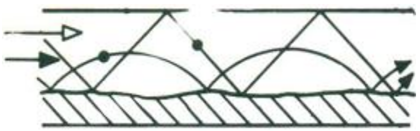
To a decrease in the speed of the carrier medium is manifested a admixture. The collisions of the particles do not occur uniformly on the whole section of the pipe, but are frequent in the lower part. With mixing ratios of less than 30 there is the transport to jump, with heterogeneous distribution of the solid material and the concentration of the solid is asymmetric with respect to the profiles of speed of the mean load-bearing and of the solid material (b).

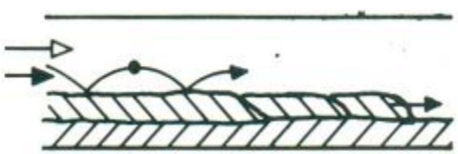
Functional characteristics

With regard to the states of the horizontal pneumatic transport, in which the weight force of the material is manifested by effect of admixture when the speed of the carrier medium decreases, can be considered six configurations:

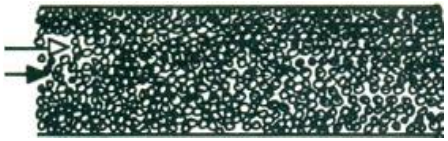

(a)


(b)


(c)


(d)


(e)


(f)

(g)

Functional characteristics

With regard to the states of the horizontal pneumatic transport, in which the weight force of the material is manifested by effect of dismiscela when the speed of the carrier medium decreases, can be considered six configurations:

2) transport a rivulets

If the speed of the carrier medium is slightly higher than that of a fall of the single particle and if the transmission ratio is close to 30 the finer particles are deposited in rivulets on the bottom (c). It is a state of transport with strong admixture and quasi-steady.

Functional characteristics

With regard to the states of the horizontal pneumatic transport, in which the weight force of the material is manifested by effect of dismiscela when the speed of the carrier medium decreases, can be considered six configurations:

3) transport a dunes with fixed deposits

If the speed of the means load-bearing is close to that of a fall, is can form of fixed deposits, so that the bottom can move in the form of rivulets or dunes. It is can have that in the upper part of the pipe there is a transport in suspension or to jump. The state of transportation, it is stationary and can cause of blockages, if the pressure is not sufficient (d)

Functional characteristics

With regard to the states of the horizontal pneumatic transport, in which the weight force of the material is manifested by effect of dismiscela when the speed of the carrier medium decreases, can be considered six configurations:

4) transport a tampons

Reducing the speed of the mean load-bearing (although less than that of fall) and increases of the mixture ratio, and if there is sufficient pressure, the solid particles can be pushed forward “a tampon” (e). It is a state of non-stationary transport

Functional characteristics

With regard to the states of the horizontal pneumatic transport, in which the weight force of the material is manifested by effect of dismiscela when the speed of the carrier medium decreases, can be considered six configurations:

5) transport at push

Is characterized by the fact that during transport the entire pipe is filled with solid material (f), similarly to what reported for the pneumatic transport vertical

Functional characteristics

With regard to the states of the horizontal pneumatic transport, in which the weight force of the material is manifested by effect of dismiscela when the speed of the carrier medium decreases, can be considered six configurations:

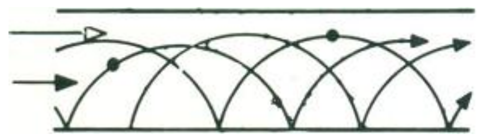
6) trasport at flow

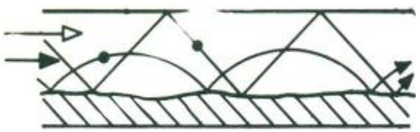
Is realized with very fine particles that can be thin, but is characterized as the vertical pneumatic transport (g)

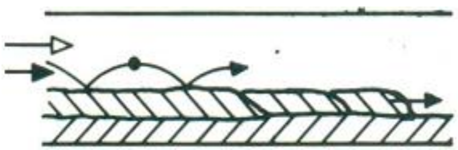
Functional characteristics

With regard to the states of the horizontal pneumatic transport, in which the weight force of the material is manifested by effect of admixture when the speed of the carrier medium decreases, can be considered six configurations:

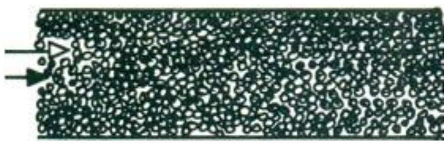

(a)


(b)


(c)


(d)


(e)


(f)

(g)

Functional characteristics

For the preliminary design of pneumatic plants should be established:

a) the type of plant more suitable for the transport;

b) the speed of the mean load-bearing along the piping of transport, which allows to support and move the solid material;

c) the ratio of mass or volume between the solid material and the fluid load-bearing.

The ratio of mass μ dimensionless is defined by the ratio of the mass flow of the material to be transported G_m and the mass flow of fluid load-bearing (air conveyorized) G_a:

$$\mu = \frac{G_m}{G_a} = \frac{\gamma_m \cdot V}{\gamma_a \cdot A}$$

where:

γ_m = specific weight of the solid material to be transported;

γ_a = specific weight of the mean load-bearing;

V = volume of material to be transported;

A = volume of the mean load-bearing.

Functional characteristics

Another important aspect ratio is the ratio between the volumetric flow of the solid material Q_m and that of the flow load-bearing Q_a:

$$R_v = \frac{Q_m}{Q_a}$$

The ratio R_v allows to see that along the pipe the density of air is not constant along the entire circuit, is decreasing from the inlet section to that of outlet, while the mass ratio μ is constant along the whole path in the case of stationary motion.