

DESIGN OF PNEUMATIC POWDER TRANSFER (CONVEYING) SYSTEM USING EXPERIMENTAL STUDIES

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Technology Degree in Chemical Engineering

By

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**INSTITUTE OF SCIENCE AND TECHNOLOGY
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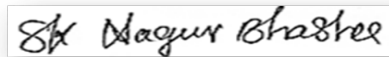
DECLARATION

We, **NAGUR BHASHA SHAIK. (Reg. No.39690008)** and **BINU BALAN (Reg. No.39690003)** hereby declare that the Project Report entitled **DESIGN OF PNEUMATIC POWDER TRANSFER (CONVEYING) SYSTEM USING EXPERIMENTAL STUDIES** done by us under the guidance of **Dr. D. VENKATESAN, M.Tech., Ph.D.**, Associate Professor, Department of Chemical Engineering, Sathyabama University and **Dr. G. SUNEEL, M.Tech., Ph.D.**, Supdt. (O) WIP, UOF& VWSF Bhabha Atomic Research Centre kalpakkam is submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in **Chemical Engineering**.

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ABSTRACT

Conventional equipment like bucket elevators, screw conveyors are many industries used for the transportation of solid granules or powdered materials. The powdering nature of material, there is a tendency for powder escaping and spillage. Replacement of the conventional transfer system with a Pneumatic powder transferring/conveying system was found to be more economical. The pneumatic transferring characteristics and operational required parameters were studied during the experiment. Negative pressure- air velocity profiles, differential pressure per unit length-air velocity profiles were established for vertical upward conveying. The air velocity related parameters were proposed for stable particle transferring/conveying.

Nuclear spent fuel reprocessing industries generally ammonium di urinate (ADU) powder is handled. Design of the powder transfer/conveying system is an essential element because of its typical characteristics. Pneumatic transport system has been broadly utilized in transferring powder from one location to some other in many industries. For current experimental studies sand of similar size as of ADU has been used. A pneumatic conveying system using negative pressure or vacuum and air-ejector is presented in this project. This system can be used for bulk conveying of ADU powder. The pneumatic device includes a cyclone separator and filter out material on the pinnacle of the cyclone separator. The pneumatic conveying machine affords excessive performance with sustainable overall performance and it's far a compact, strong, handy and moveable unit. The device offers easy and safe conveying of radioactive powder, better operating environment for the operator. The salting velocity for non-fluidization of solids for both blower system and air-ejector system are turned out to be 5.2 m/sec & 1.85 m/sec theoretical salting velocity estimated 6.0 m/sec respectively. Minimum fluidisation pressure evaluated by experiment studies 0.2 kg/cm², solid loading ratios determined by theoretical calculations 2.4 and pressure drop calculated and power requirements calculated for blower system 0.0106 kW.

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LIST OF SYMBOLS

Symbol	Description
ρ_s	Density of Sand
ρ_g	Density of Gas
μ	Viscosity of Air
d_p	Particle diameter
ε	Surface Roughness of pipe
K	Bend factor
D	Diameter of Pipe
L	Total pipe length
L_h	Horizontal length
L_v	Vertical length
U_{salt}	Saltation velocity
U_{solid}	Velocity of solid
V_g	Velocity of gas
U	Superficial velocity
S	Solid loading ratio
ΔP	Pressure drop
ΔP_{Total}	Total pressure drop
P	Power required
N_{Re}	Reynolds number

LIST OF ABBREVIATIONS

Abbreviation	Expansion
RAV	Rotary Air Valves
TDS	Total Dissolved Solids
GMP	Good Manufacturing Practice
FDA	Food and Drug Administration
UOF	Uranium Oxide Facility
ADU	Ammonium Di Uranate
CFD	Computational Fluid Dynamics
DEM	Discrete Element Method
MP	Multi Phase
PIC	Particle In cell
CPFD	Computational Particle Fluid Dynamic
kW	Kilowatt

1 CHAPTER

1.1 INTRODUCTION

Basically, pneumatic conveying units/system are very simple and excellent for conveying powder and granular materials in factory, construction site, and plant situations. The system requirements are a source of pressurized gas (usually air), a conveying device, a conveying line, and a receiver to separate the product to be conveyed from the carrier gas. The system is completely sealed and can be fully operated without moving parts contacting the conveyed goods if required. Piping can run both horizontally and vertically, up and down, and if there are bends in the pipe, a single pipe run can accommodate any combination of directions. Whether the material is conveyed vertically up or vertically down does not matter much more than horizontally. Easily control and monitor material flow to continuously check inlets and outlets many systems can be configured for fully automated operation.

This is a pneumatic conveying method with a simple structure that conveys powder and granular materials with compressed air. Negative pressure can also be applied to the system for material transport. A pneumatic conveying system consists of compressed air, conveying equipment, conveying lines and containers. The pipeline position can be horizontal or vertical up and down for different combinations of pipeline orientations. The material flow can be easily controlled and continuously monitored.

1.2 HISTORY

The basic principles of pneumatic transportation, devised by Alexander the Great in 100 BC, formulated by Chr. himself. In prehistoric times, the Romans used water lines and sewage systems. The Chinese used bamboo to transport natural gas.

The first industrial application of pneumatic conveying was probably in the form of capsule conversion systems. In this system, the material is enclosed in a cylindrical or spherical capsule, slightly smaller in diameter than the tube, and gas or liquid is used to inflate the capsule and drive it from one end of the pipeline to the other. The first pneumatic capsule system was built and

demonstrated by John Vallance in England in the 1820s. Considerable work on pneumatic capsule transportation was done by pneumatic despatch company.

1.3 MODE OF PNEUMATIC CONVEYING

Pneumatic Transfer Modes The two most common forms of pneumatic transfer are pressure transfer and vacuum transfer. In this case, pressure conveying uses compressed air to move the material through the line. Pressure systems should use supply lines such as rotary valves and pressure tanks. Compressed air systems are used for large materials that need to be moved over long distances.

The vacuum conveying or suction system uses a vacuum pump to convey the sucked material to the loader, creating a central or distributed vacuum where the vacuum air is separated from the material. When the vacuum air reaches the pump, it is filtered and released to the atmosphere due to its flexibility, the vacuum system can supply different materials to multiple processing units. In some vacuum systems, vacuum is created using compressed air and a venturi valve. Material is sucked through a venturi valve and conveyed to its destination by compressed air. This is a system that can be defined as a suction system and its use is restricted to small amounts of material.

Materials carried in dilute phases are in buoyant flow regardless of particle size, shape, or density. In a suspended flow, particles are blown or sucked through ducts and thus remain suspended in the air.

The pneumatic system uses compressed air to generate energy from air stored in storage tanks. The enclosed compressed air creates the motive force that moves the bulk material.

1.4 PNEUMATIC CONVEYANCE TYPES

The pneumatic conveyance include dilute /entrained flow and dense flow. Each type uses air pressure and closed lines or pipes to move material. The difference between them is how the air pressure is generated and how the material is passed through the system.

1.4.1 Dilute Phase

Pneumatic conveying of diluent, slurry, or dilute phases, two methods of moving materials, positive and negative. A positive phase or blowing system uses a fan or blower to apply pressure to the pipe and suspend the material. At the end of the

line, the material is removed through a separator or filter. Objects move at 15 to 35 meters per second (m/sec). A lean system design requires a pressure vessel and a low-cycle, non-constant inlet valve.

A negative pressure or vacuum system working in the opposite. Instead of pushing or blowing the material flow through the pipe line, it creates a negative pressure and pulls the material into a hygroscopic powder stick and plugs the pipe during transport. Therefore, dilution-phase extraction is used.

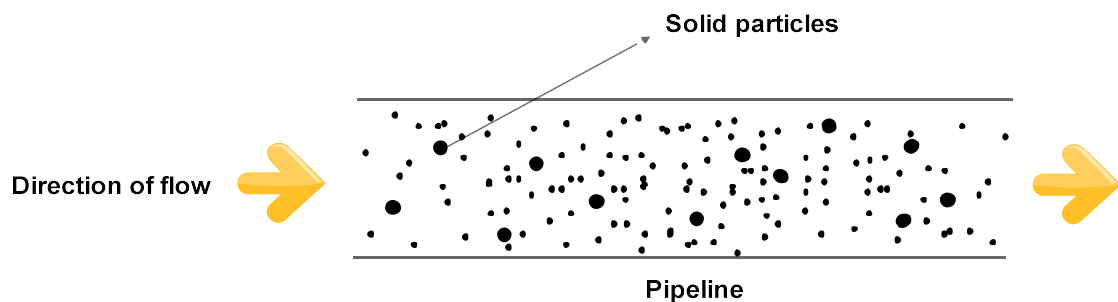


Fig 1.1: Dilute phase system

1.4.1.1 DILUTE – PHASE SYSTEMS TYPES

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

- Positive pressure system
- Vacuum system or Negative pressure
- Negative pressure & Positive pressure –system combination
- *Positive pressure*

Thin Flow Multiple sources to one or more targets/destinations, moderate at a distance and with a larger capacity than a vacuum system. A typical high pressure dilute phase system consists of a rotary valve. Piping containing long radius

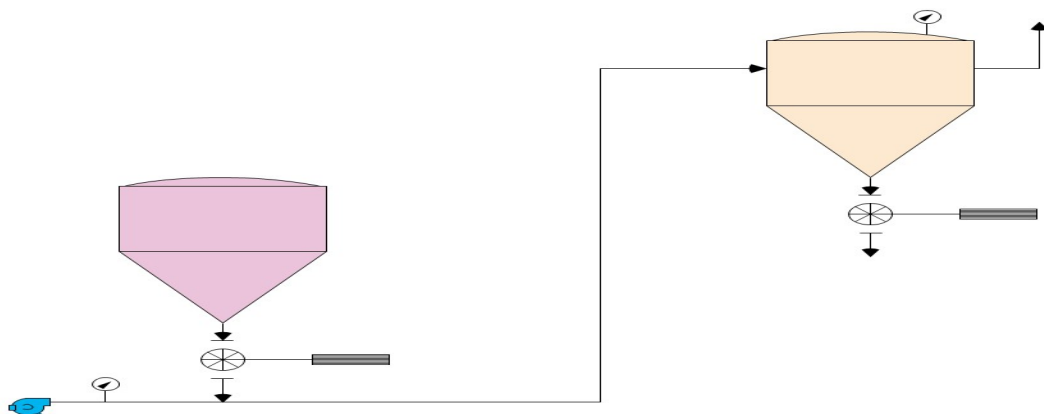


Fig 1.2: Pressure lean phase system

reinforced bends. A filter receiver or cyclone/filter assembly; and a positive displacement (root-type) blower. The following **Fig 1.2** diagram shows a typical arrangement of the components of an overpressure system.

The product enters the conveying line under high pressure via a feeding special device (usually a rotary air lock valves for metered discharge or venture discharges used). Products are often suspended in air currents and move at relatively high speeds particle density, size, shape and nature of the particle. At the end point, the airstream of suspended solids is separated by a filter vessels /cyclone separator or directly feed into the process vessels/container and discharged to downstream equipment. The blower/vacuum unit material does not pass this type of system. This gives him two advantages. First, impellers do not damage materials. Second, the fan is not subject to material wear and tear.

These systems typically work continuously. Products are always delivered at the point of origin and without interruption arrive at the destination vessels. Continuous metering applications this type of system makes easily adapt for dosing.

➤ *Vacuum - Dilute Phase*

The Vacuum transfer system is a system that operates at below-atmospheric pressure. Vacuum pressure (negative) is typically used to transfer materials from different sources such as process equipment, storage tanks trucks, tankers and rail vehicles to destinations. The negative pressure (vacuum) system is ideal for inlets for multiple product by using a simple diverter valve. However, using multiple destinations/targets is costly as each have its own filter receiver vessels with partial negative pressure capability.

The vacuum system typically uses a positive displacement equipment (root type) that provides up to 50% vacuum, along with a pipeline to its destination vessel where the air or gas stream and product stream are separated in a filter inbuilt receiver or cyclone separator to transfer the material. Products enter the conveyor line directly or through special dosing RAV devices such as rotary valves or dosing screws. Conveyed material is discharged from the storage vessel continuously through a rotary valve or intermittently through a valve to a surge hopper, storage vessel, or other delivery point. No moving parts in vacuum conveying, come into contact with the material and in the atmosphere dust not escapes. Due to its excellence leak containment, basis of cleanliness, especially when handling

hazardous, toxic powder materials. A disadvantage of this system is that the components must be designed for high vacuum if the system is subjected to high loads

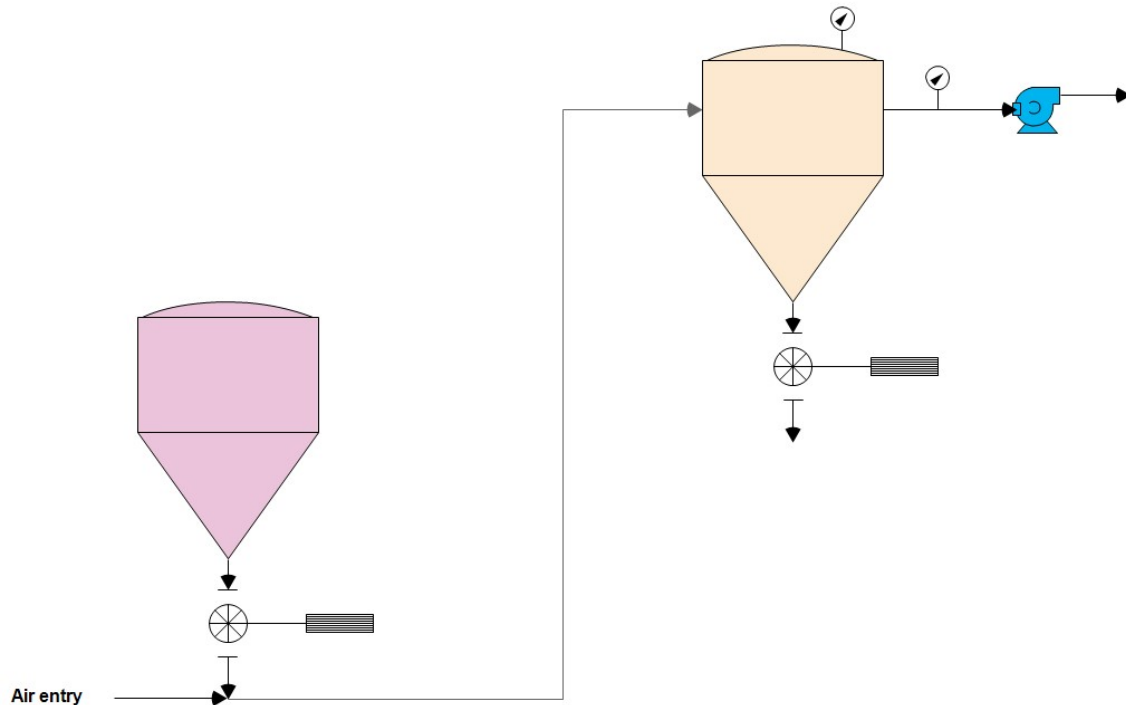


Fig 1.3: Vacuum lean phase

➤ *Negative pressure & Positive pressure –system combination*

The negative pressure & positive pressure system combination the benefits and advantages of both within the one system we will get it. These negative pressure & positive pressure system systems are used when there are more than one source material entry points and more than destination point or delivery points. Rail vehicles very common application is the unloading. Since the rail cabin cannot be pressurized air from outside (including particulate matter) was drawn into the filter from rail cabin. Solids are carried by the filters for that a filter bags or filter medium can be used after the filter to carry the solids to the final receiver movement of material pull and pushing done with the help of blower systems. If the final recipient is the point where the wagon is unloaded, it makes sense to use a complete vacuum system.

Dilute phase transferring key points:

- i. Suspended powder material in the transferring air
- ii. Transport speed faster to "salt" speed

- iii. Low system or negative pressure system ($< 1.05 \text{ kg/cm}^2$)
- iv. Solid to air ratio (> 2.0)
- v. Velocity high linearly (16.2 to 40.6 m /sec)
- vi. High wear - primarily due to high speed
- vii. Start-up reduced capital costs over time
- viii. Easier operation dense phase conveyance key points uses a high density phase pneumatic system to minimize particle wear and tube wear

1.4.2 Dense Phase

High density phase pneumatic transferring uses large amounts of material move to small amounts of air in chunks. This is similar to extrusion. Dense phase systems promote higher density concentrations of bulk solids at lower speeds.

Pneumatic dense phase transferring uses "booster pulsers" call as "air saver boosters" (air fluidizers) to agitate the walls of the pipeline product material. More than one controller or condensers mounted through the walls of the certain pipeline walls and hopper section to fluff the airflow direct the material and gases. This introduces small puffs of air to control product firmness and maintain pipe speed.

Using the booster has its drawbacks. They speed up material movement, but increase maintenance costs and downtime, and are a sales gimmick. Use boosters only when necessary and under the right conditions.

Conveying line is dense, so air can't circumvent material, which improves efficiency. Fewer particles of material in contact with pipelines and pipes reduce wear and tear on pipes. Density reduces transmission speed and tube diameter for better speed control.

The dense phase is ideal for fragile materials and mixtures due to its low velocity and air volume, preventing material decomposition.

1.4.2.1 Dense phase types

Different types of dense phase transport:

- i. Dense Phase Fluidized
- ii. Slow Slug Flow
- iii. Slow Plug Flow
- iv. Bypass transferring

v. Single Shot Transferring

It is some pneumatic transferring/conveying industries important velocity terms define:

- **Surface Velocity** - velocity of air without considering the presence of solid material/particles or porous material. Note: For ducts, air velocity refers to the cross-sectional area ignoring the material occupied by the space being transferred. Wind speed is a function of wind pressure, atmospheric conditions and wind temperature for a given material mass flow rate. When evaluating conveying air velocity anywhere in the system, the surrounding pressure and temperature values at that point in time should be considered.
- **Free Velocity** - The apparent air velocity when determined in free air conditions.
- **Conveying Minimum Speed** - The min transferring air velocity is the least surface air velocity that can be used to transfer the material. Note: During the dilute/dilution phase, without settling the material on the tube sheet the air velocity can be achieved.
- **Inlet Air Velocity** - The surface air velocity the point at where the material is introduced into the transfer system or pipeline. Single bore pipelines, this is the least air velocity in the delivery pipe line. This is variously called pick up velocity or pick up speed. In a pneumatic negative pressure/vacuum transferring system, the free air velocity is approximately equal.
- **End Velocity** - The apparent air velocity at the end of the material is transferred to the destination receiver. Single bore pipelines, this is the maximum air velocity in the delivery line. Air velocity of free in an above the atmospheric pressure delivery system, it is approximate same or equal.
Depending on the type of material, entrained flow systems require relatively high conveying velocities of air. For avoiding the material settling required air velocity must be maintained entire the transferring system. In the pipe lines due to sedimentation in the horizontal line or plane it is known as the salinity and due to subsidence in vertical line or planes, it is known as choking.
- **Salting** The process of solid particle or powder material depositing throughout horizontal pipe line/ planes. This phenomenon occurs when the gas velocity drops below its minimum flow rate.

- **Caution** - Do not select a higher speed than necessary. Excess speed negatively impacts the transfer system by causing energy loss in the form of friction, system wear and tear and increased cost operating.
- **Choking** Due to direct result of saltation choking occurs on vertical lines and horizontal lines. Choking can control easier in vertical motion because material suspended. Material dropping matter easier returns to air stream. However, a restriction of up flow just above the fan outlet indicates due to higher loading happened.
- To decrease the risk of salt formation and clogging/choking, suggested to less number of bends and leaks to be removed due to lower flow velocities downstream of the leak. For avoiding to recommend including extra air in the system design. This effectively increases the velocity in the system and facilitates material transport. Measures may be included to expel excess air through adjustable vents or dampers within the system. Entrained flow conveying can achieve higher material loading rates when:
 - Minimum air pressure and very lengthy pipeline, the material loading factor will be much lower.

The main design points are as follows.

- a. The transfer rate will be lower than the "salting velocity or salting rate" at in the system.
- b. System pressures higher (1.1 – 6.1 kg/cm²)
- c. Lower air to solids loading ratios (< 0.2)
- d. High capacity and low speed
- e. Minimum erosion - results in speed lower
- f. High investment cost to start up
- g. Flame proof valves, pipe lines etc.
- h. Lower velocity profile difficulty to operate

1.5 SELECTING A PNEUMATIC TRANSFER SYSTEM

Pneumatic transferring/conveying is a very efficient and safer method of moving solid powdered materials and is used in many of industries.

There are factors that must be considered when studying pneumatic systems as means of transportation. The equipment and type of transport should be tailored to

the material being transported. Below are some key considering point when selecting a pneumatic transferring/conveying system.

Mechanical systems, such as conveyors, can be costly and lossy when handling bulk materials. It is not designed to handle bulk material regardless of how it is configured with troughs, sides and partitions. Their design does not address the issues of dust, contamination, and potential harm to workers.

Material handling and transferring/movement is part of many industries, from automobile manufacturing to package delivery. Each of these systems is designed to meet a product's needs. In most cases they are specially developed for the needs of the product. Efficient material movement is essential for on-time production and delivery. For this reason, the use of conveyor systems is increasing.

Pneumatic systems are more economical and efficient when bulk materials need to be moved over long distances. Closed design and sealed tubes make material conveying/transportation efficient and economical.

Workers can be redirected to other applications with the assurance that materials will be delivered quickly, on time and in excellent condition.

As companies need to expand and grow, it need to change and redesign how they extract resources. Mechanical systems require work to be stopped to redesign the system, which is costly and time consuming. Such methods are not required for pneumatic systems.

Pneumatic systems are the ideal choice when companies move bulky materials such as powders, flakes, chips and granules. The pneumatic system can be configured to deliver supplies and materials to the job site and can be easily adjusted as site requirements grow or change. The first consideration is the material consistency and type that must meet the bulk type criteria. Once that decision has been made, the next logical step is to install a pneumatic conveyor system. It's easy. With more route and location options, can easily scale as supply chain grows. Pneumatic systems can transport bulk materials anywhere and pass through, over, around and under any piece of infrastructure.

1.5.1 Cost Reduction

All manufacturing companies work tirelessly to reduce manufacturing costs in order to remain competitive in the market. Businesses are constantly looking for

ways to reduce maintenance, repair and supply chain costs. These factors are some of the advantages of pneumatic systems.

Unlike other forms of mechanical transport, pneumatic transferring/conveying systems are install easily and require little maintenance. Once in operation, it delivers excellent flawless performance without the need for increased labour costs or other means of transportation. It is the cost factor that has persuaded so many bulk material operators to choose pneumatic transportation.

1.5.2 Safety

As work processes become more complex, worker safety concerns are growing. Standard forklifts and manual material handling can lead to injuries, downtime and production delays, but this is not the case with pneumatic systems.

The pneumatic conveying system is used to segregate bulk materials and keep them away from workers and potential operational damage. Sealing pneumatic transfer systems ensures containment, filtration and control of dust and contaminants from off gas streams.

1.5.3 Distance

The Mechanical conveyor system is ideal for transporting materials over short distances such as. In manufacturing facilities where materials may be moved on overhead and floor conveyors. If materials need to be transported long distances off-site, other means of transport will likely be used.

The pneumatic conveying system has virtually no limits to how far material can be moved. Large quantities of materials can be moved between buildings, cities and remote areas without worrying about material loss or damage. This particular aspect of pneumatic transfer systems is a key selling point for large operations with multiple sites spread across multiple locations.

1.5.4 Flexible

Pneumatic transfer systems consist of pressurized tubing, they are relatively easy to move and position changes. They increase the number of choices and locations and can easily be expanded with the growth of the supply chain. Pneumatic transfer systems can conveying bulk materials to any location and are capable of going through, over, around, and under any parts of the infrastructure.

1.6 MATERIAL PROPERTIES INFLUENCE OF PNEUMATIC CONVEYING

The properties of the material being conveyed play an important role in the decisions the must make when choosing a pneumatic transferring/conveying system. Similar to the "system requirements" some of the common material properties mention below.

1.6.1 *Sticky*

Sticky materials can cause problems during hopper outlet discharge, pipeline loading, and movements or transferring/conveying. The viscous material was difficult to discharge from the rotary valve, use a blow-by valve.

If problems conveying sticky materials with traditional system, then consider the innovative system. For example, the pulse phase transfer system was developed to handle such fine agglomerates.

1.6.2 *Flammability*

There are many substances that disperse in the air in finely divided form, and will spread a flame along suspension when ignited. The solid powder materials contains foods like flour, sugar, wheat and cocoa, synthetic materials like plastics, polymers, synthetic materials and flammable chemical and materials from pharmaceutical products, metallic components and metal powders, and ignition fuels like peat, lignite, coal and wood. If a pneumatic transfer closed system is used, the air or oxygen content of the carrier. The air can be controlled to permissible levels of oxygen or as an inert nitrogen can used. Appropriate safeguards must be installed when using an open system. One way to use suppression system. Pressure release/relief vent valves and safety features incorporate another way.

1.6.3 *Wet or moisture*

Material with high moisture content can normally be fed into the pipeline and processed in conventional systems if the fines are not too high. Most processing problems occur when attempting to dump wet material from the hopper. The conventional rotary valve may not discharge fine materials sufficiently, so use the blow-through type. The fine material tends to coat and bend the pipe when wet, and will slowly clog the pipe. A particular problem in this regard is wet coal with high fraction of fines. Single plug blast systems and some other innovative

systems can handle this type of material. If it is necessary to use a conventional system, heating the conveying air will solve the problem if the material is not too wet.

1.6.4 Static Electricity

If static electricity is a problem during transportation of the air humidified. This process done online and typically not required a closed transfer system. The dense phase, the quantity of air entry to be regulated is much lower than in dilute flow transfer systems, the air pollution control operating costs are lower for powdered materials can transfer in the dense phase. This entire plant and pipe network must be grounded.

1.6.5 Aggressive

The hardness of the solid particles being transferred is greater than the hardness of the transfer system components. Erosive wear occurs on all surfaces where particles impinge, manifolds and elbows. Speed is one of the main parameters so it is much less of an issue on slow systems. If the dilute phase/dilution transfer system can be used, delivery rotating and moving parts such as screws, RAV (rotary air lock valves) devices with moving parts such as rotary valves and tubing bends can be protected.

1.6.6 Fragile

If you want to avoid deterioration of the conveyed item, consider a system that can convey the conveyed item at a low speed. The degree of particle collision, especially for pipeline bends, can be decrease as this is main issue of problems. Wear and tear damage as a result of particle are interacting each other particle and particle-are hitting the pipe line wall can be considered. Feeders for pipelines that can cause particle breakage. Do not use screws either.

1.6.7 Granules

As long as the granules can be fed into the pipeline, they can be conveyed in the pneumatic conveying system without any problems. Top discharge bins and traditional rotary valves can cause loading issues with the air enter from the upper exit blast tank granular material and often not convey material, especially if the blast tank does not have an exit valve. High percentage of fines and un-

conveyable particulate matter congested streams can clog the upper discharge line. The rotary valve must avoid shearing of particulate material and therefore valves with offset inlets can be used.

1.6.8 Hygroscopicity

The material was hygroscopic, dried air can be used for transport to reduce the moisture content to adequate levels. This entire process done online and the generally not required a closed transfer system. The amount of gas/air required for extraction is significantly less than the amount of air carried by the, so for materials with low hygroscopicity, the amount of air required for extraction is less than the amount carried by the extraction is successful when the material was extracted in the dense phase no need an air dryer.

1.6.9 Low Melting Point

High speed bends during flight transfer and energy from particles hitting the pipe wall can create high particle temperatures. The effect was localized to a small area surrounding contact point on the particle or material surface area, Melt that portion of the material. This problem is pronounced when material or particles slide around pipe inside walls and pipe inside bends. Plastic materials, pellets to melt when is transferred in a slurry stream. Velocity is the dominant variable, so in general most materials in low velocity dense phase systems are much less of an issue. If such materials need transferred in the dilution stage /dilute phase, the roughened pipe line surface helps greatly decrease problem as it prevents the material from slipping.

1.6.10 Radioactive

Radioactive solid powder or granular material must be transported below absolutely safer conditions, so it is essential to have a containment system in place so that leakage control of the transport environment should be maintained. Some of these materials tend very abrasive, so a vacuum system is also required to prevent conveying air from escaping the system or eroding the material at bends.

1.6.11 Toxic

When working with toxic substances, the working surrounding environment can be strictly controlled. A negative pressure transfer system is therefore important to confirm that no material leaks out the open system is sufficient if the carrier air can be safely vented to the atmosphere with a filter.

1.6.12 Very fine

The fine powders in the micron particles and submicron range particles soot and like other fine particles can cause complications with pipe coatings. The fine particles or materials incline to stick to pipe walls when transferred/conveyed in conservative transfer systems. The surface coating constructs up gradually and significantly reduce the cross-sectional area of the pipe, thus reducing its carrying capacity. Many innovative systems can handle this type of material successfully. When using a conservative transfer system, the material must be transferred through a bendable tube or flexible hose so the accumulated fine powder material can be periodically disturbed. Vibrations or natural pulsation that occurs within the transfer lines and system is very likely sufficient to allow the material to oscillate freely and rewind onto the conveying line.

1.7 MATERIAL CHARACTERISTICS

The consideration in selecting the pneumatic transfer/conveyor system is the type of powder material actuality processed. First consider the bulk density of material for determining the vacuum requirement and vacuum receiver size and air/gas source. So other parameters to consider:

- i. Particle Shape/ Size
- ii. Friability
- iii. Wetness or Moisture Content
- iv. Abrasivity
- v. Toxicity
- vi. Explosiveness

1.8 DESIGN OF PNUMATIC CONVEYING SYSTEM

All pneumatic transfer/conveying systems use pipes lines, ducts or tubes to transport powder materials in a stream of gas or air. Air mediator creates a positive pressure or negative pressure vacuum that pushes material into the line

first and pulls it in last in the system. The basic components of the pneumatic system are:

1.8.1 Pneumatic conveyor system components

- Pressure Blower or Vacuum Pump
- Rotary Valve
- Filter Receiver
- Cyclone Separator
- Dosing System
- Hopper
- Air ejector

1.8.1.1 Pressure blower or Vacuum pump

Components One of two ways to move material can be using a pneumatic transfer system. When designing a conveying system, an important factor is the pressure loss or drop and energy loss across pneumatic transfer system, this is greatest at the end of the system. Blower output determines a flow rate in cubic meter per sec, the speed in centimetres per second. Push or pull the material into the pipeline to destination vessel.

1.8.1.2 Vacuum pump

The moving material another method using by vacuum pump. Mostly vacuum devices are regularly used for dilute phase transfer systems, now dense phase transfer systems applied to vacuum pump system. Recommended vacuum pump electrical are most efficient and way to create a vacuum. As you can see in the figure, the vacuum conveyor the right end of the pneumatic transfer pipeline and draws the material.

1.8.1.3 Rotary valves

The rotary valve is used in solids handling when two areas under pressure need to be separated while transferring material from one situation to the situation. This are used at starting and ending the pneumatic transfer/conveyor systems. In the rotary valve, air is trapped between the inlet and outlet ports of the valve. The valve vanes rotate to create pockets that allow material to enter through the inlet valve. Here the vanes rotate and allow the material to exit through the exit and

travel down. The movement of the vanes in the rotary vane restricts the airflow but allows the material to move continuously. Pressure or vacuum must be maintained in order for rotary valves to function properly.

1.8.1.4 Cyclone separator

The cyclone separator generally used for solid gas separation operations. In this two types forces are applicable one is centrifugal force and second one is gravitational force. The centrifugal force created due to tangential inlet of the inlet stream. Air or gas contain solid particles to remove particles conveying system. Air enters the cyclone separator and the rotation of the cyclone separates a particles, blowing them along with the walls and falling to the cyclone separator bottom side of the vessel.

1.8.1.5 Air ejector

➤ **Principle**

Air is using as motivating fluid. High pressure air is transformed in to high velocity. High velocity entrains and conveying a part of its momentum to the suction fluid. these combined fluids (stream + suction fluid) at low velocity enters the diffuser that's in so formed that it gradually converts velocity energy to pressure energy and discharge the aggregate at a pressure higher than suction pressure but decrease than preliminary motive fluid pressure.

➤ **Main parts**

Air ejector mainly consist of the following parts:

- a. Nozzle.
- b. Body (mixing chamber).
- c. Diffuser.

➤ **Operation of Air-ejector**

- i. The motive stream enters the ejector with a subsonic velocity.
- ii. Because the stream flows inside the converging part of the ejector, its pressure is decreased and its velocity will increase. The air reaches the sonic velocity at the nozzle throat, wherein its Mach No. is identical to 1.
- iii. The increase within the cross section area of the diverging part of the nozzle outcomes in an increase in its velocity to supersonic conditions.

- iv. The nozzle outlet plane, motive stream pressure turns into lower than the vapor pressure of suction liquid and its velocity increases to supersonic.
- v. The Suction liquid at point enters the ejector, wherein its velocity will increase and its pressure decreases.
- vi. The motive air and suction fluid mix inside the suction chamber and the converging section of the diffuser or mixture flows because it enters the steady cross section area of the diffuser. There mixing takes place.
- vii. In constant area segment of throat, the pressure of mixture increases and velocity reduces to subsonic situation.
- viii. Because the subsonic mixture emerges from the consistent cross section area of the throat, further pressure increases inside the diverging section of the diffuser, where part of kinetic energy of the combination is transformed in to the pressure. The pressure of the rising fluid is higher than suction fluid pressure however lower than motive steam pressure.

➤ **Silent feature**

- i. No moving part.
- ii. Can handle even large suction quantities.
- iii. Compact size.
- iv. Can be constructed of any material.
- v. Very reliable
- vi. Low cost.
- vii. Simple operation and can be employed in hot cell as a part of process equipment.

➤ **Limitations**

- i. It cannot be used where there are chances of liquid to get decompose like organic fluid.
- ii. Liquid temperature should be less than 40 °C.
- iii. Jet discharge pipe should be straight for minimum 500 mm.
- iv. Dry air should be used and air pressure range is 5 – 7 kg/cm².

5 kg/cm ²	--	Lower cut off pressure
7 kg/cm ²	--	Higher cut off pressure

➤ ***Disadvantages***

- i. Metering flow rate will not get.
- ii. Off gas contaminated for that off gas treatment required.
- iii. If total dissolved solid (TDS) content of suction fluid is high, than erosion and chocking occurs.

➤ ***Important procedures for operating Pneumatic transfer in dilute phases***

- a. Do not use sloping piping. Backflow (unwinding and reconvening the same material) requires the tube to recovery the product and return to normal loading, so the effect is cumulative. At best, the hoisting load is greatly increased, but the bottom bend is more likely to jam.
- b. Before the first bend, ensure a 'proper' horizontal conveying length to permit the bulk load to speed up to a steady conveying velocity or transferring speed and decrease the line load on transferring/conveying pipe. The material decelerated down by the bend takes up a large portion of the cross sectional area of the tube, further impeding airflow and increasing the pressure drop across the system.
- c. For the same reason as above, do not place elbows too close together on a pipe run.
- d. Deliberate stitching the transfer pipeline in extended runs. Since air enlarges when pressure gradients or pressure drops, it is inevitable that the velocity increases along the path of a given pipe. Material higher velocities increase wear& tear and product degradation in bends.
- e. In dilute phase systems, “more air” means “less permeation capacity”. Greater solid-gas friction losses affected by gas velocities higher can engage more energy than the additional energy initial a particular dilute phase flow system has an optimum gas flow rate. Consult an expert for proper solids/gas ratio and peak power.
- f. Product destruction and wear& tear at bends of pipe lines. This is highly depend on the material characteristics. Blind tees generally have more advantages, they a higher pressure drop or pressure gradient than extended radius elbows.

- g. The rotary valve also leaks, directing the air difference through the empty pocket that came back. Also, rotating an empty pocket to create space for material to flow in tends to fill one side of the valve with product. Backflow of gas and inlet bias cause many delivery complications. A small inlet standpipe line is useful for tasks exiting a cyclone separators or feeding a excessive pressure line.
- h. Make sure the cyclone outlet is unobstructed. For intermittent or regular drainage, provide sufficient buffering capacity so as not to adversely affect cyclone operation.
- i. Consider pressure loss in the supply line to the blower. Consider filters, mufflers, acoustic boxes or compressor housings, and extended umbilical's as needed. To ensure to compensate for temperature increment due to gas compression.
- j. Provision of suitable tools. This is important what's going on and can properly investigate any issues that may arise.

1.9 ADVANTAGES AND DISADVANTAGES OF PNEUMATIC CONVEYING SYSTEM

1.9.1 *Pneumatic Conveying Advantages*

Pneumatic transferring/conveying systems have more advantages compared to other conveying systems.

➤ ***Reduced maintenance requirements.***

Compared to mechanical conveyor systems, pneumatic conveyors have fewer moving parts and typically require less maintenance.

➤ ***Enhanced Security.***

With fewer moving parts and less maintenance required, pneumatic conveying systems pose fewer hazards to operators and maintenance personnel.

➤ ***Reduced spillage and dust emissions.***

Pneumatic Conveying Systems transport product through closed pipelines and retain more product and dust than mechanical conveying systems.

➤ ***Better hygiene.***

The pneumatic conveying system has a sealed pipeline, which greatly reduces the risk of product contamination and keeps plant working environments clean. The pipeline cleaned and dried.

➤ ***More flexibility.***

The pneumatic conveying system customized to existing powder handling/transferring equipment, taking up less space and offering more flexibility than mechanical conveying systems. Several entry and exit points and longer conveying distances are possible.

1.9.2 Disadvantages of Pneumatic Conveying

The pneumatic conveying system is suitable for many powder handling systems, but it is not the best solution for all facilities. The drawbacks are:

➤ ***Reduced energy efficiency***

Because pneumatic conveying systems use airflow to move the product through the system, it usually takes more energy to reach the right air pressure.

➤ ***Requires a larger dust collection system.***

The pneumatic transfer system or conveying system requires a superior fine dust receiving system as the product must be separated from the conveying system air stream at its destination.

➤ ***Some materials are difficult to convey.***

Pneumatic conveying systems are generally excellent for low density bulk powders such as flour, sugar and whey, but are not suitable for larger particle size materials or very sticky materials. For example, fatty materials are difficult to transport by air and can cause deposits in pipelines.

➤ ***Not ideal for combustible bulk solids***

Combustible dust is airborne and poses a deflagration or other fire hazard in the presence of an ignition source. Pneumatic transportation systems use air as their primary means of transportation and require special attention.

1.10 INDUSTRIAL APPLICATIONS

➤ ***Food Industry:***

The food company is a massive industry that always demands greater standards of good hygiene and productivity. For this reason, more and more people are

turning to our pneumatic conveying/transferring systems more hygienic and resourceful than traditional mechanical older transferring methods when transporting materials in bulk.

The pneumatic powder transferring/ conveying system used to transfer a variety of food processing raw materials and finished food products. The different varieties of food materials like oats, rice, , seeds, salt, , starch, gluten, milk products, corn, grains, flour, cereals and whey powders, baking ingredients, cooking additives and flavourings materials etc.

➤ **Pharmacy**

Pharmacy industry-specific requirements mean that all pneumatic transferring/conveyor systems used in the industry must be design and executed in accordance with Good Manufacturing Practice (GMP) guidelines. These guidelines include US Food and Drug Administration (FDA) certification of materials, operation safety, avoid the cross contaminations and comfort of system cleaning. Vacuum transferring/conveying in combination with the Dilute Phase transferring/Conveying system elongated been popular in the pharmacy industry as it can be aspirated to ensure that all powder is retained within the system.

➤ **Chemicals**

The products of the chemical industry can be dangerous and require regulations such as explosion chemicals and toxic, hazards, radioactive materials and fine dust, for controlling the exposers and safe handling the chemicals in environmental surrounds protection needed and avoided the cross-contamination. The pneumatic powder transferring/conveying systems essential for chemical industries.

➤ **Minerals**

The pneumatic powder transferring/conveying systems wide familiarity in design, handling and transferring/conveying systems used in the minerals extraction factories. Examples of the use of these systems in this industry using different sludge blending purpose and inside the tank agitation purpose and the handling or transferring of minerals from lower elevation to higher elevations different kinds of minerals like lime stone, coal, gypsum, cement, different sizes of sand and fly ash etc.

➤ **Plastics/Polymers**

The plastics and polymers industry has been most extensively serviced industry since in 1969, covering all the components used in blending, blending, milling, extrusion and moulding processes. The pneumatic conveying systems process and store materials. And powdered polymers and additives widely transferring from one location to another location.

➤ **Cement**

Two pneumatic powder transfer/conveying systems include dense phase and dilute phase. Dilute phase conveyance: In this method, the cement is suspended in a stream of air, ensuring that the cement powder remains perfectly homogeneous, e.g. during the mixing process

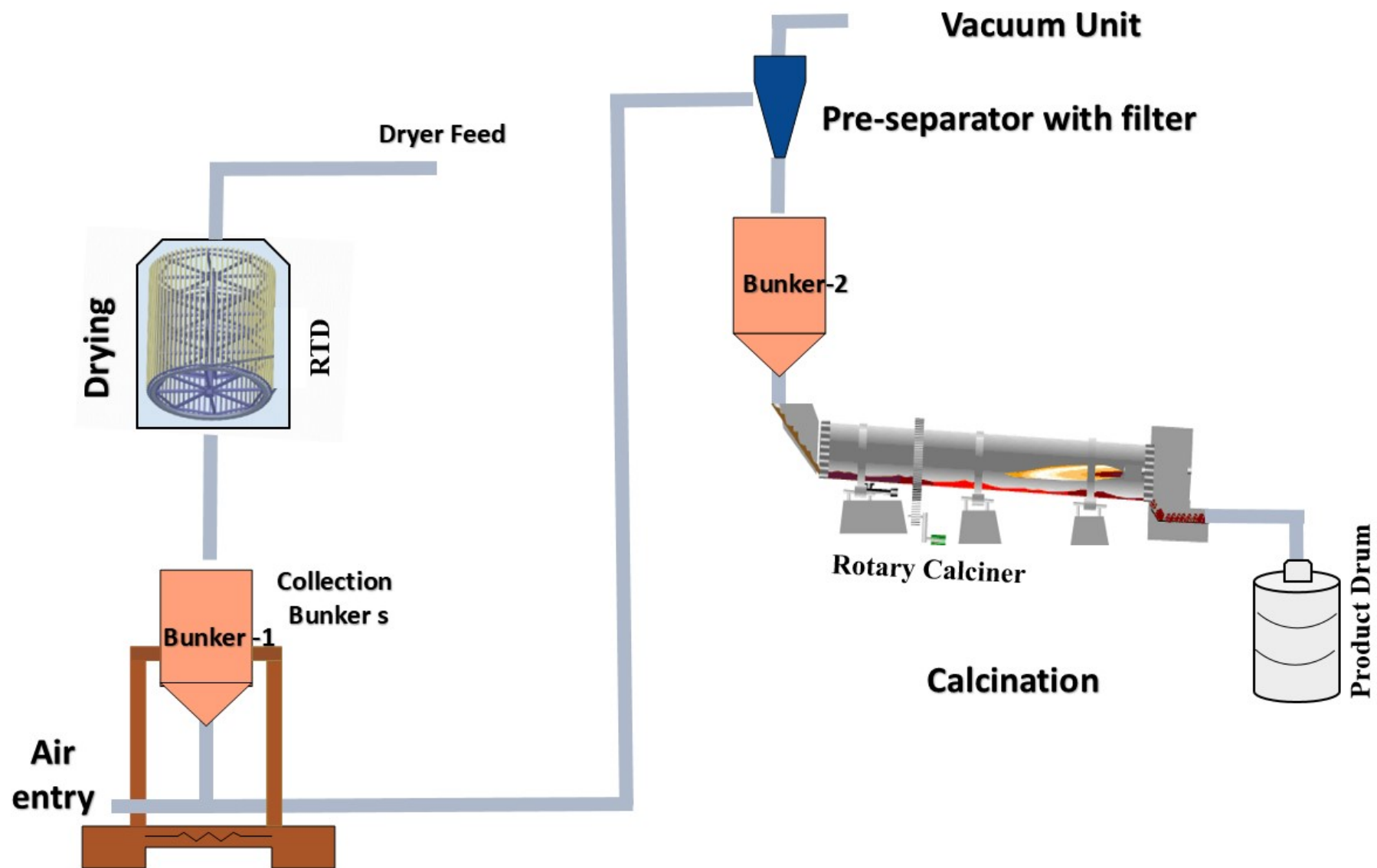


Fig 1.4: Process Flow Sheet of Pneumatic Powder Transfer System in Uranium Oxide Plant

2 CHAPTER

2.1 LITERATURE SURVEY

Solids transfer in industries is mainly carried out in two ways namely: (i) Mechanical transfer which include belt conveyers, screw conveyers, bucket elevators etc. and (ii) Pneumatic transfer. Pneumatic conveying is a prominently used method of transfer in more industries such as coal, sugar, pharmaceutical, food, salt, cement, agricultural seeds, lime, granular chemicals, plastic chips etc.

Uranium Oxide is generated by chemical processing of Uranyl Nitrate solution with Ammonia. During the process, Ammonium Di-Urinate (ADU), an intermittent product is formed which is calcined in the final to obtain Uranium Oxide. ADU is in the form of a powder and conventionally it is transferred mechanically. Powder handling and its transportation are important. ADU powder being radioactive powder pose serious issues such as leakage, spillage, clogging or chocking of transfer lines and equipment and the line, great hold up, radiation cross contamination due to its rotating and moving parts of equipment's, wear and tear, particularly when materials or particles are rasping, thus necessitating regular maintenance while transferring using mechanical mode. Thus, pneumatic transferring/conveying system is opted for transferring the radioactive powder. Pneumatic transferring/conveying system can be functioned in two ways viz., under negative pressure (vacuum) or under positive pressure transfer system. Negative pressure system is favoured for smaller distances while transferring from several different sources to a one are more destination vessel on the other hand positive pressure system is favoured for elongated or extended distances while transferring from a one are more source to several destinations vessel.

Vacuum pneumatic conveying system is more preferred as compared to pressure system as the pressure needs double containment to avoid powder leakage from the system which is not required for a vacuum system. But the only concern is the efficiency which is expected at the time of leakages. Additionally, in positive pressure passage system, there is greater possibility of powder degradation or damage due to attrition and breakage of powder. Thus, negative pressure (vacuum) system is stands on top of the selection over positive pressure transferring system to transport ammonium di-uranate powder. There are general two phases of conveying in pneumatic transportation viz., lean/ dilute phase

transfer and dense phase transfer. In dilute phase transferring/conveying the material was transferred in suspension in air along with the pipeline while in dilute phase material was transferring/conveyed in non-suspension method at minimum velocity throughout or at some parts of the pipeline. This is called flight transport. Conveying material without stopping entirely or part of the pipe at low speed was called high dense phase transferring/conveying. The transportation and handling of ADU powder occurs frequently in the nuclear industry.

The properties of ADU powder depend on the previous stage of the manufacturing process, and its quality influences the uranium oxide powder produced in subsequent stages. The powder is radioactive and toxic. Uranium oxide powder must be handled with great care to prevent human exposure and environmental spread. Since the particle is valued, great retrieval is the primary goal for the duration of processing. At a same time, it is essential that the particles does not decompose (distribution or change particle dimensions) for the duration of conveying. However, hence there is inadequate literature support for pneumatic transfer of ADU particles. Previously, ADUs were manually transferred to the Uranium Oxide Factory (UOF) under approved administrative controls. Efforts have been made to designing and develop pneumatic powder transfer systems for valued and dangerous or harmful powders with grater conservational safeguard, suitable for nuclear and similar chemical industrial applications. Generally, in a vacuum, the pneumatic system is created by a blower/ air ejectors

Here, in the current study, a new proven technique for vacuum generation, i.e.air ejector, was verified and the outcomes were matched with those of existing methodologies. Also, tests were performed both flowable and non-flowable solids.

P. Guo et al. studied Pneumatic conveying systems design for solar particle tower systems whose net energy consumption is less as compared to the mechanical hoist systems has been discussed extensively. The effect of temperature on energy requirement and the effect of surface to volume on wall losses has been studied. The study concludes that with the increase in the temperature the energy requirement decreases due to the decrease in voidage and wall losses reduced upon the increase in pipe diameter due to the reduction in surface area to volume ratio. Shibo et al. studied a model of CFD-DEM has been developed to study a pneumatic system of 102 m which consists of two vertical pipes, seven horizontal pipes and eight bends. The model consists of a short pipe with much longer

developed flow zone to reduce the computational load. The model also include the air compressibility. The model predicts the particle rope formation and disintegration.

L.P. Dhole et al. carried out a study by using venture feeding in push pull type pneumatic system to develop suction head at the venture throat. The study concludes that by using this technique maximum suction effect is attained but the material flowrate is not up to the desired flow. This can be achieved by increasing the quantity of air and by changing the dimensions of system. S. Manna et al. designed a special pneumatic system specifically for Uranium Oxide powder transfer. The particle size distribution before and after the transfer, its recovery, safety and environmental issues have been addressed in the study. The study concludes that 99.5% efficiency is achieved with the technology and also almost zero cross contamination was obtained.

K. Amila Chandra et al. studied the prediction of flow characteristics by using MP-PIC Method in a pneumatic conveying system. The result show a reasonably satisfactory predictions of the dilute phase pneumatic conveying system using MP-PIC Method. P. Akhil Raj et al. studied the replacement of the existing system for powder transfer with the pneumatic transfer system. The design is intended for a long term permanent solution to avoid spillage and reduce the revenue. S. Umarul Farooque et al. proposed, designed and estimated the cost of replacing the current system with pneumatic transfer system. The design is meeting the standards set for the existing system and also satisfies the functional requirement.

Lv Juan [8] worked on numerical modelling of sulphur powder charging characteristics in pneumatic conveying system. The results conclude that there is considerable effect of bend ration on mass ratio of sulphur powder and is inversely proportional. Woo Chang Sung et al. studied the effect of particle size distribution on hydrodynamics of pneumatic conveying system based on CPFD Simulation. The main parameters of the study includes saltation velocity, and pressure drop per length. Q. Guan et al. studied the characteristics of conveying and operating and structural parameters which influences mechanism. Models of pressure drop for horizontal and vertical pipes were established. The solid flow rate is directly proportional total pressure drop. E.O Amponsah-Abu et al. designed and constructed controller ad simulated the actual scenario by using electric bulbs.

3 CHAPTER

3.1 AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1.1 Aim

- To understand the basic pneumatic conveying system and to study the effect of different variables on system design.
- To transfer the particulate/ powder material between storage locations to different feeding equipment.
- To determine the energy loss produced inside the pipeline due to friction and bends.
- To find the different size particles fluidizing velocities at different pneumatic flows.

3.1.2 Scope

- To design of Dilute Phase Vacuum Conveying System and Calculation of its saltation velocity.
- To find the pipeline diameter, length and the material of the pipe.
- To transfer of bulk quantity of powder material.

3.1.3 Methodology

3.1.3.1 Dilute Phase Pneumatic Vacuum Conveying System

- Dilute phase pneumatic transfer/conveying is a method of moving non-abrasive, non-fragile materials that have a low bulk density. The materials move along an enclosed pipe, in slug form using small amounts of gas/air at a high velocity and low pressure.
- Transportation of solids as entrained solids in air stream with air as conveying medium under vacuum from a source to destination vessels.

3.1.3.2 Major Design Parameters for Pneumatic Conveying of Solids:

- The solids + gas mixing ratio (Solid Loading Ratio)
- Air flow rates.
- Pressure heads and Separation of suspended solids from air stream

4 CHAPTER

4.1 EXPERIMENTAL STUDIES, MATERIALS AND METHODOLOGY

4.1.1 *Experimental Studies*

Characteristics of the powder to be transported play a key function at the overall performance of the pneumatic conveying device. Standard characteristics of ADU powder are indexed in **Table 4.1** the air flow rate required for powder conveying is directly proportional to the particle density and particle size. Consequently, this impacts the capability of the blower and its rating. Salting velocity is prime parameter which shows the regime of go with the flow all through its managing. Elements on which salting velocity relies upon on are particle size, particle density, particle shape, overseas debris inclusion, and many others. Conveying of powders at low salting velocity may purpose a number of mechanical issues which includes jamming, accumulation, choking, seal leakage and so on. Which make contributions to decrease in performance and powder recovery. Also, conveying of powder having moisture may be very tough as it blocks the line and filter cloth. Similarly, the material of construction of the device need to be immune to erosion/ corrosion so that you can keep away from contamination of transported powder

Table 4.1: Typical Characteristics of ADU and Silica Sand

S. No.	Characteristics	ADU	Silica Sand
1.	Specific gravity	4.6 – 5.2	2.2 – 2.5
2.	Bulk density	5.4 - 6.0 gm/cc	2.4 - 2.6 gm/cc
3.	Moisture content in the cake	0.5 %	0.1 %
4.	Angle of repose	55°	34°
5.	Size	30 µm	300 µm

Sand with similar physical properties has been used for the experiment. The typical characteristics of the sand used for the experiment are presented in **Table 4.1**. Two vessels of 0.6 m length each having a volume capacity of 5 lits for source vessel and 7 lits of destination vessel. Source vessel can accommodate 7 kg and destination vessel can accommodate 10 kg of sand. The experiment envisages the transfer of silica sand in a SS pipe having a vertical run of 1.5 m and horizontal run of 0.5 m. there a total of 3 bends in the line which are all elbow bends. The bend factor for the bends is 0.7. Two separate experimental conditions have been

used for generating vacuum viz., blower and air-ejector. The blower has a maximum power rating of 1400 kW and has a capacity of generating -4000 mm WC vacuum. Air ejector used in the experiment is having a nozzle of size 8 NB and the maximum Head that can be achieved is -1600 mmWC (Compressed air is used as a working motive fluid and operation pressure is $4.5 - 6.5 \text{ kg/cm}^2$). In each experimental condition, two set of sub conditions were tested i.e., sand in fluidized condition and sand in non-fluidized condition. The fluidization of the sand has been done by using compressed air with varying pressures having a flow rate of 2.2 lph. The experimental setup which is used for testing is presented in **Fig.4.1** the material collected from the destination is weighed by using weighing machine in the given time. The vacuum generated and the flow rate are measured and logged. There are a total four set of experimental conditions tested.

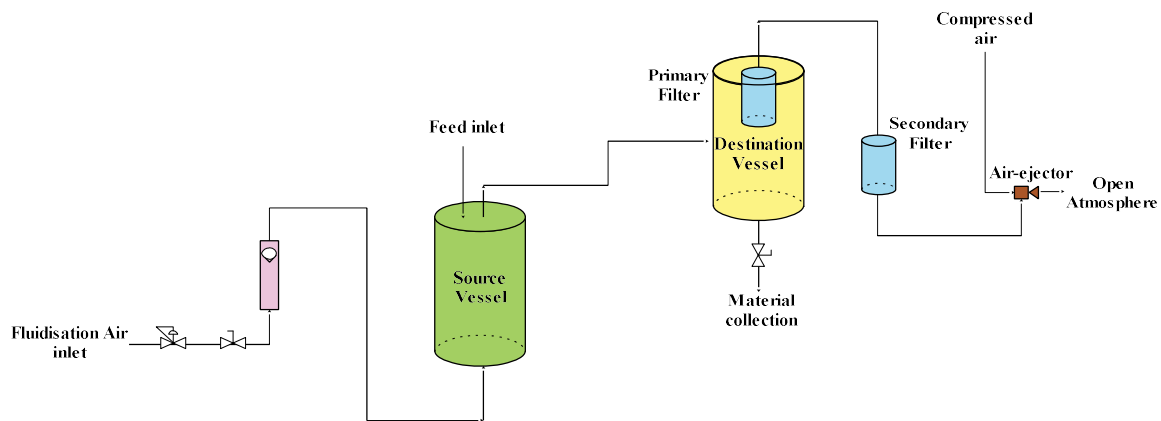


Fig 4.1: Dilute Phase Vacuum Conveyor System (with fluidization) using air ejector

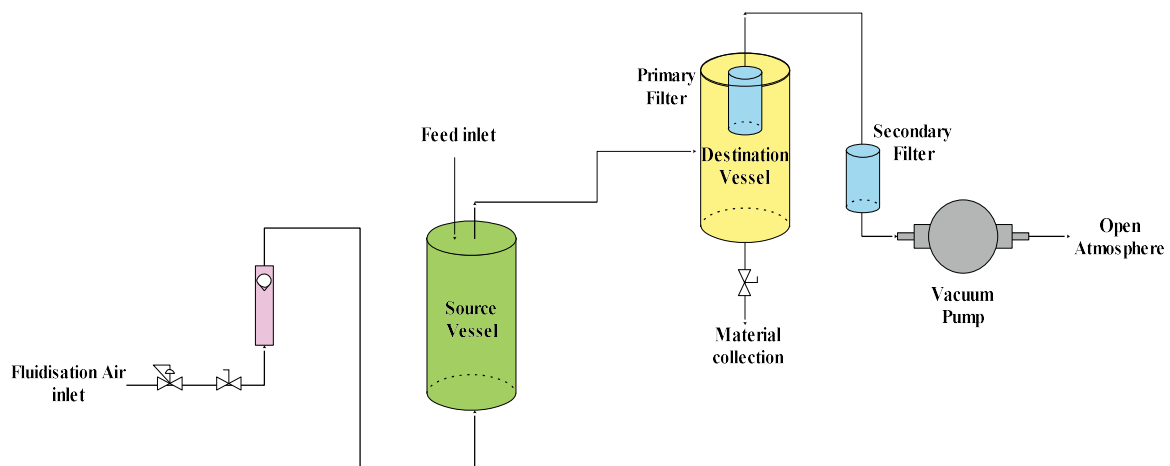


Fig 4.2: Dilute Phase Vacuum Conveyor System (with fluidization) using vacuum pump

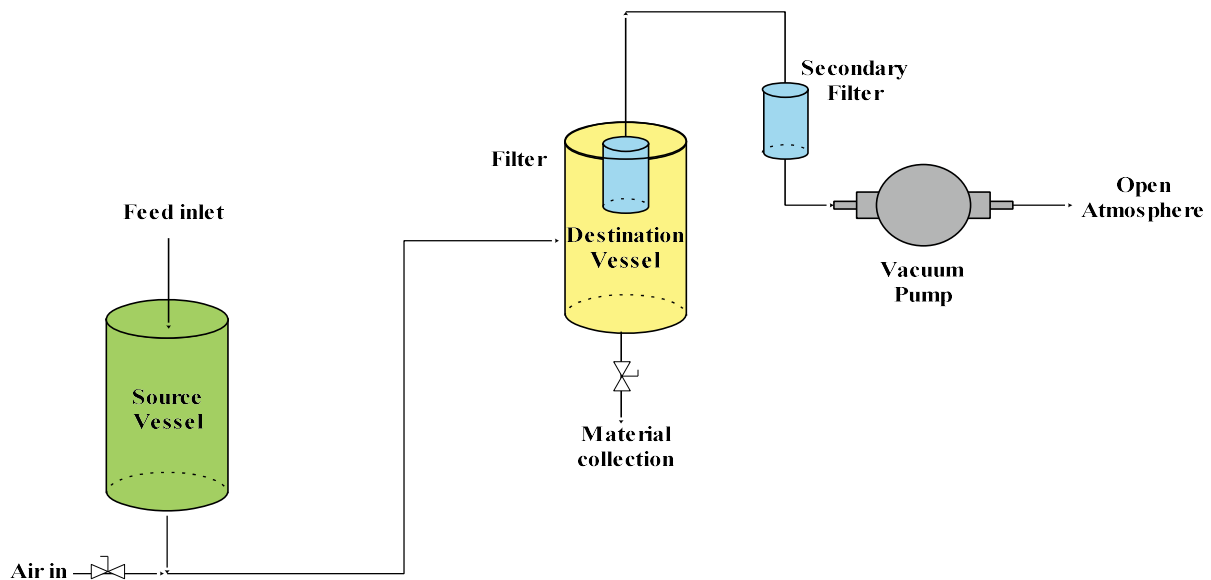


Fig 4.3: Dilute Phase Vacuum Conveyor System (without fluidization) using Vacuum unit.

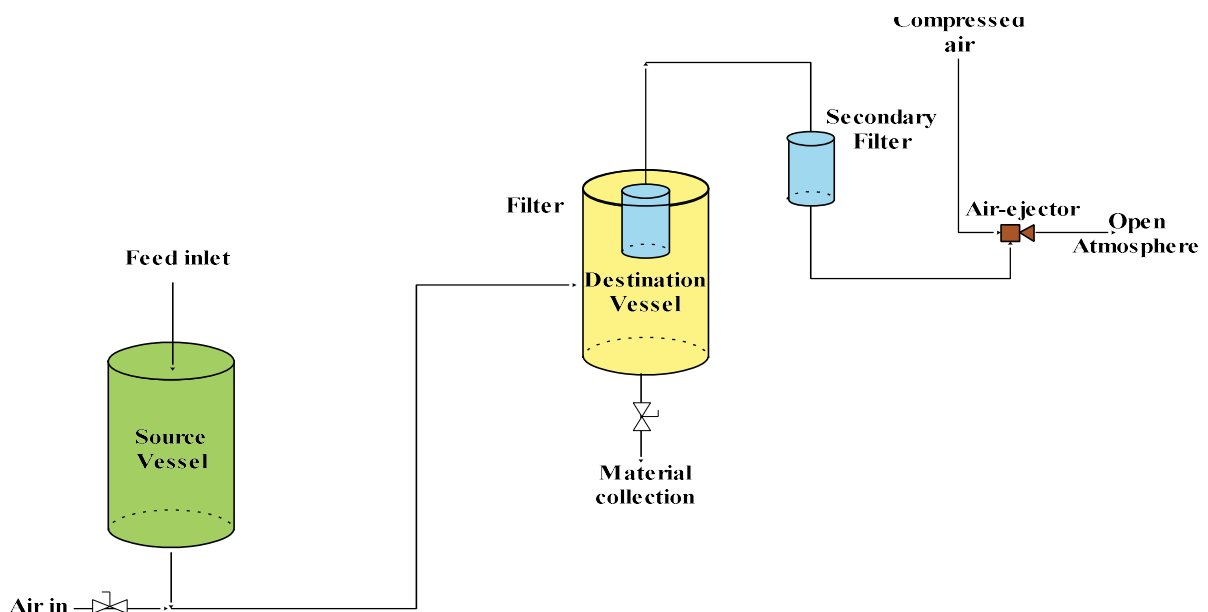


Fig 4.4: Dilute phase vacuum conveyor system (without fluidization) using air ejector

4.1.2 Experimental Procedure

- Material description
- Equipment details
- Experimental procedure

Ammonium di-urinate powder generated from the drying operation equipment has to be transferred to a calciner for calcination to produce Uranium Oxide. The transfer is usually carried out by filling the ADU powder in a bunker and the bunker is transferred by using a crane to the feeding hopper of the calciner. The whole

operation is a batch operation and has a high chance of powder spillage, bunker mishandling and contamination. ADU is toxic and radioactive. Its usage in experiment poses serious safety issues such as radiation exposure to the person working in the experimental area and the powder being fine may cause contamination. Hence, Silicon sand of similar physical properties has been used for the experiment.

Table 4.2: Sand Composition

S. No.	Component	Percentage (%)
1.	Silica as SiO ₂	97.48
2.	Magnesium as MgCO ₃	0.63
3.	Iron as Fe ₂ O ₃	1.14
4.	Calcium as CaO	0.14
5.	Alumina as Al ₂ O ₃	0.2

Table 4.3: Sand Characteristics

S. No.	Sand Characteristics	Magnitude
1.	Appearance	White crystalline
2.	Chemical purity	Silica > 95% SiO ₂
3.	Fraction size	+297 – 420 micron (+50 – 40) mesh
4.	Hardness	7-8 moh
5.	Strength	25 kg/cm ²

Table 4.4: Experimental Equipment Details

S. No.	Equipment	Range/ Capacity
1.	Transparent cylindrical conical bottom vessels – 2 no.s	5 lits & 10 lits
2.	Pressure Regulating Valve	upto 2 kg/cm ² range
3.	Pressure Gauge	upto 2 kg/cm ² range
4.	Digital Manometer (for measuring vacuum)	-4000 mm WC to 0 mm WC
5.	Vacuum unit – Roots Multipurpose make	1200 to 1300 W, 50 Hz

6.	SS mesh for filtration	50 μm
7.	Rotameter for measuring air/ fluidization flow rate	0-300 lpm
8.	Hot wire anemometer (digital)	Upto 50 m/s
9.	S.S. Pipe	19 mm dia. and length 2 m
10.	Weighing machine	Upto 10 kg
11.	Rotary Air Valve/ Gate valve – 2 no.s	20 NB
12.	Ball valves – 1 No.	20 NB
13.	Air ejector	8 NB 0.6 to 17 lpm flowrate
14.	Funnel	--
15.	M seal, sealant	--
16.	Experimental stand	--

4.1.3 Steps involved in the experiment

- Experimental set up is ready/ available.
- Known quantity of sand has been taken and charged in to the source tank.
- Vacuum unit/ system connected to destination vessel ensured.
- For measuring air flow rate and vacuum in source vessel. Hot wire anemometer and manometer connected and check for its working/ healthy condition.
- For fluidizing source vessel/ source tank bed, compressed air with regulated pressure valve to control flow of air passing through rotameter has been used.
- As the silicon sand in Source tank/ vessel starts to fluidize, record the fluidization pressure.
- Once the column gets fluidized, start vacuum unit for pneumatic conveying.
- Record the initial vacuum and air flow rates.
- Record the flows at different vacuum by adjusting the control valve.
- Record the time taken for complete transfer of sand.
- After complete material/ sand transfer, drain the sand and weigh the sand collected (material flow from bottom of the source vessel to elevated destination tank with a tangential inlet)
- Repeat the experiment for different fluidization pressures such as 0.2, 0.4, 0.6 and 0.8 kg/cm².

- Plot the flowrates for different fluidization pressures, system vacuum and material movement.
- Repeat the experiment without fluidization condition and connected to vacuum unit/air ejector (material flow from bottom of the source vessel to elevated destination tank with a tangential inlet)
- Plot the flowrates for ejector air pressures, system vacuum and material movement.
- Plot the salting velocity graph at different fluidizations pressure air flow rate and pressure drop/ unit length.
- Compare the theoretical salting velocity, solid loading ratio with experimental values using the vacuum unit/air ejector and find the system pressure drop and power requirement.
- Experimental results and observations reported.

5 CHAPTER

5.1 EXPERIMENT RESULT AND DISCUSSION

To design an air transportation system, we need to calculate the following design data:

- Pipeline diameter, length and pipe material design.
- Pressure loss in pipelines because of friction and bends.
- Selection of Air Movement Systems, Drive Systems, Material Feed Systems, and Stationary Gas Discharge Systems

All the above standards have been designed and decided on using preferred design calculations from David mills' Pneumatic Conveyance system design manual/ guide.

When designing a new pneumatic system layout, the primary consideration is the mode of transport or operation. Since methods for conveying powder such as particles have been proposed, dilute phase conveying is the most ideal conveying method.

For dilute phase formation, the important variables to consider are:

- **Solids Loading Factor (S)**

Solids loading factor or dense segment is a beneficial parameter for visualizing flow. It's miles the ratio of the mass go with the flow rate of the material being conveyed divided with the aid of the mass flow rate of the air used to deliver the material. It's far expressed in a dimensionless form. For flight acceleration, the favoured solids to air ratio is 2:1.

$$S = m_s / m_a \quad (1)$$

m_s = mass flow rate of powder (kg/sec)

m_a = mass flow rate of air (kg/sec.)

S = Solid loading factor

- **Conveying capacity**

In the standard design of pneumatic transferring, the transferring capacity is inversely proportional to the transferring distance:

$$\text{Transferring capacity} \propto 1/(\text{Transferring distance}) \quad (2)$$

➤ **Conveying pressure**

Transferring pressure and the transport distance relationship is linear or proportional. This means that the longer the Transferring distance, the greater the pressure available for transferring, thus affecting the overall transferring capacity of the device.

$$\text{Transferring pressure} \propto \text{Transferring distance} \quad (3)$$

➤ **Design Calculation**

The design calculation uses values such as powder density, mass, etc., and also considers the conveying length of horizontal and vertical cross sections.

➤ **Piping Design**

To design the duct that carries the powder/ air mixture from the starting point to the discharge point, take into account two sections of duct, one horizontally and one vertically.

Total pipeline length = 2 m

Horizontal section length = 0.5 m

Vertical section length = 1.5 m

Number of bends = 3 no

5.1.1 Experimental System Design

Pneumatic conveyor system design requires the following parameters: Material, Length and diameter of pipeline used.

Design basis: Material transfer rate, $m_s = 50 \text{ kg/hr}$

The properties used for the design calculation are given in **Table 5.1:**

Table 5.1: Properties Used for the Design Calculation

S. No	Property	Symbol	Value
1	Sand density (kg/m ³)	ρ_s	2500.00
2	Gas density (kg/m ³)	ρ_g	1.18

3	Viscosity of Air at 30°C (Pa.s)	μ	0.0000185
4	Particle diameter (m)	d_p	0.000300
5	Surface Roughness of pipe	ϵ	0.00010
6	Long Bend	-	90°
7	Bend factor	K	0.70
8	Diameter of Pipe (m)	D	0.019
9	Pipe total length (m)	L	2
10	Horizontal length	L_h	0.5
11	Vertical length	L_v	1.5

Calculation of Saltation Velocity:

Empirical Correlation is given by Rizk

$$u_{salt} = \left[\frac{4m_s 10^a g^{b/2} D^{(b/2-2)}}{\rho_g \pi} \right]^{1/(b+1)} \quad (4)$$

$$a = 1440d_p + 1.96$$

$$b = 1100d_p + 2.5$$

Saltation velocity, $u_{salt} = 6 \text{ m/s}$

Calculation of gas velocity & solid particle velocity:

Saltation Velocity, $u_{salt} = 6.0 \text{ m/s}$.

To have the flow in dilute phase & solid loading ratio: 2.4, multiplication factor=2.7

Velocity of $u_{solid} = 2.7 \times 6$ $u_{solid} = 16.20 \text{ m/s}$.

Taking in account of slip between solid & gas, (dividing factor 0.9),

Velocity of gas V_g :

$$V_g = 16.20/0.9 \quad V_g = 18.0 \text{ m/s}.$$

Solid loading ratio S:

$$S = \frac{m_s}{m_g} = \frac{m_s}{\rho_g \times A \times V_g} \quad (5)$$

$$S = 0.0138 / (0.0002832 \times 1.12 \times 18) \quad S = 2.4$$

Superficial gas velocity U: =1.5 times of u_{salt}

$$U = 1.5 \times 6.0 \quad U = 9 \text{ m/s}$$

Calculation of diameter of pipe A:

Diameter of pipe selected (actual)

$$D = 19\text{mm}$$

Cross-sec area of pipe

$$A = \pi (D^2) / 4$$

$$A = 0.785 \times 0.019 \times 0.019$$

$$A = 0.000284 \text{ m}^2$$

9.4.0 PRESSURE DROP CALCULATION:

Total length of pipe,

$$L = 2 \text{ m}$$

Vertical length of pipe line,

$$L_v = 1.5 \text{ m}$$

Horizontal Length of pipe line

$$L_h = 0.5 \text{ m}$$

Pressure drop due to solid acceleration ΔP_1 :

$$(\Delta_{P1}) = \left(m_s \times \frac{V_s}{A} \right) \quad (6)$$

$$\Delta_{P1} = (0.014 \times 16.02) / 0.000284$$

$$\Delta_{P1} = 800.3 \text{ Pa}$$

$$\text{Re No for gas/ air} = (1.18 \times 18 \times 0.019) / 0.0000185$$

$$= 21814.5$$

$$\text{Relative Roughness } \varepsilon / D = 0.000010 / 0.019$$

$$\varepsilon / D = 0.00052 \text{ (}\varepsilon \text{ value from graph)}$$

Friction Factor (From Moody graph)

$$f_g = 0.022$$

Pressure drop due to gas and wall friction ΔP_2 :

$$(\Delta_{P2}) = \left[\left(f_g \times \frac{L}{D} \right) + \sum K_m \right] \times \left(\rho_g \times \frac{V_g^2}{2} \right) \quad (7)$$

$$\Delta_{P2} = (0.02 \times 2 / 0.019) + (3 \times 0.7) \times (1.12 \times 0.5 \times 18 \times 18) \quad \Delta_{P2} = 844.1 \text{ Pa}$$

$$f_s = \frac{(55.5 \times D^{1.1})}{(V_g^{0.64} \times D_p^{0.26} \times \rho_s^{0.91})} \quad (8)$$

$$f_s = ((55.5 \times 0.019^{1.1}) / ((18^{0.64}) \times (0.019^{0.26}) \times (2500^{0.91}))) \quad f_s = 0.000743$$

$$K = \left[\left(f_s \times \frac{V_s}{f_g \times V_g} \right) \right] \quad (9)$$

$$K = ((0.000743 \times 16.20) / (0.022 \times 18.0))$$

$$K = 0.0304$$

Pressure drop due to solid and wall friction ΔP_3 :

$$\Delta_{P3} = K \times S \times \Delta_{P2} \quad (10)$$

$$\Delta P_3 = 0.0304 \times 2.4 \times 844.1$$

$$\Delta P_3 = 60.60 \text{ Pa}$$

Pressure drop due to gas lift ΔP_4 :

$$\Delta P_4 = g \times h \times \rho \quad (11)$$

$$\Delta P_4 = 9.81 \times 1.5 \times 1.18 = 17.36 \text{ Pa}$$

Pressure drop due to solid lift ΔP_5 :

$$\Delta P_5 = (h \times \text{mass flow rate of solid} \times g) / (\text{Area} \times V_s) \quad (12)$$

$$\Delta P_5 = (1.5 \times 0.014 \times 9.81) / (0.000284 / 0.014) = 44.86 \text{ Pa}$$

Total Pressure drop ΔP_{Total} :

$$\Delta P_{\text{Total}} = (\Delta P_1 + \Delta P_2 + \Delta P_3 + \Delta P_4 + \Delta P_5) \quad (13)$$

$$\Delta P_{\text{Total}} = 1767.321 \text{ Pa}$$

$$\text{Equivalent pressure Head require in m WC} = 0.1802 \text{ m}$$

Power requirement calculation (using vacuum unit/Air ejector):

Required Flow Rate Q:

$$Q = \text{Density of Gas} \times \text{Cross-Sectional Area} \times \text{Velocity of Gas} \quad (14)$$

$$Q = 1.18 \times 0.000284 \times 18 \times 3600 = 21.66 \text{ CMH}$$

$$\text{System Head Required, H} = 0.1802 \text{ m WC,}$$

Power Required P:

$$P = 1000 \times 9.81 \times 0.180162 = 10.64 \text{ W}$$

$$P = 0.01064 \text{ kW}$$

5.1.2 Observation Tables

Pneumatic powder transfer experimental studies carried out various methods (like Variation of powder transfer rate with air velocity fluidization of solids for blower system, non-fluidization of solids for blower system and using air ejectors) and varying the parameters other parameters performance noted and related observations tables and correlating graphs drawn.

Table 5.2: Variation of Powder Transfer Rate with Air Velocity Fluidization of Solids for Blower System (Fluidization Air Pressure 0.2 kg/cm²)

S.No	Fluidization Pressure (kg/cm²)	System Negative Pressure (mmWC)	Air Velocity (m/sec)	Powder Transferred (kg/min)
1	0.2	-1532	1.4	0.80
2	0.2	-1182	1.7	0.82
3	0.2	-789	2.8	0.85
4	0.2	-732	3.5	0.90
5	0.2	-650	5.9	0.86
6	0.2	-1120	7.2	0.82

Table 5.3: Variation of Powder Transfer Rate with Air Velocity Fluidization of Solids for Blower System (Fluidization Air Pressure 0.4 kg/cm²)

S.No	Fluidization Pressure (kg/cm²)	System Negative Pressure (mmWC)	Air Velocity (m/sec)	Powder Transferred (kg/min)
1	0.4	-710	3.5	0.84
2	0.4	-350	8.9	0.90
3	0.4	-550	9.1	0.85

Table 5.4: Variation of Powder Transfer Rate with Air Velocity Fluidization of Solids for Blower System (Fluidization Air Pressure 0.6 kg/cm²)

S.No	Fluidization Pressure (kg/cm²)	System Negative Pressure (mmWC)	Air Velocity (m/sec)	Powder Transferred (kg/min)
1	0.6	-444	10.0	0.84
2	0.6	-300	9.9	0.90
3	0.6	-510	9.3	0.85

Table 5.5: Variation of Powder Transfer Rate with Air Velocity Non - Fluidization of Solids for Air Ejector System (Air Ejector Pressure 6 kg/cm²)

S.No	Air Ejector Pressure (kg/cm²)	System Negative Pressure (mmWC)	Air Velocity (m/sec)	Powder Transferred (kg/min)
1	6.0	-770	2.0	0.84
2	6.0	-380	2.5	0.90
3	6.0	-610	3.0	0.85

Table 5.6: Variation of Powder Transfer Rate with Air Velocity Non - Fluidization of Solids for Vacuum System

S.No	System Negative Pressure (mmWC)	Air Velocity (m/sec)	Powder Transferred (kg/min)
1	-1362	3.0	0.80
2	-861	3.5	0.82
3	-741	4.0	0.83
4	-624	4.5	0.84
5	-579	5.0	0.85
6	-547	5.5	0.88
7	-1268	6.0	0.85

5.1.3 Result graphs:

5.1.3.1 Fluidization of solid material with different pressures parameters graphs.

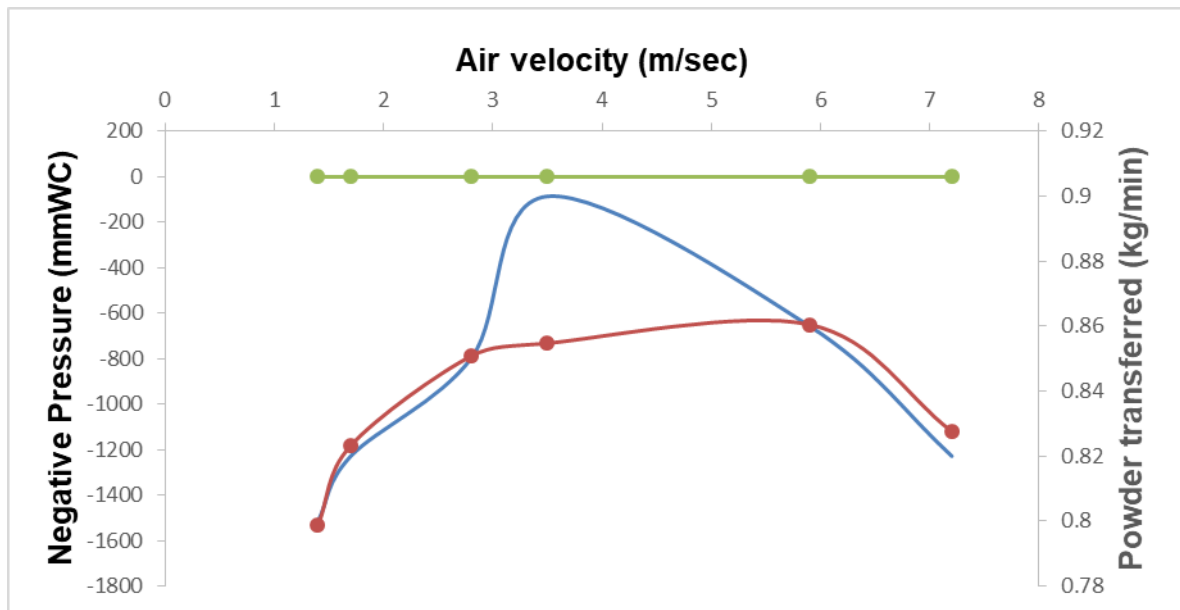


Fig 5.1: Variation of powder transfer rate with air velocity fluidization of solids for blower system (fluidization air pressure 0.2 kg/cm²)

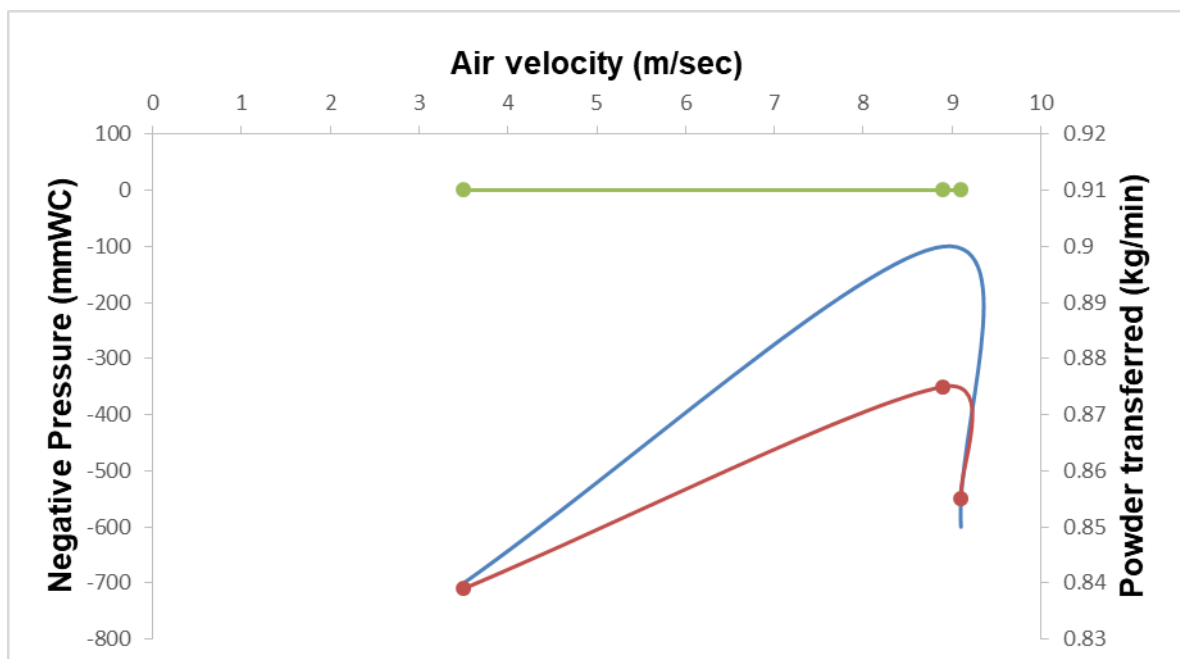


Fig 5.2: Variation of powder transfer rate with air velocity fluidization of solids for blower system (fluidization air pressure 0.4 kg/cm²)

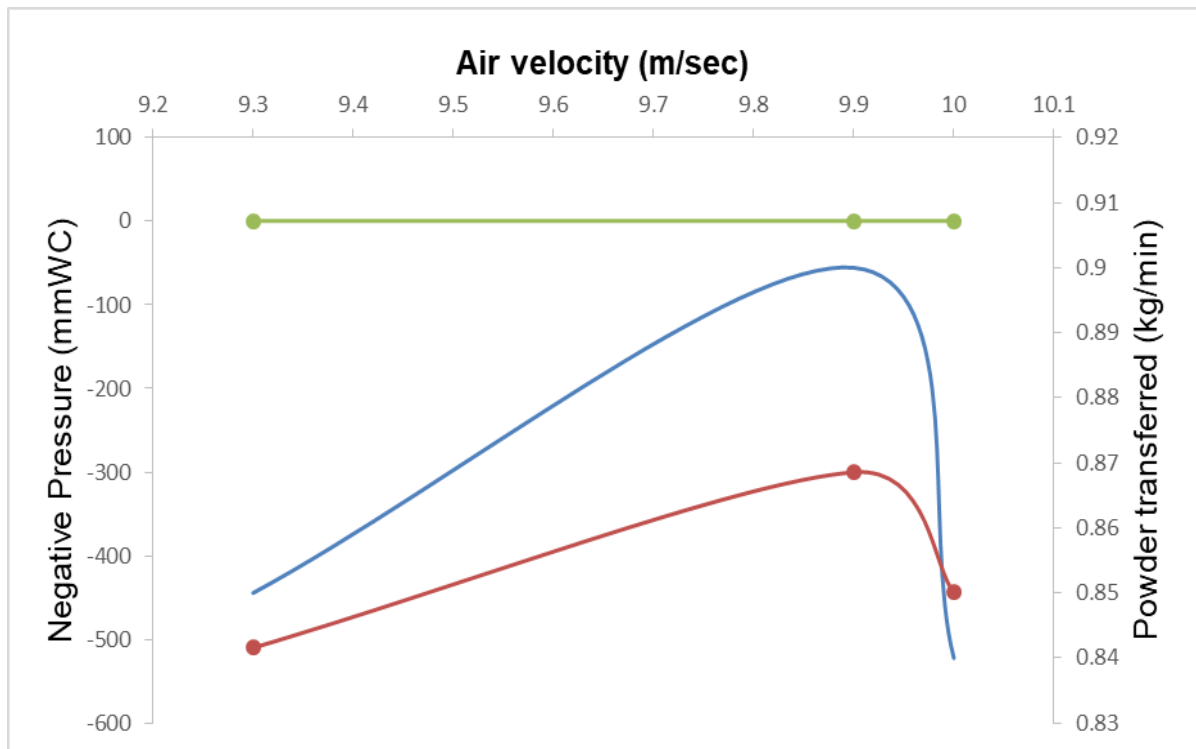


Fig 5.3: Variation of powder transfer rate with air velocity fluidization of solids for blower system (fluidization air pressure 0.6 kg/cm²)

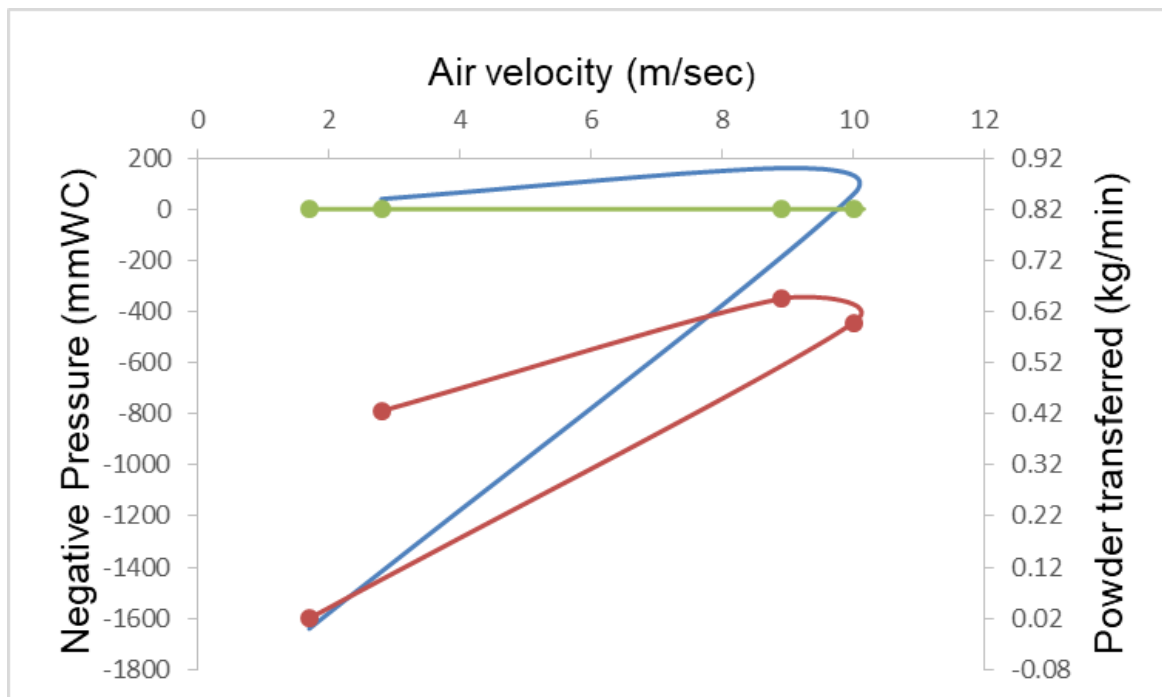


Fig 5.4: Variation of powder transfer rate with air velocity fluidization (different pressures 0.2, 0.4 and 0.6 kg/cm² comparisons) of solids for blower system

5.1.3.2 Non-fluidization of solid material with using air ejector & blowers graphs

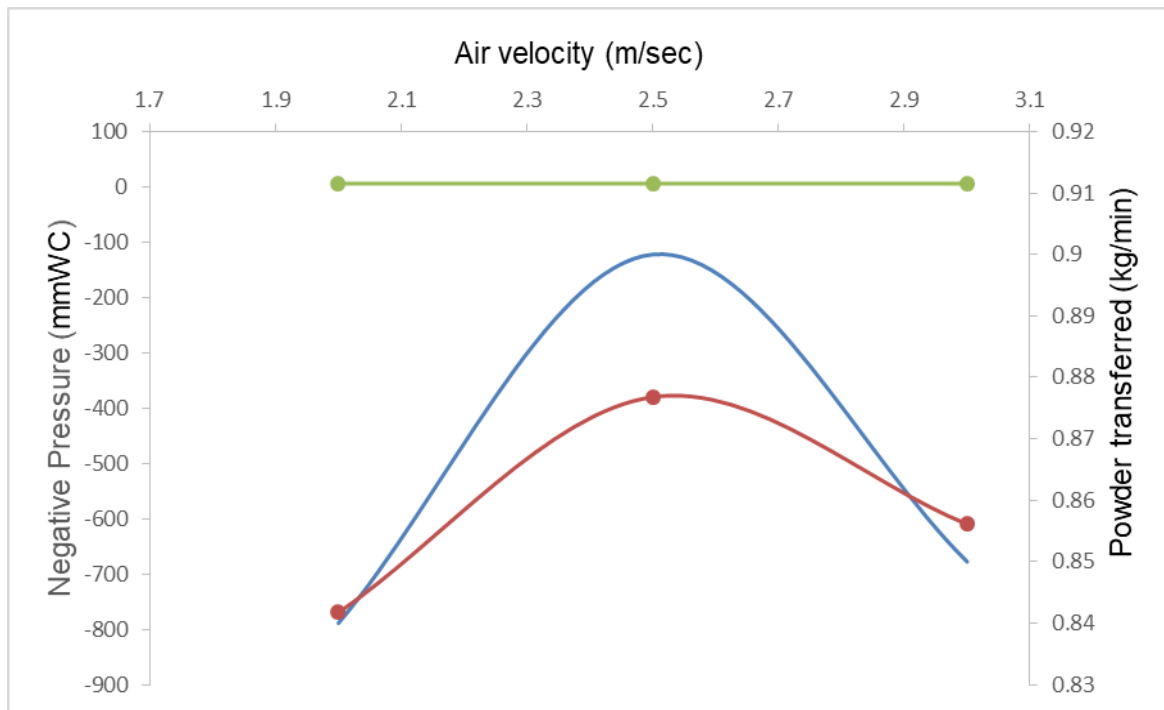


Fig 5.5: Variation of powder transfer rate with air velocity non -fluidization of solids for air ejector system (air ejector pressure 6 kg/cm²)

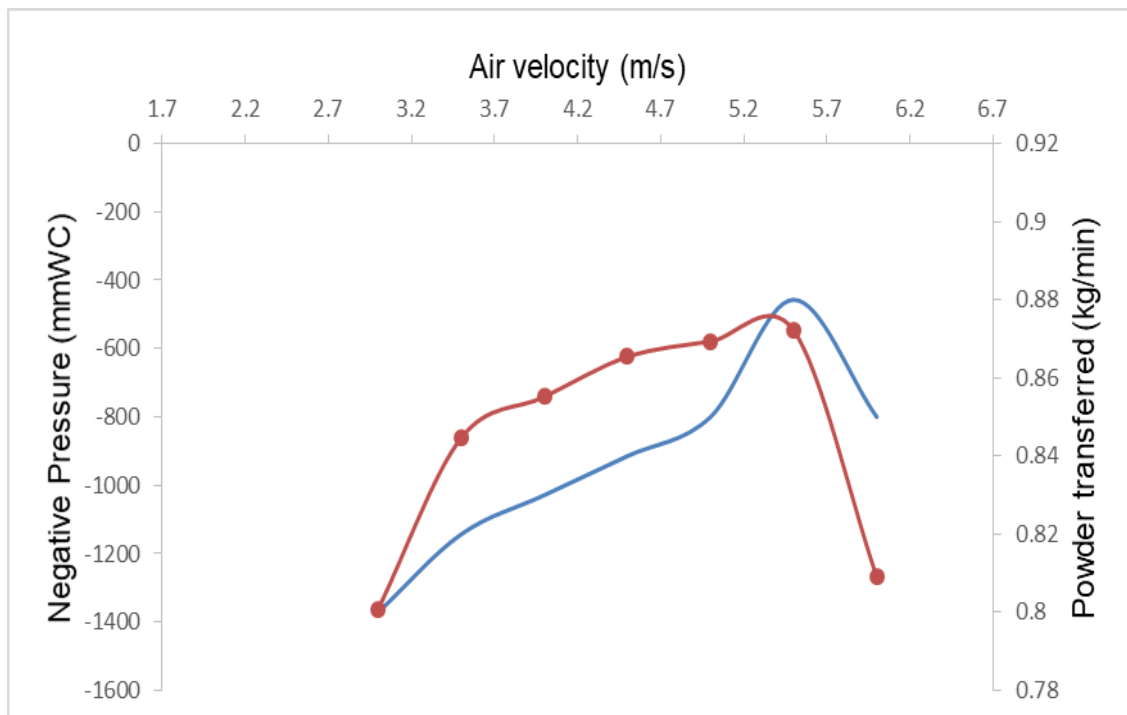


Fig 5.6: Variation of powder transfer rate with air velocity non-fluidization of solids for blower system

5.1.4 Saltation velocity experiment results

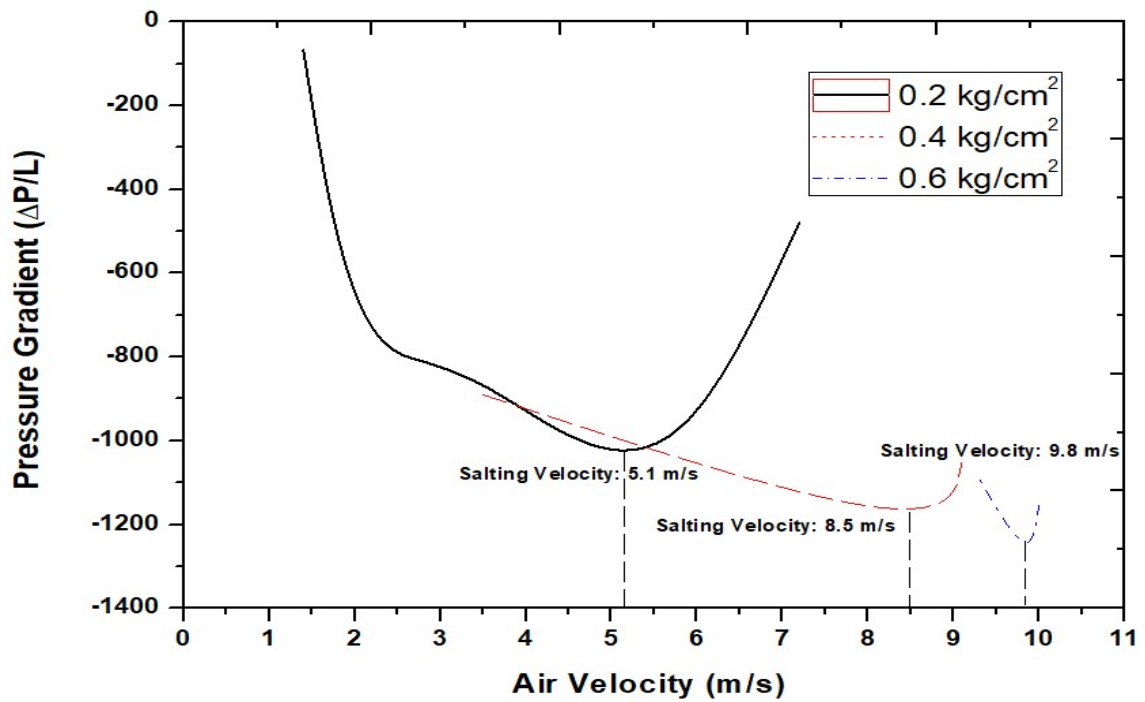


Fig 5.7: Pressure gradient with air velocity for various fluidization pressures

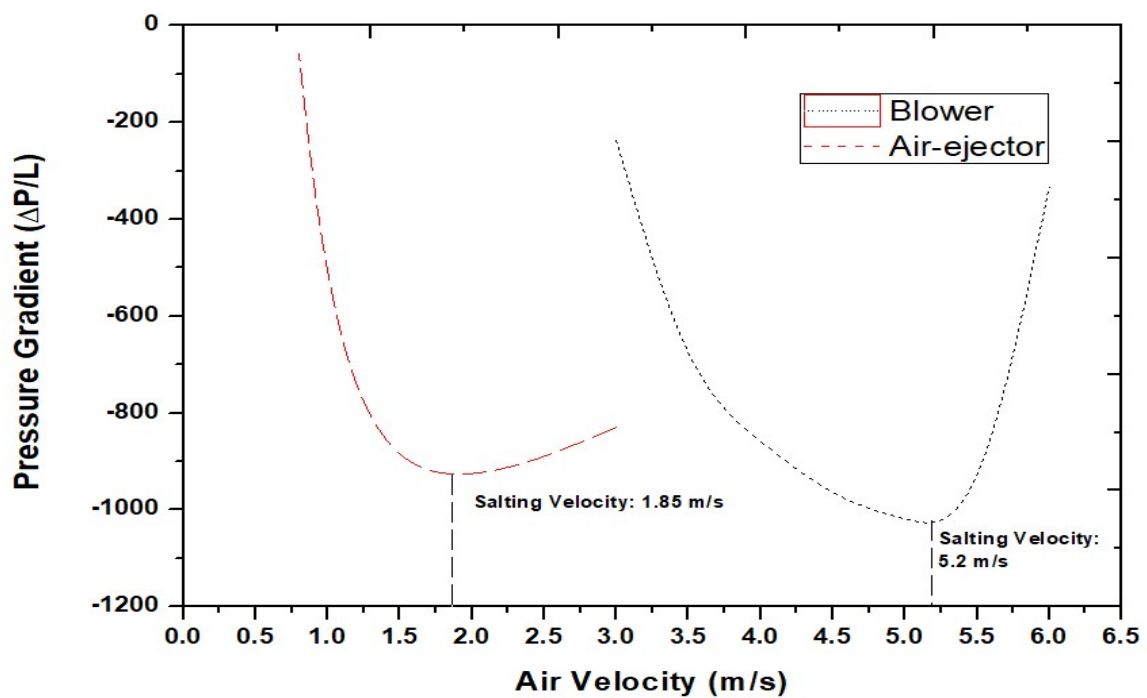


Fig 5.8: Pressure gradient with velocity at non-fluidization of solids for both blower system and air-ejector system

5.2 SALTING VELOCITY GRAPH DISCUSSION/ OBSERVATION

As shown in **Fig 5.17**, it can be observed that as the fluidization pressure increases the salting velocity increases. Hence, for the current case 0.2 kg/cm^2 for the plant scale application as it is the optimized considering all the prevailing conditions.

The salting velocity for non-fluidization of solids for both blower system and air-ejector system are turned out to be 5.2 m/sec & 1.85 m/sec respectively as shown in **Fig 5.17**. from the analysis of the **Fig 5.28**, it can be concluded that the saltation velocity is considerably less in case of using an air-ejector system as compared to blower system. Also, using an air-ejector in the system does not have any effect on the overall power or energy consumption for transfer system as the air-ejector uses the compressed air which is an integral part of the system which do not need any special power to produce in particular to this system.

➤ ***Actual Experimental set ups***



Fig 5.9: Actual experimental powder transfer set up (with fluidization) using the vacuum unit.



Fig 5.10: Actual experimental powder transfer set up (without fluidization) using vacuum unit.



Fig 5.11: Actual experimental powder transfer set up (without fluidization) using Air Ejector.

6 CHAPTER

6.1 CONCLUSION

A compact pneumatic transfer/ conveying system can be design for pneumatic transfer the powder solid particles with different types of conveying techniques (like: fluidization of powder material with air which is connected to vacuum unit, without fluidization (or) dilution of powder material with air mixing which is connected to vacuum unit). Basic understanding of pneumatic conveying system and study the effect of different variables on system design was carried out (like finding the salting velocity with different air flows, pressure drop and friction losses calculated in transfer line, Solid & gas separation system filter incorporation and finding the pipe line size theoretically etc.).

The current study concludes that as the fluidization pressure of the powder bed is increased the saltation velocity also increases and hence according to the current plant scenario an optimized 0.2 kg/cm^2 can be used for the fluidisation of the powder bed. The present study also concludes that in comparison with blower system, air-ejector system provides a lesser saltation velocity which directly affects the economics and ease of operation of the system. Hence, air-ejector is better choice as compared to blower system in due of its ease of operation, economics, compact size, and safe transfer. Powder transfer carried out with more efficiently & economical and pneumatic transfer system offers harmless or safer and easily transfer/conveying powder with negligible working areas contamination & exposers and hence, improve the operational working surroundings and industrial environment of the plant.

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