4

Conveying

Belt Conveyors
Screw Conveyors
Pneumatic Conveyors
Chain Conveyors
Bucket Conveyors
Storage of Solids

The term '*conveying*' is applied to the transportation of solids. The transportation of liquids is much simpler, cheaper and less troublesome than handling solids. In many operations, solids are handled in a finely divided state, so that they remain suspended in a stream of fluid. However, such a system is not suitable for handling all types of solids. Therefore, it may be necessary to transport solids as such. This unit operation is important in the storage and handling of raw materials, finished products and packed goods. The advantages and objectives are given below.

Efficient and Effective Conveying—Objectives and Advantages

1. Decreased product costs and increased manufacturing capacity.
2. Decreased cost of raw material. For example, penalty charges are levied when cars are not loaded or unloaded according to schedules. Losses due to spillage or torn containers is reduced.
3. Decreased processing time and conservation of energy.
4. Rigid in-process controls leading to decreased quality control and quality assurance costs.
5. High degree of uniformity, reproducibility of the process and compliance with the cGMP regulations (current good manufacturing practices).
6. Minimum contamination and dust formation.
7. Increased employee safety and reduced labour costs.

If raw materials are not moved as required by production schedules, the manufacturing process will be slowed down. In addition, machine time and operation time will be wasted. As a result in-process inventories will be increased.

Improper handling and storage can lead to damage, outdated and loss of materials. Improper handling of granules, strips, bottles and chemicals can place employees in physical danger. This can often lead to employee frustration and reduced morale due to constant production delays.

In today's world of automation, solid conveying has gained a greater importance. It is often necessary to prevent the contact of material with the persons, in order to avoid contamination (as in case of antibiotics). Similarly working personnel should not be exposed to poisonous and obnoxious substances. Therefore, a closed conveying system is essential. Such a closed circuit manufacturing operation calls for automatic handling systems. The feeding of materials into a reactor is always done mechanically. Similarly, discharge should also be made automatic. Conveyors are used in the production of all dosage forms such as tablets, capsules, liquid orals, injections.

Conveyors are classified into five major groups. These are:

1. Belt conveyors
2. Screw conveyors
3. Pneumatic conveyors
4. Chain conveyors
5. Bucket conveyors

Some important conveyor systems, construction, working and applications are discussed in this chapter.

BELT CONVEYORS

The basic elements of the belt conveyor are:

1. Belt and belt tightening systems
2. Belt drive and power supply
3. Roller supports for belt
4. Feeding arrangements
5. Discharge arrangements

Principle

Horizontally or inclined placed motor driven rotating belt on pulleys convey the material from feeding point to the discharge point.

Construction

The construction of a belt conveyor is shown in Figure 4-1. Belt conveyor consists of a core or carcass (meaning skeleton or backbone for

the belt) of several piles of cotton duck, each layer is impregnated and bonded with rubber. The carcass is then covered with a thin layer of rubber that binds the piles together. Both the ends of the belt are joined together, so that the belt can revolve continuously. The belt may run horizontally or slightly inclined from the feed point.

- If the belt is too thin for its width, it will sag between idlers.
- If the belt is too thick, it does not trough properly.

Sometimes, the length of belt is increased due to a variety of factors such as temperature and humidity of the atmosphere. In such cases, it is necessary to keep the belt taut. Hence, tighteners (or take-up) are installed to maintain an even-tension on the belt under all conditions. The simplest take-up consists of a cast iron bed with a travelling block moving along a screw.

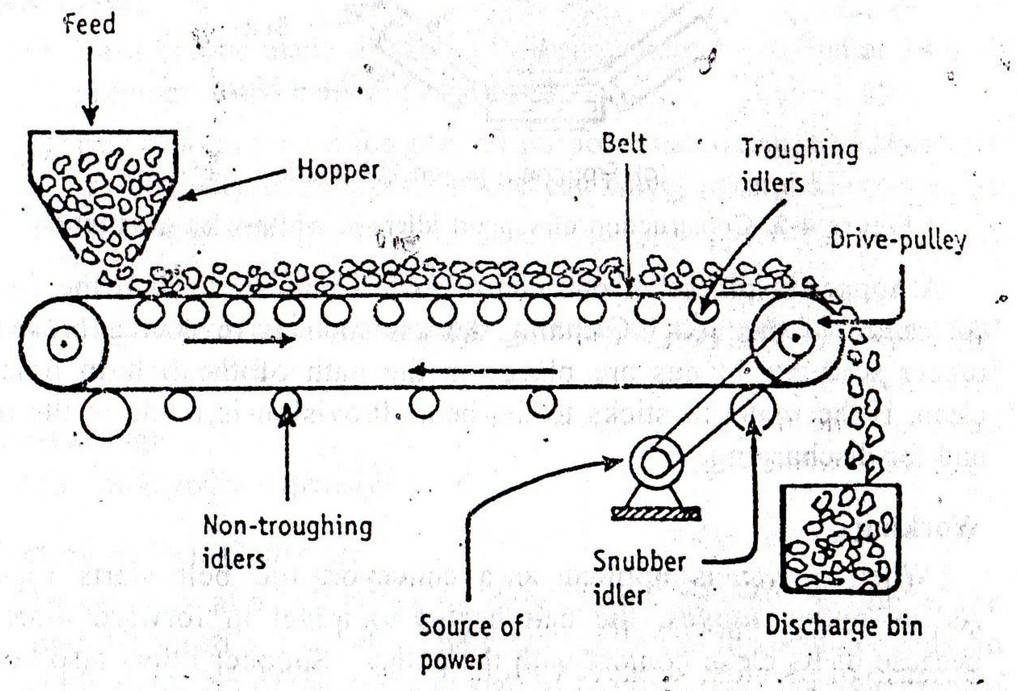
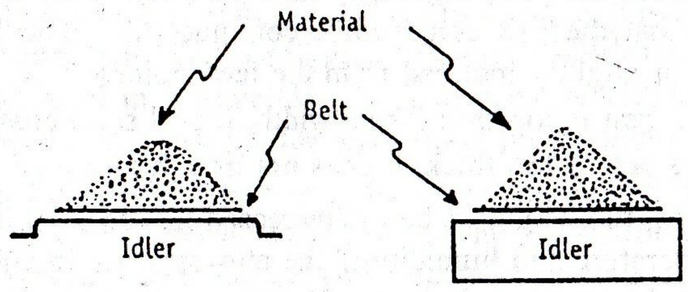


Figure 4-1. Construction of belt conveyor system.

The belt is allowed to move with the help of a *belt drive*. The simplest belt drive is a bare steel pulley actuated with some source of power. The drive of the belt conveyor is fixed at the discharge end (It is rarely arranged at the feed end). There should be appropriate contact between the belt and pulley. Introducing snubber idlers just below the pulley can increase the contact.

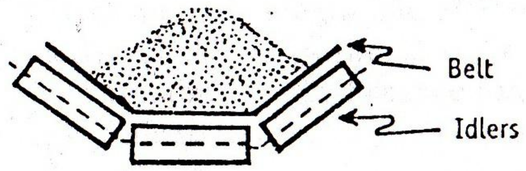
The belt is supported by rollers, which are arranged on a shaft. These are called *idlers*. The idlers are carried on bush bearings lubricated with grease-cups. The idlers are generally troughed to depress the

belt at the centre and rise at the edges (Figure 4-2c). This permits the belt of a given width to carry more material per linear metre without spillage. The belt returns on ordinary, non-troughing rolls.



(a) Flat belt on continuous plate (non-troughing)

(b) Flat belt on flat belt idlers (or non-troughing)



(c) Troughed belt on 20° idlers.

Figure 4-2. Construction of support idlers in width-wise description.

A hopper is placed at one end in such a manner to load the feed at the centre of the belt. Cleaning devices such as revolving brush and rubber scrapper blades are placed in the path of the belt in order to clean, if the material sticks to the belt. Provision is made at the other end for discharging.

Working

When power is applied to a conveyor, the belt starts rotating. As the pulley moves, the belt begins to travel in forward direction, because of its close contact with the pulley. Snubber idlers also help in maintaining the close contact between the pulley and belt.

The material (to be transported) is loaded on its centre of the belt with the help of a hopper. The material travels above the belt. The belt moves forward on troughing idlers. This permits the belt to carry more material per linear metre without spillage. The amount of feed delivered depends on the width and speed of the belt. At the discharge end, the material may be unloaded manually or mechanically.

Once the material is unloaded, the belt returns on lighter non-troughing rolls to the point of feeding.

Pharmaceutical Applications

Belt conveyors are used in transporting containers for filling, capping, sealing, labelling, pasting, visual inspection etc., in the production of injectables, liquid orals, ointments and jellies.

In the strip and blister packings of tablets and capsules, strips are conveyed on a moving belt. During this process, the strips are packed in the cartons.

Belt conveyors are used in the manufacture of lozenges. It is a continuous process of candy base cookies. When a mass of sugar base is on the conveyor, the water is removed. At the end of the belt, the candy base is mixed, tempered, formed, roped, melted, acidulents and flavours are added, cooled and sized.

Advantages

(1) Belts can be made of asbestos fibres, neoprene, teflon and vinyl polymer. Cord belts are also used.

(2) Belt conveyors are for general purpose installation and available in relatively large sizes. These can travel several kilometres as in case of coal mines.

(3) Routine maintenance of belt conveyor is easy.

(4) Belt conveyor is economical in terms of cost per unit tonne that it can handle.

Disadvantage

Belt conveyor is expensive.

Selection of Belt Conveyor

The capacity of a belt conveyor depends on the cross section of the load and the speed of the belt. The cross section of the load depends on the width and slope of the belt and size of the material. The selection of a belt conveyor depends on:

- Power required.
- Mechanical and tensile strength of the belt system to handle the wider varieties of materials.
- Lump size.
- Troughability of the belt.
- Ability of the belt to support the load between idlers.
- Chemical resistance of the belt to the material to be handled.

Manufacturers of belt conveyors publish charts or formulae for the construction of conveyors, size and power requirements.

SCREW CONVEYORS

The basic elements of the screw conveyor are:

1. Trough system
2. Flights and power supply
3. Feeding arrangements
4. Discharge arrangements

Principle

Horizontally or inclined or vertically placed motor driven screw like flight conveys the material in the trough from the feed point to discharge point.

Construction

The trough is a U-shaped vessel in which the material is enclosed during conveying (Figure 4-3). The trough is usually made of a sheet of steel and available in standard lengths. If a trough of more length is required, then more number of such units are joined together.

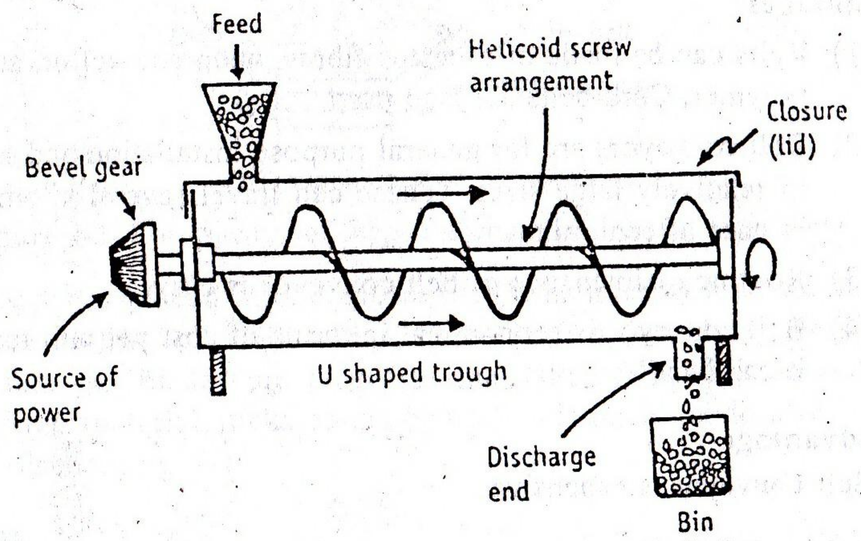


Figure 4-3. Construction of a typical screw conveyor.

Screw element usually consists of a spiral blade (conveying mechanism is like a screw), which is called *flight*. The simplest form of the flight is the sectional conveyor. Helicoid flight is shown in Figure 4-3. It is made of a single long ribbon that is twisted and wrapped into a spiral shape. These standard flights are welded to the central shaft. Alternatively the conveyer element (helicoid flight element) is suspended with the help of hangers along the length of the trough. Usually one hanger is used for each flight section. Hangers contain bushings of white cast iron, so that lubricants need not be used.

The drive end and discharge ends are known as *box-ends*. At the drive end, shaft is connected to the drive by bevel gears. Power is

transmitted through the shaft to the flight. The shaft is rotated around an axis and remained nearer to the bottom of the trough. The feed is normally introduced by plain spouts, which gives uniform flow of material. At the discharge end, arrangements are made to receive the material using open-end trough or open-bottom trough.

Working

When power is applied, the drive rotates the shaft through the bevel gears. The screw element starts rotating. The flight is rotated round an axis and remained nearer to the bottom of the trough. Feed is normally introduced by plain spouts. The material will be trapped between the gaps of the spiral blades. As the flight moves, the material also moves forward along the path of the sections. The material is received using open-end trough or open-bottom trough.

Applications

(1) Screw conveyor is used for transporting finely divided solids or pasty solids.

(2) Materials having properties such as light-weight, medium-weight, abrasive, non-abrasive and different densities can be easily handled using screw conveyor. It is a versatile conveyor system.

(3) Special flights and casings are available for operations such as mixing, de-watering, heating and cooling.

(4) It has the capacity to handle the materials of about 280 metre cube per hour.

Advantages

(1) Materials can be conveyed horizontally, vertically or inclined.

(2) Screw conveyors are easy to operate and occupy less space.

(3) Different constructions are available and can be adapted for a variety of materials. Screw conveyors can be fabricated in a variety of materials ranging from cast iron to stainless steel.

(4) Screw conveyor can be operated at positive and negative pressures.

(5) High and low temperatures can be maintained by insulating the casing.

(6) It can be made dust free.

Disadvantages

(1) Screw conveyors operate at relatively low rotational speeds.

(2) Extremely cumbersome handling when conveyor becomes larger.
(3) At high speeds, abrasive problems arise.
(4) Power consumption per unit weight transferred is high.

Selection of Screw Conveyor

The size and speed of a screw conveyor are determined to make a choice of the design. The type of construction depends on the requirements such as:

- Scale of operation
- Severity of service
- Value of the material

PNEUMATIC CONVEYORS

The basic elements of the pneumatic conveyor are:

1. Air supply (or vacuum) system
2. Air slide and pipeline
3. Feed arrangements
4. Discharge arrangements (air and feed separation)

Principle

When a high velocity air is passed through a bed of solid particles, the individual particles are dragged by the air. Finally they are suspended in the air. Such a system is known as *fluidized bed*, which is described as a condition of fully suspended particles. In this condition, the suspension behaves like a dense fluid and can be transported from one point to another in processing plants. At the discharge end, the gas is separated and the solids are recovered.

Construction

The construction of a pneumatic conveyor is shown in Figure 4-4. Fans or cycloidal blowers are connected to the conveying system. An air slide consists of a chute with a porous base through which air passes. The path of material travel may vary from a few metres to several hundred metres. Conveyor mechanism can be operated for horizontal and vertical distances. The material supply (feed) is connected to the air slide through a rotary feeder valve. The other end of the pipeline is connected to a cyclone separator.

Working

The cycloidal blowers (or fans) produce air at pressure about 7.0 kilopascals. This air is passed through the air slide at the rate of 1.5 metre per minute. During this process, the rotary feeder valve rotates and allows the feed to enter the pipeline. These solids are suspended into a stream of air in a *fluidised state* until it reaches the receiving end. The material is then admitted to cyclone separator to remove large particles and fine particles, if any. The large particles are collected into the bin. The fine particles are removed in a bag filter. The gas can be recycled to the blower inlet in a closed system to save the valuable gas. These systems are used for free flowing materials.

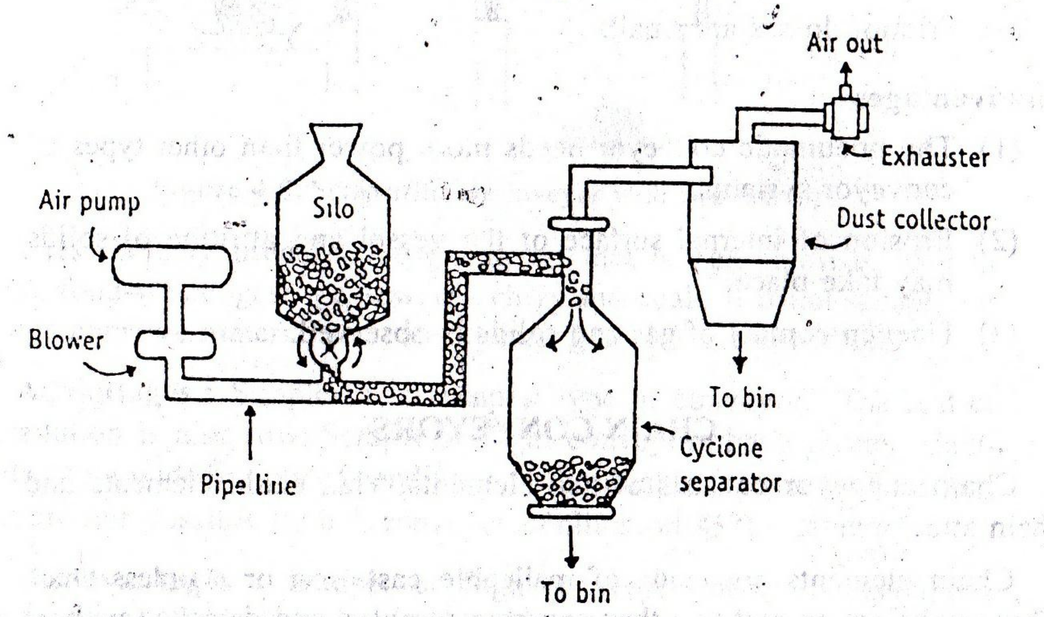


Figure 4-4. Pneumatic conveying system, pressure type.

For the design and satisfactory operation of pneumatic conveying, it is necessary to know about properties of powders such as density, particle size distribution, cohesiveness, angle of friction, angle of repose and fluidization characteristics.

Applications

(1) Pneumatic conveyor is the most important handling technique in chemical industry.
(2) It is used in the formulation of powdered insufflations.
(3) Generally, light and bulky materials such as grains can be transported easily.
(4) Pneumatic conveyor is used for handling of unpleasant and injurious (toxic) materials, since it is a closed system.

(5) Powders containing poisonous constituents can be transported.

(6) Fine powders and pellets having the size up to 6.0 millimetres and bulk densities from 16 to 3000 kg per metre cube can be handled by pneumatic conveyor.

Advantages

(1) While conveying the material, the path involves many turns and lifts. In such cases, other types of conveying become costly.

(2) Pneumatic conveyor is economical compared to other types of conveyors.

(3) Friction losses are small.

Disadvantages

(1) The pneumatic conveyor needs more power than other types of conveyor systems.

(2) Erosion of internal surface of the vessel and attrition of solids may take place.

(3) Uneven contact of gas and solids is observed.

CHAIN CONVEYORS

Chain conveyor consists of two elements, viz., chain elements and chain attachments.

Chain elements are made of malleable cast iron or stainless steel. These links are so cast that they can be assembled and detached without use of tools.

Chains are endless and move continuously. The material is loaded into a suitable container and placed on the chains. These are usually constructed on the job.

Advantages : Chain conveyor is a cheap and simple piece of equipment. It can be adapted to a wide variety of problems.

Scraper/Flight Conveyors

Flight conveyor consists of one or two endless chains passing through a trough or a set of guides. The chains have plates of wood or steel called *flights* attached at regular intervals. The flights are shaped to fit the troughs. The chains pull the flights and the material along the trough and passes over sprockets at the end of the run. One of the sprockets acts as the drive. In an elaborate form, flight conveyor is

supported by two chains of roller pintle type (Figure 4-5). Scraper conveyors with speeds of 30 metre per minute are common, but the speed may ranges from 8 to 60 metres per minute.

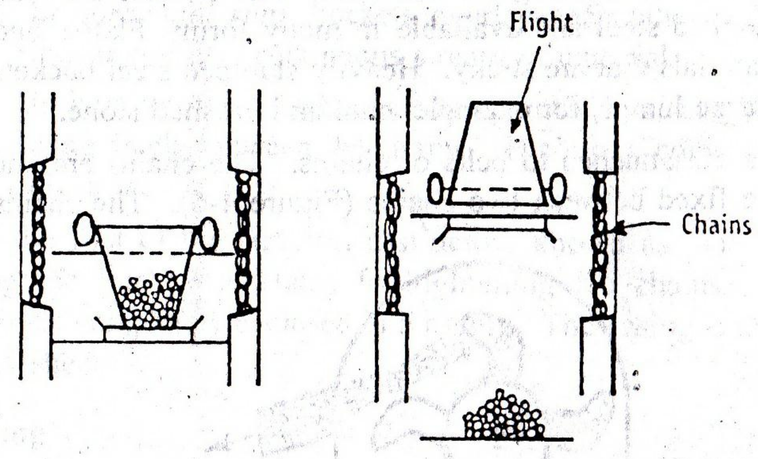


Figure 4-5. Scraper/flight conveyor with two chains.

Uses: Widely used for loose material that is non-abrasive, such as grain, food-waste, garbage, sawdust, chips and coal. It is not suitable for friable abrasive material such as clinkers, gravel and crushed ore.

Advantages : Simplest and cheapest type of conveyor. The cost of installation is also low. Scraper or flight conveyors have greater adaptability to a wide variety of conditions. It is suitable for steeper situations that are not possible by belt conveyor (inclination 45°).

Disadvantages : Scraper or flight conveyor needs heavy power requirements. Repairing charges are high.

Apron Conveyors

Apron conveyors are usually used for heavy loads and short runs. The simplest apron conveyor consists of two endless roller chains, which are connected by double beaded steel pans. The beading prevents the material from slipping backward when conveyor is inclined. Wooden or metal boxes are fixed between the chains and the whole conveyor drags on the support. Apron conveyors are used for

- transporting heavy loads.
- short runs at low speeds.
- conveying material such as lumpy, abrasive and hot, provided that these are not injurious to flexible belts.

BUCKET CONVEYORS

Construction

Buckets are used for loading the materials. The buckets are made of cast iron or stamped steel and available in many forms. Flatter buckets are used for materials that are sticky. Heavily stamped steel buckets are employed for large lumps, for example, coal and crushed stone.

The buckets are attached to belts or chains. The chains are endless and buckets are fixed between two chains (Figure 4-6). The chains are

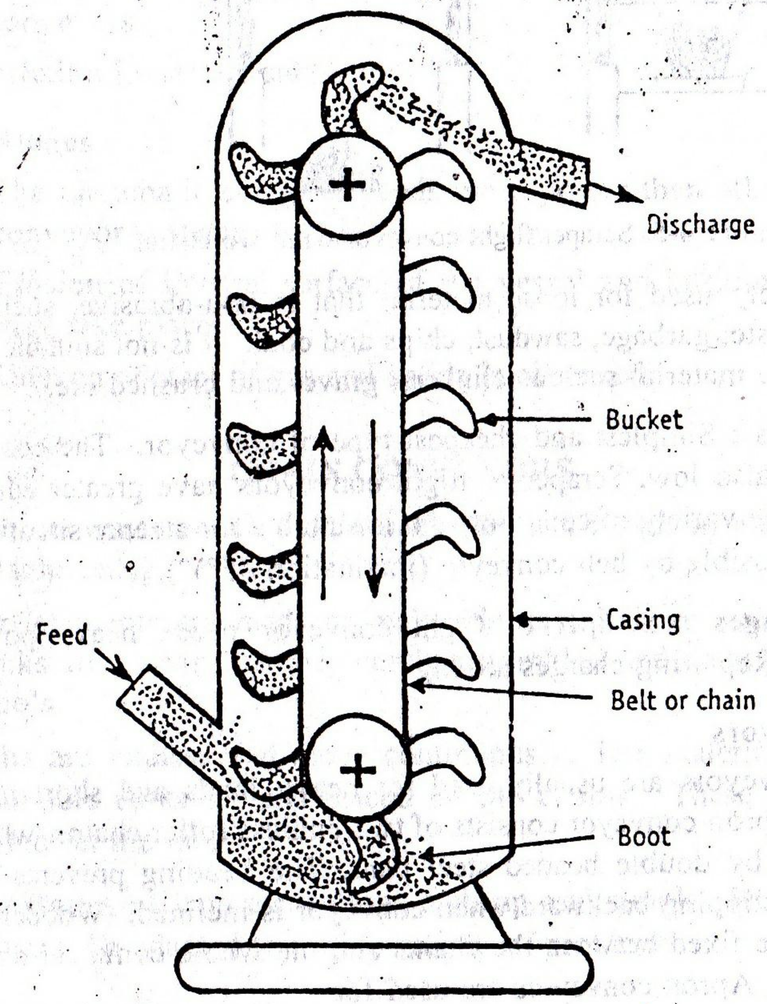


Figure 4-6. Construction of a bucket conveyor.

generally long pitch, straight and side type. The buckets are spaced to prevent interference in loading and unloading. For heavier loads, two chains may be used. The attachments are riveted to the ends of the chains. The attachments are slightly above the level of the chain so that the ends of the sprocketed booth do not strike the back of the buckets.

The weight of the conveyor results in the stretching of the chain under load. Therefore, tightening devices are generally provided for altering the position of the sprocket at the foot of the elevator.

- In *horizontal runs*, buckets overlap each other and the feed is introduced as a continuous stream of material.
- In *vertical lines*, the buckets are pivoted in such a way that they hang freely between the chains. Therefore, conveyor acts as an elevator.

At the foot of the elevator, a structure known as 'boot' is used for feeding the buckets and also for tightening the chains. Buckets are sometimes completely enclosed in a casing. The casing is made of wood or steel sheet.

Working

The elevators are generally driven from the head sprocket. At the foot of an elevator, there is a structure known as 'boot', which helps in feeding. The buckets are normally fed by digging into the materials particularly in case of loose material and granular solids. The buckets maintain their carrying capacity by gravity, but they can convey the material horizontally or vertically or any desired path. Loading can be done by the flow of material through a chute into the buckets. Buckets may be readily discharged at any point by a tripping device, causing each bucket to turn through 90 degrees. The types of discharges are continuous, positive and centrifugal.

Applications

Bucket conveyors are used in transporting coal, crushed stone, grains etc.

Advantage

Bucket conveyors are very flexible.

STORAGE OF SOLIDS

Attention must be paid to the storage of solids. The storage is an important operation, if the material is too valuable or too soluble when exposed to atmosphere as in outdoor piles. The following are used for storing solids.

Bunkers : These are used for storage of pulverised solid material. During plant shut down, the solid material is stored in bunkers. Coarse solids such as gravel and coal are stored outside in large piles, unpro-

tected from the weather. Out door storage can lead to environmental problems such as dusting and leaching.

Hoopers, bins and silos : A *bin* is fairly wide and not so tall. It is a cylindrical or rectangular vessel of concrete or metal. A *silo* is tall and relatively small in diameter. A *hopper* is a small vessel with a sloping bottom. It is used for temporary storage before feeding solids to a process. These containers are loaded from the top by some kind of an elevator and discharged ordinarily from the bottom.

Now-a-days, there have been extensive improvements in the use of solid conveying equipment. For example, granulation and tabletting operations are completely automated and computer controlled. The above system utilizes pumps and bucket conveyors to move materials upward whenever required. Examples are transporting granules and transporting compressed tablets for batching and film coating. These use belt conveyors and pneumatic conveyors to move the material horizontally.

QUESTION BANK

Each question carries 5 marks

1. Illustrate the concept of solid transport by fluidisation.
2. Describe the principle of pneumatic conveyer with a labelled diagram.
3. Describe the different types of conveyors used in pharmaceutical industry.
4. List advantages of screw conveyor and screw elevator. How do you compare these with pneumatic transport of solids?
5. Describe the construction and working of a screw conveyor.

Each question carries 10 marks

1. Describe the construction and working of belt conveyor system for solid transport.
2. Name the devices used for transportation of solids. Describe pneumatic conveyor.