**Introduction to** **Pneumatic Conveying System**

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**Abstract**

Pneumatic conveying is a material transportation process, in which bulk particulate materials are moved over horizontal and vertical distances within a piping system with the help of a compressed air stream. Pneumatic conveying is a very practical method for in-plant distribution of large amounts of dry powdered, granular, and pelletized materials. Using either positive or negative pressure of air or other gases, the material to be transported is forced through pipes and finally separated from the carrier gas and deposited at the desired destination.

The main advantage of pneumatic conveying system is that material is transferred in close loop, thereby preventing the environmental effect on the material and vice versa. No standard procedure is available for the design of pneumatic conveying system. As the configuration of the system changes, variable involved also changes, and one has to change the design considerations based on the applications. So there is wide scope for experimentation and analysis in the field of pneumatic conveying system.

**Introduction**

A pneumatic conveying system is a process by which bulk materials of almost any type are transferred or injected using a gas flow as the conveying medium from one or more sources to one or more destinations. Air is the most commonly used gas, but may not be selected for use with reactive materials and/or where there is a threat of dust explosions.

A well designed pneumatic conveying system is often a more practical and economical method of transporting materials from one point to another than alternative mechanical systems (belt conveyors, screw conveyors, vibrating conveyors, drag conveyors and other methodologies) because of three key reasons:

1. Pneumatic systems are relatively economical to install and operate

2. Pneumatic systems are totally enclosed and if required can operate entirely without moving parts coming into contact with the conveyed material. Being enclosed these are relatively clean, more environmentally acceptable and simple to maintain

3. They are flexible in terms of rerouting and expansion. A pneumatic system can convey a product at any place a pipe line can run.

**Advantages of a pneumatic**

**Conveying system (over a mechanical conveying system)**

A conventional mechanical conveying system runs in a straight line, with minimal directional changes, and each directional change typically requires its own motor and drive. The mechanical conveying system may be open rather than enclosed, potentially generating dust. It also has a relatively large number of moving parts, which usually require frequent maintenance. The system also tends to take up a lot of valuable real estate in a plant.

On the other hand, a pneumatic conveying system uses a simple, small-diameter pipeline to transfer material. The pipeline can be arranged with bends to fit around existing equipment, giving the system more layout flexibility, and the system also has a relatively small footprint. The system is totally enclosed and typically has few moving parts.

**Disadvantages of a pneumatic conveying system (over mechanical conveying system)**

* A pneumatic conveying system typically requires for more horsepower to operate than an equivalently sized mechanical conveying system.
* A pneumatic conveying system also requires a larger dust collection system than a mechanical conveying system.

**Types of Pneumatic Conveying**

There are several methods of transporting materials using pneumatic conveying. In general, they seem to fall into three main categories: dilute phase, dense phase, and air conveying.

1. Dilute-phase conveying is the process of pushing or pulling air-suspended materials from one location to another by maintaining a sufficient airstream velocity. Dilute phase conveying is essentially a continuous process, characterized by high velocity, low pressure and low product to air ratio.

2. Dense-phase conveying relies on a pulse of air to force a slug of material from one location to another. Dense-phase system is essentially a batch process, characterized by low velocity, high pressure and high product to air ratio unlike dilute phase which is a low product to air ratio.

3. Air-activated gravity conveying is a means of moving product along a conveyor on a cushion of air.

**Dilute-phase conveying**

This process uses a relatively large amount of air to convey a relatively small amount of material and at lower pressures than dense phase systems. The material is transported at high velocities through the system while being suspended in air.

It is often referred to as suspension flow because the particles are held in suspension in the air as they are blown or sucked through the pipeline. To keep the material in suspension, it is necessary to maintain a minimum conveying air velocity that, for most materials, is of the order of 2500 – 6000 fpm.



Dilute-Phase - (Suspension Flow)

There is virtually no limit to the range of materials that can be conveyed with dilute – phase system. Products commonly conveyed in dilute phase systems include flour, resins, specialty chemicals, ground feeds, and granular and palletized products. Of the various types of pneumatic systems, a dilute phase system will generally be lowest in capital cost.

**Types of dilute – phase systems**

The dilute-phase system can be designed in three ways:

1. Positive pressure system

2. Negative pressure or vacuum system

3. Combination of positive – negative system

**Positive pressure system – Dilute phase**

Positive pressure systems operate above atmospheric pressure and are used to convey bulk materials from a single or multiple sources to one or multiple destinations, over medium distances and with greater capacity than possible using vacuum systems. A typical positive pressure dilute phase system will consist of a rotary valve; pipe-work which would include long radius reinforced bends; a filter receiver or cyclone/filter arrangement; and positive displacement (roots type) air blowers.

For dilute phase conveying, higher materials loading ratio that can be achieved:

• If the conveying distance is short,

• If the conveying line pressure drop is low, or

• If a low value of conveying air velocity enough to prevent saltation.

If the air pressure is low or if the pipeline is very long, then the value of materials loading ratio will be very much lower.

**Negative pressure system– Dilute phase**

Negative pressure conveying systems are those that operate with air pressures below atmospheric pressure

Negative pressure systems generally use positive displacement (roots type) exhausters providing up to 50% vacuum to convey materials through a pipeline to the destination where the air and product are separated at a receiving vessel with a filter, or a cyclone.

The product enters the convey line directly, or if metering is required, via a special feeding device such as a rotary valve or screw feeder. The conveyed product is discharged from the receiving vessel either on a continuous basis by a rotary airlock or intermittently by valves to surge hoppers, storage vessels or other discharge points.

In vacuum conveying, no moving parts contact the materials and no dust can escape into the atmosphere. Because of this superior leak containment, they are often specified on the basis of cleanliness, particularly when handling hazardous materials.

Applications :-Vacuum conveying systems are particularly suitable for systems which convey materials at low to moderate capacities over medium distances, from multiple points to a single destination. These systems are versatile and adaptable for different materials and the low operating pressures allow lower cost pipelines and fittings. This method is frequently used for central vacuum cleaning systems and other applications, which require a reticulated network of vacuum pipes to convey product to a single collection point.

**Material velocity**

In dilute phase conveying, with particles in suspension in the air, the mechanism of conveying is one of drag force. The velocity of the particles, therefore, will be lower than that of the conveying air. It is a difficult and complex process to measure material velocity, and apart from research purposes, particle velocity is rarely measured. It is generally only the velocity of the air that is ever referred to in pneumatic conveying.

1. In a horizontal pipeline the velocity of the particles will typically be about 80% of that of the air. This is usually expressed in terms of a slip ratio, defined in terms of the velocity of the particles divided by the velocity of the air transporting the particles, and in this case it would be 0.8.

2. In vertically upward flow in a pipeline a typical value of the slip ratio will be about 0.7.

These values relate to steady flow conditions in pipelines remote from the point at which the material is fed into the pipeline, bends in the pipeline and other possible flow disturbances. At the point at which the material is fed into the pipeline, the material will essentially have zero velocity. In order for material to accelerate to conveying velocities, an initial section of straight piping is necessary.

Sufficient velocities must be maintained throughout the conveying system to avoid material settling. When settling occurs in the horizontal plane, it is known as saltation. When settling occurs in the vertical plane, it is called choking.

Saltation is the process of deposition of solid particles along a horizontal pipeline. This phenomenon occurs when the air velocity falls below the minimum conveying value.

Choking in downward movement often occurs in the vertical line as a direct result of saltation in the adjacent horizontal line. Upward movement is often easier to control because all that is needed is sufficient momentum (velocity) to keep the material in suspension

**System Pressure Drop**

The performance of a pneumatic conveying system, in terms of achieving a given material flow rate, depends essentially on the system resistance. Higher the system resistance, higher will be the pressure drop in the system or higher will be the static pressure of the fan.

We have discussed before that the pressure drop in pneumatic system is proportional to:



where

• Δp is the pressure drop

• L, the length of straight pipeline

• ρ, the air density

• v, the conveying air velocity

• d, the pipeline bore

**Conveying Distance**

Conveying pressure is directly proportional to conveying distance and inversely proportional to conveying distance. Conveying distance has a very significant influence on pneumatic conveying system performance. Higher conveying distance signify higher pressure drop. Assume, for example, that a system is capable of conveying 100 tons/hr over a distance of 300 ft with a pressure drop of 30 psi. If the distance is doubled, and there is no change in pressure, the material flow rate will be reduced by at least half, to a maximum of 50 tons/hr, if there is no change in pipeline bore. With a halving of material flow rate and no change in air flow rate, the solids loading ratio will also be halved and the specific power consumption will increase.

**Components of dilute – phase system**

Major pneumatic system components include:

1. Pressure blowers and vacuum pumps with integral sound enclosures

2. Rotary airlock valves

3. Transfer line including piping, elbows; divert valves (flex-tube diverters, wyes-diverters, plug diverters and other line diverter configurations).

4. Filter receivers

5. Cyclone separators

6. Dust collectors and bin vents

7. Controls and electrical equipment

**Fan selection considerations for material handling**

The fan / blower is the heart of the dilute phase pneumatic conveying system. If the material does not come in contact with the fan, backwardly inclined fan will be a good choice. If the material being conveyed will be going through the fan, special considerations must be given to the fan design. The fan blade type selection is very important because one does not want to select a blade type that is prone to collecting material. Backward curved and airfoil blades are efficient, but they often collect material on the blades. Radial blades are better suited for material handling applications.

Fan speed is also important. The operating speed should be minimized as much as possible. High-speed fans with high tip speeds create higher velocities that correspond directly to the level of erosion and impact on the fan and system components. The fan should be selected with the critical speed significantly higher than the operating speed. Good engineering practice dictates that for material handling fans, the critical speed shall be at least 1.5 times greater than the operating speed.

**Material Intake Methods**:

1. Gravity Feed

A hood or hopper can be used for dry, free-flowing materials. A venturi feeder can be used to introduce material into the airstream. Like the hood, it has no moving parts so there is virtually no maintenance. However, the design of the venturi must be tailored to each application and even the best ones can be rather easily blocked if system conditions vary. Typical throat velocities are 2 to 3 times the velocity in the main duct.

1. Mechanical Feed

The most common feeder used in pneumatic conveying is the rotary valve, which is also known as a rotary feeder, star feeder, rotary seal, rotary airlock or cellular wheel.

**Material discharge methods**

Material typically exits via filter receivers or cyclone separators. Positive pressure systems can additionally employ fill/pass valves to discharge material from the system at one use point, or redirect the material to another use point.

* Filter Receivers- Filter receivers separate solids from the air stream using filter media and gravity.
* Cyclone Separators- Cyclones operate by generating a vortex of particulate laden air. Centrifugal force pushes the particulates toward the outer cyclone wall where they lose velocity and spiral downward to the discharge.
* Fill/Pass Valves- Fill/pass valves are commonly used to discharge material directly into individual or multiple process vessels and/or to deliver it to several destinations along a common conveying line.
* Directly Into Process Vessels- Both pressure and vacuum systems can feed material directly into blenders, reactors and other enclosed process vessels that are vented to a downstream bag house or other dust collection device, eliminating the need for individual filter receivers. It can be used in both pressure and vacuum systems.

**Ways to Increase Capacity**

1. Optimize solids/air ratio

2. Minimize the number of bends

3. Shorten the total conveying distance

4. Reduce conveying velocities to just above saltation

5. Step up the line diameter near the end of the system

• Doing so decreases the total system pressure drop

6. Minimize flex hose length and eliminate where possible

**Ways to Minimize Wear in Conveying Lines**

1. Reduce conveying velocities

2. Use wear resistant materials for more prevalent abrasive materials - Sand, carbon black, etc.

3. Minimize line length and number of bends

4. Enter the vessel radially, not tangentially

6. Step up the line diameter before the vessel entrance

**Dense phase conveying**

The main principle of a dense phase conveying system is to slow down the velocity of the product in the pipe to a point that is below the speed at which the product breaks or degrades

At low velocities, the product lies for periods of time in the bottom of a horizontal line and it is blown under pressure to the discharge point in slugs or plugs.

The dense phase pneumatic conveying systems uses low volume, medium pressure air stream and relies on a continuously expanding volume of air pushing cohesive slugs of material along the pipe. This system uses a transfer vessel/pump tank to feed the material into the conveying line. It is a batch system with plugs of material separated by cushions of air. The velocity range at the source can be as low as 200 fpm for the majority of products. The product velocity at the destination is always a function of the system differential pressure, but in most cases it rarely exceeds 2000 fpm.



Fluidized Dense - Phase

Dense phase technology reduces the air consumption to the absolute minimum by allowing the system to convey at maximum density. This maximum density conveying technique has three main advantages.

* First, because the conveying pipe line is so dense with the bulk material, the air cannot “slip” past the bulk material, which is a common inefficiency in dilute pneumatic conveying systems. If we eliminate the slip, we can improve efficiency.
* Second, when the conveying pipe is at maximum density, only a small percentage of the particles are in contact with the conveying pipe at any given time. The majority of the particles are in the interior of the pipe, therefore not abrading the pipe. So, this significantly decreases pipe wear
* Third, by increasing the pipe density, the conveying velocity can be decreased.



Figure: Material Handling System

Figure shows the relation between pressure drop and end velocity with respect to dense phase and dilute phase materials used in pneumatic conveying system.

**Conclusion**:-

So pneumatic conveying system is preferred over conventional mechanical conveying system when the conveying material is in dilute or dense phase, system required flexibility, low maintenance and material is separated from the atmosphere.

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