

ENGINEERING STANDARD

FOR

PROCESS DESIGN OF SOLIDS HANDLING SYSTEMS

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0. INTRODUCTION

Handling of solids play an important role in the vast number of industries, particularly in chemicals and petrochemical process industries. Bulk materials handling comprises a wide range of techniques incorporating a number of handling modes. Attempts are made here to highlight some of the important modes specifically utilized in OGP process plants by providing basis on which the basic conveying requirements, and parameters are given for proper selection, design of the systems.

"Process Design of Offsite Facilities for OGP Processes", are broad and contain various subjects of paramount importance. Therefore, a group of Process Engineering Standards are prepared to cover this subject. This group includes the following Standards:

STANDARD CODE	STANDARD TITLE
IPS-E-PR-360	"Process Design of Liquid and Gas Transfer and Storage"
IPS-E-PR-370	"Process Design of Loading & Unloading Facilities"
IPS-E-PR-380	"Process Design of Solids Handling Systems"

This Engineering Standard Specification covers:

"PROCESS DESIGN OF SOLIDS HANDLING SYSTEMS"

1. SCOPE

This Engineering Standard Specification is intended to cover basic minimum process requirements, and governing the selection of a proper handling system for bulk materials, with specific concern to capacity requirements, material characteristics, process requirements, and flow properties of solids. Classification codes summarizing bulk solids behavior, process design considerations from the views of operating conditions and other process design information and criteria to the extent specified herein are covered.

2. REFERENCES

Throughout this Standard the following standards and codes are referenced to. The editions of these standards and codes that are in effect at the time of publication of this standard shall to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall mutually agreed upon by the Company and Vendor/Consultant.

BSI (BRITISH STANDARDS INSTITUTION)

BS 4409, Part 1, 1991	"Screw Conveyors, Specification for Fixed Trough Type"
BS 4409, Part 3, 1982	"Screw Conveyors, Method for Calculating Driver Power"

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO 7119, 1st. Ed., 1981	"Continuous Mechanical Handling Equipment for Lose Bulk Materials Screw Conveyors"
ISO 5048, 2nd. Ed., 1989	"Continuous Mechanical Handling Equipment Belt Conveyors"
ISO 2148, 1st. Ed., 1974	"Continuous Handling Equipment Nomenclatures"

ANSI/CEMA (AMERICAN NATIONAL STANDARD INSTITUTE/CONVEYOR EQUIPMENT MANUFACTURERS ASSOCIATION)

350 Class III E, 1st Ed., 1971	"Screw Conveyors"
350 Class IV E, 1st. Ed., 1970	"Package Handling Conveyors"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-M-GM-210	"Material and Equipment Standard for Conveyors"
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IATA (INTERNATIONAL AIR TRANSPORTATION ASSOCIATION)

CAB (CIVIL AERONAUTICS BOARD)

3. SYMBOLS AND ABBREVIATIONS

CAB	Civil Aeronautics Board.
CEMA	Conveyor Equipment Manufacturers Association.
D	Nominal screw diameter, in (m).
DOT	Department Of Transportation.

g	Acceleration due to gravity, in (m/s ²).
H	Height to which the material to be elevated, in (m).
IATA	International Air Transportation Association.
I_v	Volume flow rate, in (m ³ /h).
L	Length of conveyor, in (m).
OGP	Oil, Gas and Petrochemical.
P_H	Power necessary for the progress of the material, in (kW).
P_N	Drive power of screw conveyor at no load condition, in (kW).
P_{st}	Power due to inclination, in (kW).
ρ (rho)	Bulk density, in (kg/m ³).
ϕ (Phi)	Trough filling coefficient, (dimensionless).
θ (theta)	Cone angle, in (rad).
W	Product capacity, or carrying capacity of belt, in (kg/s).

4. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

5. GENERAL CONSIDERATIONS

5.1 Most Salient Features

Selection of a specific handling system for bulk materials requires a full knowledge of the physical and chemical properties of the materials to be handled. Material characteristics and the prevailing plant conditions, play an important role in determining the flow behavior of the product, thereby influencing the type of the equipment selected. The most salient features for selection of a suitable handling system are:

a) Capacity

Capacity requirement is a prime factor in conveyor selection. Belt conveyors which can be manufactured in relatively large sizes, to operate at high speeds, deliver large tonnage economically. On the other hands screw conveyors become extremely cumbersome as they get larger and can not be operated at high speeds without creating serious abrasion problems.

b) Distance

Length of travel is definitely limited for certain type of conveyers. With high-tensile-strength belting, the length limit on belt conveyors can be a matter of miles. Air conveyors are limited to 300 meters, vibrating conveyors to 100 meters. In general as the length of travel increases, the choice among alternatives become narrower.

c) Lift

Lift usually can be handled most economically by vertical or inclined bucket elevators, but when lift and horizontal travel are combined, other conveyors should be considered. Conveyers that combine several direction of travel in single unit are generally more expensive, but since they require a single drive, this feature often compensates for the added base cost.

d) Materials

Material characteristics, both chemical and physical characteristics should be considered especially flowability, abrasiveness, friability and lump size. Effects of chemicals, moisture and oxidation effects from exposure to atmosphere can be harmful to the material being conveyed, or to the conveyor's material. Certain type of conveyors lend themselves to such special requirements better than the others.

e) Processing

Processing requirements can be met by some conveyors with little or no change in design. For example, screw conveyors are available for a wide variety of processing operations such as mixing, dewatering, heating and cooling. A continuous flow conveyor may provide a desired cooling for solids simply because it puts the conveyed material into direct contact with heat conducting metals.

f) Flow properties of solids

The flow characteristics of bulk solid materials depend on their physical and chemical properties. The main characterizing factors to be considered in selection of solids conveying systems are:

1) Product grouping

The flowability of the product yields two main categories of bulk solids is specified under 1.1 and 1.2 herein below:

1.1) Group I

This group includes free-flowing materials, i.e., non cohesive products; those that do not undergo any plastic deformation when subjected to high pressures. When the load is removed, the particles return to their original condition in terms of both shape, and flow characteristics.

1.2) Group II

All products which undergo plastic deformation when subjected to external pressure i.e., cohesive products for which the degree of deformation is strongly influenced by both temperature and moisture. When the load is removed, the particles do not regain their original shape, thereby yielding poor flow condition.

5.2 Fluidization Characteristics

The ability of the material to fluidize and whether the product has an affinity to trap air or gas is of major importance when designing and selecting of solids handling and storage systems.

5.3 Flow Function

Flow functions for both short and long residence time in silos and storage bins shall be taken into account in design and selection. Additional complications occur when the product is stored at elevated temperature or when humidity could influence the moisture content of the product.

5.4 Important Flow Features

For the successful operation of any materials handling system the flow of solids from bins and silos must be controlled. The following important features should be considered in selection and design of such storage facilities.

5.4.1 Factors influencing flow

Three essential factors must be considered when designing a storage hopper or bin:

1) Geometric form of the hopper: the elements which must be considered includes:

- a) cone angle θ (theta);
- b) size of outlet;
- c) shape (circular or rectangular);
- d) hopper construction material.

2) Product characteristics:

- a) particle size and shape;
- b) particle size distribution;
- c) particle density and bulk density;
- d) cohesiveness of the product;
- e) fluidizability;
- f) floodability;
- g) deaeration characteristics.

3) Additional factors:

- a) influence of humidity;
- b) temperature of product and process;
- c) storage time;
- d) ambient conditions.

6. CONVEYING OF BULK SOLIDS

6.1 Conveyor Selection

6.1.1 Main guidelines and prime factors are given under Clause 5 of this Specification that must be considered in the course of evaluating and selection. However, it is advisable to check with the manufacturer to be sure that the application is proper.

6.1.2 Conveyor selection must be based on the as-conveyed characteristics of a material. For instance if packing or aerating can occur in the conveyor, the machine's performance will not meet expectations if calculations are based on an average mass per cubic meter. Storage conditions, variations in ambient temperature and humidity, and storage methods may all affect conveying characteristics. So, such factors should also be carefully considered before making a final conveyor selection.

6.2 Mechanical Conveyors

6.2.1 General

6.2.1.1 Mechanical conveying techniques are the most widely used form of materials handling in chemical and petrochemical industries. Mechanical conveyors have distinct advantages in terms of the ability to effect accurate control in the monitoring of material from one process to another.

6.2.1.2 Under this Standard Specification, some basic features of the various types of mechanical conveyors as well as the safety and environmental considerations are covered.

6.2.2 Selection of mechanical conveyors

6.2.2.1 Not contrary with requirements given in Clause 5, the review to conveyor selection guide given in Table 1 is recommended to be considered.

TABLE 1 - CONVEYOR SELECTION GUIDE

Material's transfer		Conveyor profile						Material properties										
Load- ing	Discharge	Angle of inclination	Con- vey- er	Verti- cal lift	Materials	Flowability		Tempera- ture	Corro- siveness	Abra- siveness								
						Angle of repose	Specific material											
Controlled feed	Controlled feed	Controlled feed	Controlled feed	Controlled feed	Silt (under 250 mesh) Very fine (100 mesh to 250 mesh) Fine (25 to 100 mesh) Medium (10 to 25 mesh) Coarse (2 to 10 mesh) Large (1 to 2 mesh) Very large (1/2 to 1 mesh) Boulders (over 2 mesh)	Free-flowing (15 to 35 deg) Sluggish (35 to 60 deg) Sticky (60 to 80 deg) Sludge & filtercake Setting (tripper phos.) Packing (sodium bicarb.) Metal turnings Wood chips Sintered & pulpwood Non-freeable Friable Dust excessively	Coal (below 9°C) Ammonia (4-45°C) Hot (150-150°C) Very hot (150-450°C) Hot temp. (over 450°C)	Noncorr. (above 7 pH) Mildly corr. (5 to 7 pH) Very corr. (1 to 5 pH) Non-abras. (1 to 3 Moh) Mildly abras. (3 to 5 Moh) Very abras. (above 5 Moh)										
Apron conveyor—deep pan	•	•	•	•	•	•	•	•	•	•								
Apron conveyor—hinged pan	•	•	•	•	•	•	•	•	•	•								
Apron conveyor—shallow pan	•	•	•	•	•	•	•	•	•	•								
Belt conveyor—rubber belt	•	•	•	•	•	•	•	•	•	•								
Belt conveyor—thistle	•	•	•	•	•	•	•	•	•	•								
Belt conveyor—steel band	•	•	•	•	•	•	•	•	•	•								
Belt conveyor—with plow	•	•	•	•	•	•	•	•	•	•								
Belt conveyor with mobile tripper	•	•	•	•	•	•	•	•	•	•								
Belt conveyor with stationary tripper	•	•	•	•	•	•	•	•	•	•								
Drag chain conveyor	•	•	•	•	•	•	•	•	•	•								
En masse conveyor	•	•	•	•	•	•	•	•	•	•								
Flight conveyor	•	•	•	•	•	•	•	•	•	•								
Gravity discharge conveyor	•	•	•	•	•	•	•	•	•	•								
Pivoted bucket conveyor	•	•	•	•	•	•	•	•	•	•								
Screw conveyor	•	•	•	•	•	•	•	•	•	•								
Slat conveyor	•	•	•	•	•	•	•	•	•	•								
Sliding chain conveyor	•	•	•	•	•	•	•	•	•	•								
Vibrating conveyor	•	•	•	•	•	•	•	•	•	•								

How to use tables:

Blank dots in spaces indicates equipment suitable. Blank space indicates not suitable; numbers in spaces indicates qualifications.

Conveyor type

Key:

1. Special considerations required. Consult manufacturer.
2. In combinations of inclined and horizontal units only.
3. Investigate maximum operating angle for material handled.
4. At controlled belt speeds.
5. Tripper must be located on horizontal section.

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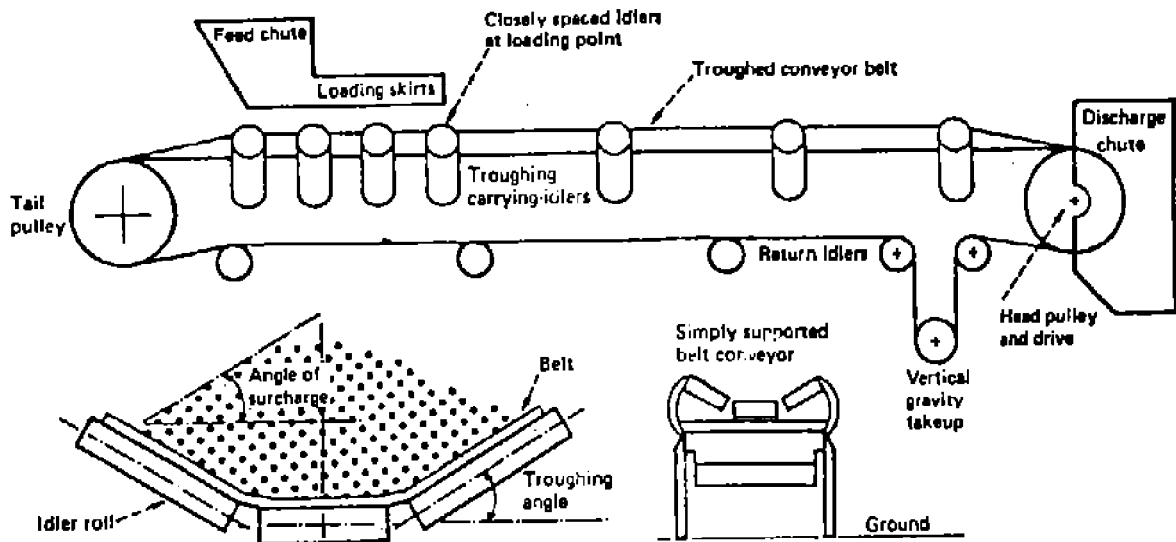
How to use tables:

Blank dots in spaces indicates equipment suitable. Blank space indicates not suitable; numbers in spaces indicates qualifications.

6.2.3 Belt conveyors

6.2.3.1 General

Belt conveyors are the most widely used and versatile mode of mechanical conveying systems employed to transport materials horizontally or on an inclined either up or down. Fig. 1, represents a typical belt-conveyor arrangement, with following main components of the system:



TYPICAL BELT-CONVEYOR ARRANGEMENT

Fig. 1

- a) The belt, which forms the moving and supporting surface on which the conveyed material rides.
- b) The idler, which form the supports for the carrying and return strands of the belt.
- c) The pulleys, which support and move the belt and control its tension.
- d) The drive, which imparts power to one or more pulleys to move the belt and it's load.
- e) The structure, which supports and maintains the alignment of the idlers and pulleys, and supports the driving machineries.

6.2.3.2 Requirements

6.2.3.2.1 Unless otherwise specified, all conveyers, drives, supports, electricals including control pannel and other materials necessary to complete the conveying system shall be furnished by the Vendor.

6.2.3.2.2 Vendor shall furnish all appliances, special tools, and accessories that are necessary or incidental to the proper installation and operation of the equipment, even though these items may not be included in the drawings, specifications, or data sheets.

6.2.3.2.3 A summary of utility requirements including electric power, plant and instrument air, cooling water, steam, etc., shall be submitted with the Vendor's quotation.

6.2.3.2.4 Vendor shall submit recommendations for following 3 categories of spare parts:

- a) Erection and pre-commissioning.
- b) Commissioning and initial operation.
- c) 2 years of normal operation.

6.2.3.3 Design

6.2.3.3.1 Conveying system shall be designed for 24 hours, continuous operation at the rated output in the specified environment.

6.2.3.3.2 General arrangement drawings of conveying system showing location of gravity take-up, bents, support locations, etc., which shall be prepared by the Vendor.

6.2.3.3.3 Vendor shall be responsible to guarantee performance of the belt conveyor system. The data sheets, and drawings shall indicate minimum requirements, but these shall in no way relieve the Vendor from his responsibility for providing a system capable to meet the required performance.

6.2.3.3.4 Materials of construction shall be selected and specified in accordance with service condition and handling material specification.

6.2.3.3.5 Belt conveyors shall be CEMA Grade 2, designed for the material conveying temperature.

6.2.3.3.6 The following operating conditions shall be considered in belt conveyor design:

- a) Service condition, is the first step which should be considered. The method by which the conveyor will be fed, the point where loading will take place, and where the material will be discharged.
- b) Surroundings, which involve such conditions as high temperature or corrosive atmosphere can affect the belt, machinery and structure.
- c) Continuous service, may require extremely high quality components and even specially designed equipment for servicing while the belt is in operation.
- d) Belt width and operating speed, are functions of the bulk density and lump size of the material, using the narrowest possible belt for a given lump size and operating it at maximum speed can result in lowest cost.
- e) For detailed design requirement of belt conveyors, reference is given to ISO 5048, 1989, "Continuous Mechanical Handling Equipment Belt Conveyors".

6.2.3.3.7 The following criteria shall be considered in design of the belt conveyor:

- a) Belt conveying capacity, belt incline, and belt loading points shall clearly be determined in design data sheets.
- b) Design and engineering of belt conveyors must be directed toward keeping the belt in operating condition.
- c) The belt transfer points should be reduced to a minimum to cut degradation, dust and cost.
- d) All belt lines should be elevated to a specified level above ground to ease inspection, maintenance, and cleanup.
- e) Clearances above roadways and rail lines should permit the passage of cranes and other mobile equipment, as well as fire control vehicles. Minimum vertical clearances between finished grade (or top of flooring) and the bottom edge of the lowest part of the conveyor housing or structure shall be as per Table 2.
- f) Care should be taken to control dust emissions. The amount of dust released depends upon the physical characteristics of the bulk material and the manner in which the material is handled. An enclosure around the transfer should be placed to control the dust emission.
- g) In addition to requirements specified in 6.2.3.2 and 6.2.3.3 above, the following design information shall be submitted for the Company's review:
 - 1) Dimensioned outline drawings showing equipment physical arrangement and elevation.
 - 2) Completed specification sheets giving manufacture, size, type or model of specific equipment to be furnished.

- 3) Materials of construction.
- 4) Calculations and data necessary to support and interpret the calculations.
- 5) Detailed drawing and data showing:
 - a) device for cleaning the conveying surface of the belt;
 - b) length of each type and size of belt to be furnished for field splices;
 - c) type and location of idlers;
 - d) seal and lubrication sign of idlers.

For further information reference is made to IPS-M-GM-210, "Material and Equipment Standard for Conveyors".

For general definitions and nomenclatures of the terms used under Clause 6 above, reference is given to ISO 2148, 1974, "Continuous Handling Equipment Nomenclatures".

TABLE 2 - MINIMUM VERTICAL CLEARANCE

LOCATION	MINIMUM CLEARANCE (m)
a. Above major roads open to unrestricted traffic (such as periphery of process Unit area limits)	6.0
b. Within process Unit areas: above internal roadways provided for access of maintenance and firefighting equipment	3.5
c. Above walkways and elevated platforms	2.0
d. Under any low level piping in paved or unpaved areas	0.6

6.2.4 Screw conveyors

6.2.4.1 General

6.2.4.1.1 The screw conveyor is one of oldest and most versatile conveyor types, it consist of a rotating helicord placed in a stationary trough. Power to convey is transmitted through the pipe or shaft and is limited by the allowable size of this member.

6.2.4.1.2 The allowable loading and screw speed are limited by characteristics of the material. Light, free-flowing, non-abrasive materials fill the trough deeply, permitting a higher rotating speed than with heavier and more abrasive materials. The manufacturer's recommendations should be considered in determining the allowable loading.

6.2.4.1.3 In addition to their conveying ability, screw conveyors can be adapted to a wide variety of processing operations. Almost any degree of mixing can be achieved with screw conveyor.

6.2.4.1.4 There is a diversified number of uses for screw conveyors, such as controlled heating or cooling, mixing, and blending. This Standard only applies to a screw conveyor used in horizontal or inclined position (up to approximately 20°) for a regular, controlled and continual supply of the bulk materials.

6.2.4.1.5 Required power is made up of two components, that is necessary to drive the screw empty and that necessary to move the material. The first component is a function of conveyor length, speed of rotation, and friction in the conveyor bearing. The second is a function of the total mass of material conveyed per unit of time, conveyor length, and depth to which the trough is loaded. Calculation procedure of power required shall be as per 6.2.4.4 of this Standard.

6.2.4.1.6 Variety of screw conveyors can be used for handling of solid materials, depending on the characteristics of the material to be conveyed. Typical screw conveyors with relevant nomenclature are given in ISO 2148, 1974, Clause 2.14.13, "Continuous Handling Equipment Nomenclatures".

6.2.4.2 Field of application

6.2.4.2.1 The design calculations and requirements shall only be used for a screw conveyor, used in a horizontal or inclined position as specified in 6.2.4.4.

Note:

Excluded from this Standard are the special screws for following special fields of application:

- Extracting screws
- Calibrating screws
- Mixing screws
- Moistening screws
- Inclined screws (above 20°)
- Vertical screws.

a) The nominal capacity of a screw conveyor I_v shall be obtained from the equation given under clause 6 of British Standard BS 4409, Part, 3 1982 and ISO 7119, 1981.

b) In selection of the trough filling coefficient the conditions specified in BS 4409, Part 3, 1982 or ISO 7119, 1981 shall be considered.

c) The peripheral speed of the screw should not be too high so as to prevent the material being thrown upwards which will spoil its transport. The peripheral speed should be chosen as a function of the screw diameter D , the physical properties of the material and the filling coefficient.

6.2.4.3 Drive power of loaded screw

6.2.4.3.1 The total drive power of the loaded screw in kilowatts is given by the formula in Clause 8 of BS 4409, Part 3.

6.2.4.3.2 Drive power due to progress of material P_H

6.2.4.3.2.1 The power necessary for the progress of the material P_H should be obtained from the formulas given in Clause 8.1 of BS 4409, Part 3.

6.2.4.3.3 Drive power of conveyor at no load P_N

The drive power P_N is very low compared to the power required for the progress of the material. This value is proportional to the diameter D and length of the screw L . In practice it is given in kilowatts and should be obtained from the formula given under Clause 8.2 of BS 4409, Part 3.

6.2.4.3.4 Power due to inclination P_{st}

The power P_{st} in kilowatts, will be the product of the capacity W by the height H and by the acceleration due to gravity g . This value should be obtained from the formulas given under Clause 8.3 of British Standard BS 4409, Part 3.

6.2.4.3.5 Total power necessary for the shaft of the screw conveyor

The total power necessary is the sum of the various powers and should be obtained from the formula given under Clause 8.4 of British Standard BS 4409, Part 3.

6.2.4.4 Design requirements

6.2.4.4.1 Screw conveyor enclosure shall be ANSI/CEMA, No. 350 Class III E for indoor or sheltered service, and Class IV E for outdoor applications.

6.2.4.4.2 Enclosures shall be designed to allow access over the entire length of the conveyor.

6.2.4.4.3 Screw conveyors shall be sized based on a trough loading of no greater than 30% of trough volume with the specified lowest material bulk density ρ (rho) exhibited during transport by the equipment.

6.2.4.4.4 Design information to be submitted for review by the Company shall include but not be limited to the following:

- a) dimensioned outline drawings showing equipment physical arrangement and elevations;
- b) completed specification sheets giving manufacturer, size, type of model of specific equipment;
- c) material of construction;
- d) calculations and data necessary to support and interpret the calculations.

For further information reference is made to IPS-M-GM-210, "Material and Equipment Standard for Conveyors".

6.3 Continuous Handling Equipment or Pneumatic Conveyors

6.3.1 General

6.3.1.1 Pneumatic conveyors are commonly used to transport dry granular or powdered materials, both vertically and horizontally, to remote plant areas that would be hard to reach economically with mechanical conveyors.

6.3.1.2 Pneumatic systems can be completely enclosed to prevent product contamination, material loss and dust emission. Furthermore, some materials are better protected from degradation when they are conveyed using an inert gas or dried air. Conveying rates are comparable to those for most mechanical conveyors.

6.3.2 Advantages and disadvantages of pneumatic conveyors

6.3.2.1 Pneumatic conveying offers the following advantages:

a) Flexibility

The system can follow any route; a change in flow direction is achieved by simple addition of a pipe bend; it is relatively easy to extend pipeline length.

b) Pollution-free Transport

Because solids are contained in a closed conduit, toxic materials can be transported safely and the product is also protected from environmental contamination.

c) Reduction in manpower and minimal maintenance

Pneumatic conveying systems have virtually no moving parts, require minimal maintenance, and have relatively modest manpower requirements.

d) Control

With the latest feeding techniques, pneumatic conveying systems can be easily integrated into modern chemical plants employing sophisticated process control.

e) Range of products transported

Pneumatic conveying techniques have been successfully applied to a wide range of products. Modern handling techniques have facilitated the transportation of flakes, powders and granules.

6.3.2.2 The pneumatic conveyors may also offer certain disadvantages as:

a) Higher power consumption

When compared with other mechanical handling systems.

b) Limited distances

Pneumatic handling techniques are generally limited to the indoor transportation of materials, although there are systems operating which move products over a maximum distance of 4000 m.

c) Limited throughput

Pneumatic conveying techniques are best suited to handling products at rates of hundreds, rather than thousands of tonnes per hour.

6.3.3 Types of pneumatic conveying systems

6.3.3.1 Pneumatic conveyors are classified according to following basic types:

a) Pressure system

1) In pressure systems (see Fig. 2a) material is dropped into air stream (at above atmospheric pressure) by a rotary air-lock feeder. The velocity of the stream maintains the bulk material in suspension until it reaches the receiving vessel, where it is separated from air by means of cyclone or air filter.

2) Pressure systems are used for free flowing materials of almost any particle size, up to 6.35 mm. These systems are favored When one source must supply several receivers. Conveying air is usually supplied by positive-displacement blowers.

b) Vacuum systems

1) Vacuum systems (see Fig. 2b) are characterized by material moving in an air stream of pressure less than ambient. The advantages of this type are that, all the pumping energy is used to move the product, and that material can be sucked into the conveyor line without the need of conveying feeder.

2) Vacuum systems are typically used when flows do not exceed 7000 kg/h. The equivalent conveyor length is less than 305 m. They are widely used for finely divided materials.

3) Vacuum systems are designed with special interest for flows under 7.6 kg/min. used to transfer materials short distances from storage bins or bulk containers to process Units. These type of conveyors are widely used in plastics and other processing operations where the variety of conditions requires flexibility in choosing pickup devices, power sources, and receivers.

c) Pressure-Vacuum systems

1) Combined pressure-vacuum systems (see Fig. 2c) combine the best of both the pressure and vacuum methods. A vacuum is used to induce material into the conveyor and move it a short distance to a separator. Air passes through a filter and into the suction side of a positive displacement blower.

2) The most typical application is the combined bulk vehicle unloading and transferring to product storage, (see Fig. 2d).

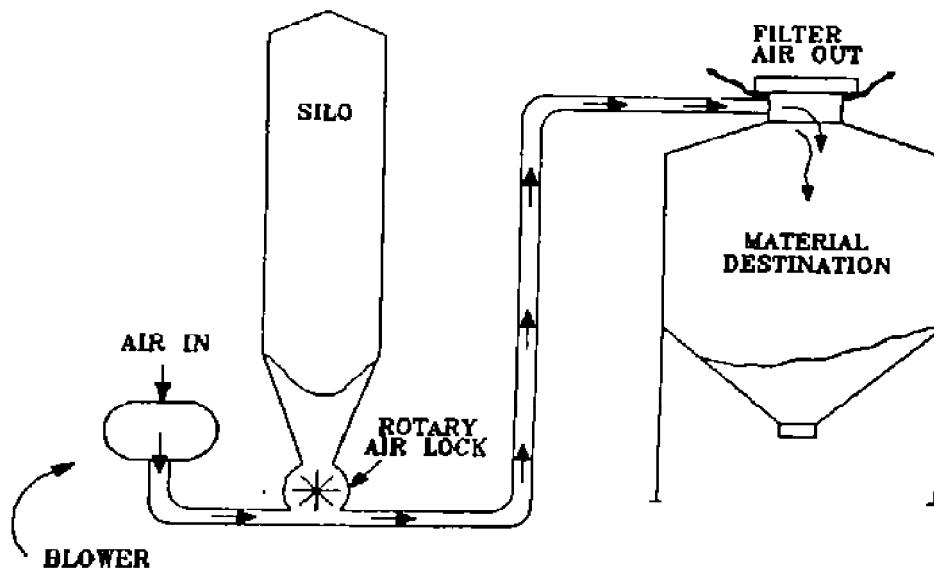
d) Fluidizing systems

1) Fluidizing systems generally convey pre fluidized, finely devided non free flowing materials over short distances, such as from storage bins to the entrance of a main conveying system.

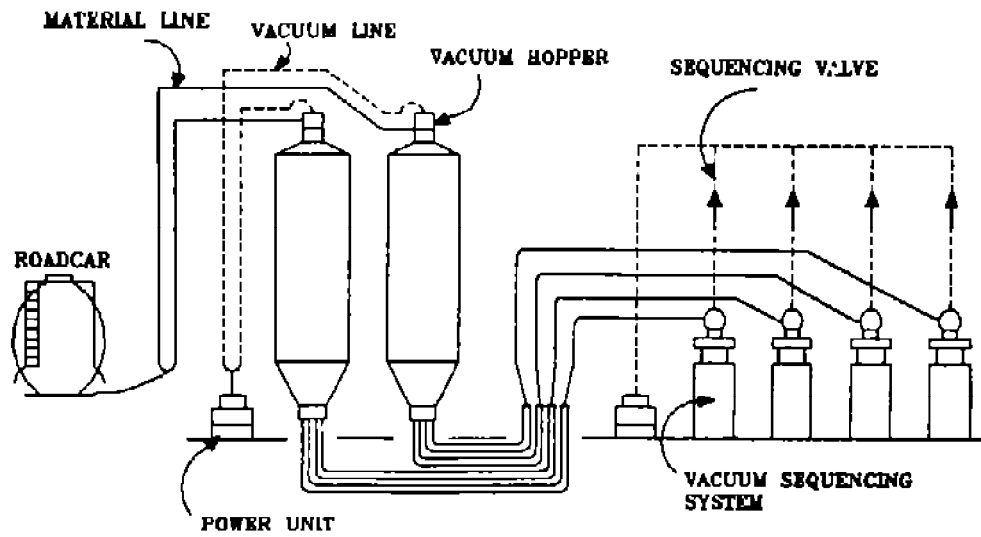
Fluidizing is accomplished by means of a chamber in which air is passed through a porous membrane that form the bottom of membrane (see Fig. 2e).

2) Pre fluidizing has the advantage of reducing the volume of conveying air needed, consequently less power is required.

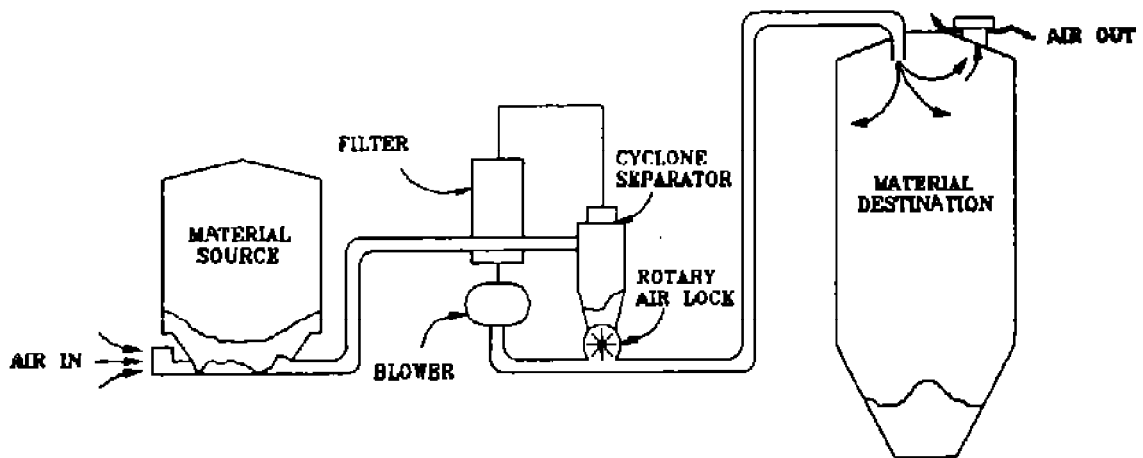
3) The most common application of this type of conveyor is the well-known railroad airslide covered hopper car.



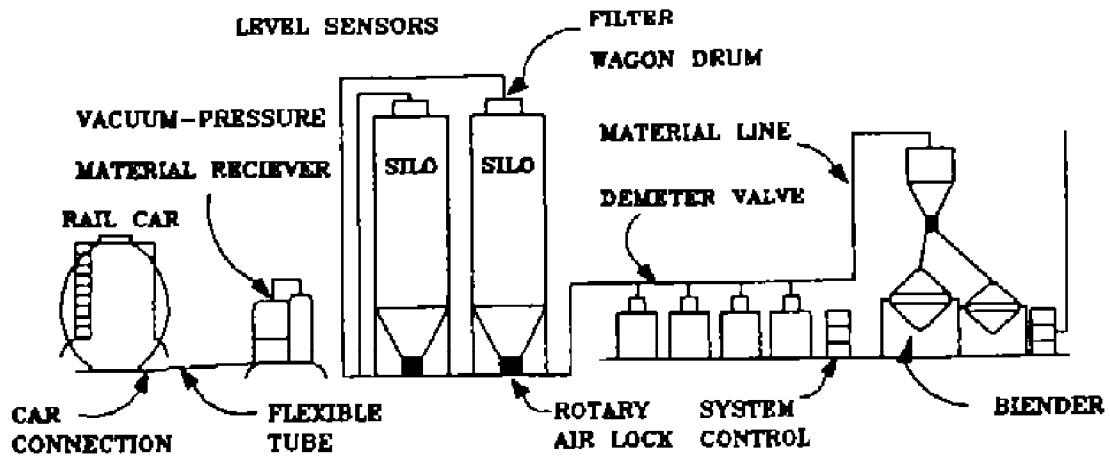
PRESSURE SYSTEM
Fig. 2a



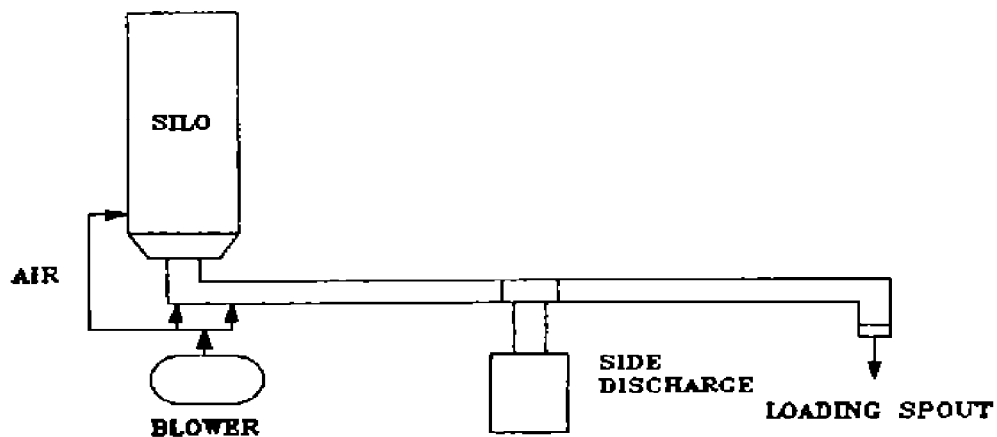
VACUUM SYSTEM
Fig. 2b



PRESSURE-VACUUM
Fig. 2c



PRESSURE VACUUM UNLOADING AND TRANSFER
Fig. 2d



FLUIDIZING SYSTEM
Fig. 2e

6.3.4 Effects of material properties

6.3.4.1 The properties of a material decide whether or not it can be successfully conveyed. Material properties are used in determining of the type of system required and the design details of auxiliary equipment.

6.3.4.2 Material properties should properly be analyzed according which, the system capacity, power demand and other effects to be considered. A summary of how material properties affect the design of a pneumatic conveyor is shown in Table 3.

TABLE 3 - EFFECTS OF MATERIAL PROPERTIES ON SELECTION OF PNEUMATIC EQUIPMENT

PROPERTY	USED TO DETERMINE
Relative density (specific gravity)	Power and air requirements
Settled specific mass	Power and air requirements
Aerated specific mass	Bin and hopper volumes; feeder capacities
Sieve analysis-complete spectrum down to +325 mesh and average particle size in micrometers (microns) through 325 mesh	Dust collection requirements; feeder clearances; type of seals at points of air pressure differential; type of bearing protection required, power requirements
Abrasiveness relative to a commonly known abrasive material	Type of conveying system materials of construction; type of feeder; type of seals at points of air pressure differential; type of bearing protection required; power requirements
Moisture content and rate of deliquescence	Type of conveying system; dust collection requirements; storage turnover requirements; air drying and bin venting requirements, type of feeder; necessity for flow inducers in bins and hoppers
pH or corrosiveness relative to some well-known acid	Materials of construction; air drying and venting requirements
Tackiness relative to some well-known sticky material	Type of conveying system; air drying and venting requirements; type of dust collection system
Aeration and deaeration characteristics	Type of conveying system; type of flow inducers in bins and hoppers; type of level indicator, design of chutes from bins and hoppers; requirements for deaeration
Angle of repose	Design of bins and hoppers; type of flow inducers in bins and hoppers
Toxicity	Type of dust collection; type of flow inducers in bins and hoppers
Temperature limitations	Requirements for cooling conveying air; insulation requirements for bins, dust collectors and ducts
Crystal structure or form of particles	Type of conveying system; type of feeder; form of piping system
Absorption of odors	Location and type of conveying air filters

6.3.5 Design considerations

6.3.5.1 The energy needed to operate the system shall be assessed for:

- a)** to ensure that the most efficient system is chosen;
- b)** to make an accounting of the utility requirements that must be furnished i.e., electric power and compressed air.

6.3.5.2 The actual brake horse power (in kilowatts) necessary to develop the required air horse power (in kilowatts) depends on the volumetric and mechanical efficiencies of the air mover. In estimating power requirements, the following efficiencies may be used:

- a)** 76% for reciprocating compressors.
- b)** 67% for sliding-vane compressors.
- c)** 65% for positive displacement blowers with lobed impellers.

- d) 70% for positive displacement blowers with meshed screws.
- e) 64% for fans with radial blades.

6.3.5.3 In any air mover used for pneumatic conveying, the volume of air entering the pipeline must equal the mass rate of flow required to maintain the material to air ratio of the conveying system at Standard Conditions.

6.3.5.4 All of the calculation procedures and specific design equations used by the Vendor for determining of:

- a) volume of air entering the air mover;
- b) power consumption;
- c) pressure drop.

Should be provided for the Company's review and all design basic data and information should be included in data sheets relevant to specific equipment and conveying lines.

6.3.5.5 Since pneumatic conveyors and their component, are subject to continual improvements by a fast-changing supplier industry, Vendor manufacturers should be invited to submit alternative designs.

**TABLE 4 - AIR VELOCITIES NEEDED TO CONVEY SOLIDS
AND VARIOUS BULK DENSITIES**

BULK DENSITY (kg/m³)	AIR VELOCITY (m/min.)	BULK DENSITY (kg/m³)	AIR VELOCITY (m/min.)
160	884	1120	2347
240	1094	1200	2438
320	1256	1280	2515
400	1402	1360	2591
480	1539	1440	2652
640	1780	1600	2804
720	1882	1680	2880
800	1981	1760	2957
880	2072	1840	3118
960	2179	1920	3200
1040	2270		

7. HANDLING BULK MATERIALS IN PACKAGES AND CONTAINERS

7.1 Main Factors

Main factors that should be considered during the selection process are:

7.1.1 Properties of products

Information on product with respect to its handling properties pertinent to the performance of packages and containers should be tested and specified in accordance with Conveyor Equipment Manufacturers Association (CEMA) codes. Classification code which summarizes behavior of bulk solids commonly transported in container.

7.1.2 If a product is defined to be poisonous, flammable or oxidizing, special consideration must be given to potential hazards. The container must then meet the regulations for transportation as a Dangerous Article, set forth by internationally accepted bodies and organizations such as International Air Transportation Association (IATA) and Civil Aeronautics Board (CAB), and such others.

7.1.3 Transport and storage of a highly degradable pelletized product in bags may present the risk of breakage, specially if the bags are shipped across the country or must frequently be rehandled. So, particular attempt should be made for container selection on the basis of straight forward analysis of practical limitations on container applicability.

7.1.4 Materials that pack under pressure should not be packaged in containers that are stored in such manner as to foster consolidation.

7.2 Selection of Container

7.2.1 The cost of the product and the cost of the container, must be factored into economic evaluations.

Note:

(As a general guidance, low-selling-price products are seldom found in the more expensive containers. Such containers are generally associated with a comparatively expensive product, or with special conditions that justify their higher costs).

7.2.2 Paper bag

7.2.2.1 Paper bag, is the most versatile and economical package available for storing and handling a wide variety of powdered, granular, prilled, or lump bulk products carrying the following advantages:

- a)** It can be manufactured in variety of sizes and strengths.
- b)** Full bags can be dense-packed and stacked for efficient use of storage space; empty bags require very little space.
- c)** Outer surface bags can be specially treated to resist abrasion, scuffing and insect infestation.
- d)** Special barrier sheets can be built into the bag to prevent passage of moisture and odors, to resist penetration by grease and oil.

7.2.2.2 The following basic factors should be considered in sizing of the paper bags:

- a)** What mass of bags are most convenient for the customers.
- b)** The product bulk density before and after bagging.
- c)** The bag size which fits the available pallets. **d)** The kind of filling equipment.
- e)** Pallet size which best fits the truck, rail units or other transport means.
- f)** The height of stacked pallets with concern on the safety measures.
- g)** The best bag-loading pattern.

7.2.3 Fiber drums

7.2.3.1 Fiber drums are rigid containers which are used widely for handling and storing of bulk-solid products with the following foremost advantages and disadvantages:

- a)** Light mass.
- b)** Economy.
- c)** Readiness for filling with no setup or assembly required.
- d)** They can be stacked several tiers high.
- e)** One disadvantage of fiber drums is that empty units require a great deal of storage area.

7.2.3.2 In fabrication of fiber drums by the manufacturers, they must follow united freight classification regulations or such similar regulations acceptably to the Company and subject to Company's approval.

7.2.3.3 Fiber drums should be ordered according to their inside diameter, wall thickness, and overall outside height. Specifications should define wall construction, types of ends, and any special barrier treatment.

7.2.4 Steel drums

7.2.4.1 Steel drums are used for certain dry products requiring strength, water tightness, weatherability and general ruggedness. In this regard, specification given by Department of Transportation (DOT), is recommended to be considered.

7.2.4.2 Steel drums must bear a code indicating the metal gage, volume capacity, maker's name, date of manufacturer, and so, forth.

8. STORAGE OF SOLIDS IN BULK

8.1 Outdoor Bulk Storage (Pile)

8.1.1 General

8.1.1.1 A hydrophilic-products processing plant needs a large storage area to keep its products dry during the low-demand season. Long experience achieved in many plant, proved that hydrophilic material, such as ammonium nitrate can be safely stored outside in bulk. This approach may be applied to similar bulk materials.

8.1.1.2 The outdoor bulk storage bins are considered as easy and economical to construct and simple in operation.

8.1.2 Designing and outdoor storage bin

In design phase many factors have to be considered as; storage capacity, rate of stockpiling, operation, the materials physical and chemical properties, shape of the stockpile, area required, available capital investment, operating cost, product protection, etc.