BP 304 T. PHARMACEUTICAL ENGINEERING (Theory)

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UNIT-V

MATERIALS OF PHARMACEUTICAL PLANT CONSTRUCTION

INTRODUCTION

For manufacturing of pharmaceuticals, bulk drugs, antibiotics, biological products etc., number of equipments are used. The equipments are generally used for processing and packing of products. A wide variety of materials are used for manufacturing of theses equipments. Some products are highly acidic while some are highly alkaline. Some products such as storage of biological products need to be handled carefully. Therefore design of equipment, material selection and fabrication technique need to be considered carefully. These factors affect the success or failure of new chemical plant. If container will not compatible with material then there are chances of contamination. So, the proper choice of material is very important both for construction of processing equipments as well as containers and closers for storage of finished products. The choice based on expert advice, previous experience and laboratory tests.

FACTORS AFFECTING DURING MATERIALS SELECTED FOR PHARMACEUTICALS PLANT CONSTRUCTION

The selection of a material for the construction of the equipment depends on the following properties:

1. Chemical factors
    a. Contamination of the products
    b. Corrosion of materials of construction
2. Physical factors
    a. Strength
    b. Mass
    c. Wear properties

d. Thermal conductivity
e. Thermal expansion
f. Ease of fabrication
g. Cleaning
h. Sterilization
i. Transparency

3. Economic factors

1. Chemical Factors

Each time a chemical is placed in a container or equipment, the chemical is exposed to the construction material of the container or equipment. Therefore, the material of construction may contaminate the product (*contamination*) or the product may destroy the material of construction (*corrosion*).

a. **Product contamination**:

Iron contamination can change the color of products (such as gelatin capsules), catalyze some reaction that can increase the decomposition rate of the products. The leaching of glass can make the aqueous product alkaline. This alkaline medium may catalyze the decomposition of the product. Heavy metals, such as lead, inactivate penicillin.

b. **Corrosion of construction materials**

The products can be corrosive in nature. They can react with the material and can destroy it. This can decrease the life of the equipment. Extreme pH, strong acids, strong alkalis, powerful oxidizing agents, tannins etc., reacts with the materials, therefore, some alloys that having special chemical resistance are used.

2. Physicals Factors

a. **Strength**:

The material must have sufficient physical strength to withstand the pressure and stress required. Iron and steel can satisfy these properties. The tablet punching machine, the die and the upper and lower punches are made of stainless steel to withstand very high pressure. Glass, though has strength but fragile in nature. The aerosol container must withstand very high pressure, so tin containers covered with some polymers (lacquered) are used. The plastic materials are weak, so they are used in some packaging materials, such as blister packs.

b. **Mass**:

For transportation, lightweight packaging materials are used. Plastic, aluminum and paper packaging materials are used to package pharmaceutical products.

c. **Wear properties**:

When there is a possibility of friction between two surfaces, the softer surface disappears and these materials contaminate the products. For example, during milling and grinding, grinding surfaces can wear out and contaminate the powder. When pharmaceutical products of very high purity are required, grinding surfaces of ceramic and iron are not used.

d. **Thermal conductivity**:

In evaporators, dryers, stills and heat exchangers, the materials used should have very good thermal conductivity. In this case, iron, copper or graphite tubes are used for effective heat transfer.

e. **Thermal expansion**:

If the material has a very high coefficient of thermal expansion then as the temperature increases, the shape of the equipment changes. This produces unequal stresses and can cause fractures. Therefore, materials that are capable of maintaining the shape and dimension of the equipments at the working temperature should be used.

f. **Ease of fabrication**:

During the manufacturing of equipment, the materials undergo various processes, such as casting, welding and forging. For example, glass and plastic can be easily moulded into containers of different shapes and sizes. The glass can be used as coating material for reaction vessels.

g. **Cleaning**:

Smooth and polished surfaces facilitate ease in cleaning. After completing the operation, the equipment is thoroughly cleaned so that the previous product cannot contaminate the next product. The surfaces of glass and stainless steel can be smooth and polished.

h. **Sterilization:**

In the production of parenterals, ophthalmics and bulk drugs, all equipment must be sterilized properly to avoid microbial contamination of the product. This is usually done by introducing high pressure stream. The material must withstand at high temperature (121^0C) and pressure (15

pounds per square inch). If there are rubber materials, it must be vulcanized to withstand the light temperature.

i. **Transparency**:

In the reactors and fermentors a visual port is provided to observe the progress of the process that takes place inside the chamber. In this case, borosilicate glass is often used. In the parenteral and ophthalmic containers, the particles, if any, are observed with polarized light. The walls of the containers must be transparent to see through it. The glass is used as perfect material.

3. Economic Factors

The initial cost of the equipment depends on the material used. Several materials may be suitable for construction from the physical and chemical point of view, but of all the materials only the cheapest material for the construction of the equipment is chosen. Materials that require a lower maintenance cost are used because in the long term it is economical. The material used for construction of plant is classified as metals (ferrous and non ferrous) and non metals (organic and inorganic).

CORROSION

It is defined as the reaction of a metallic material with its environment, which causes a measurable change to the material and can result in a functional failure of the metallic component or of a complete system. Exposure of surface to air, water and caustic chemicals are the measure causes of corrosion. The surface changes due to corrosion are carried through the equipment and destroy the performance and fabrication in due course. According to the environmental conditions corrosion can be of dry or wet type as follows:

1. Dry Corrosion: It involves the direct attack of gases and vapor on the metals through chemical reactions. As a result an oxide layer is formed over the surface. This type of corrosion is not common.

2. Wet Corrosion: This corrosion involves purely electrochemical reaction that occurs when the metal is exposed to an aqueous solution of acid and alkali. The moisture and oxygen are also responsible. This type of corrosion is quite common.

e.g. $Zn + 2HCl \rightarrow ZnCl_2 + H_2\uparrow$

THEORY OF CORROSION

1. Corrosion Reaction on Single Metal

A single piece of metal (e.g. Fe) when comes in contact with acid (e.g. HCl) small galvanic cells may be set up on the surface. Each galvanic cell consists of (i) anode regions and (ii) cathode regions.

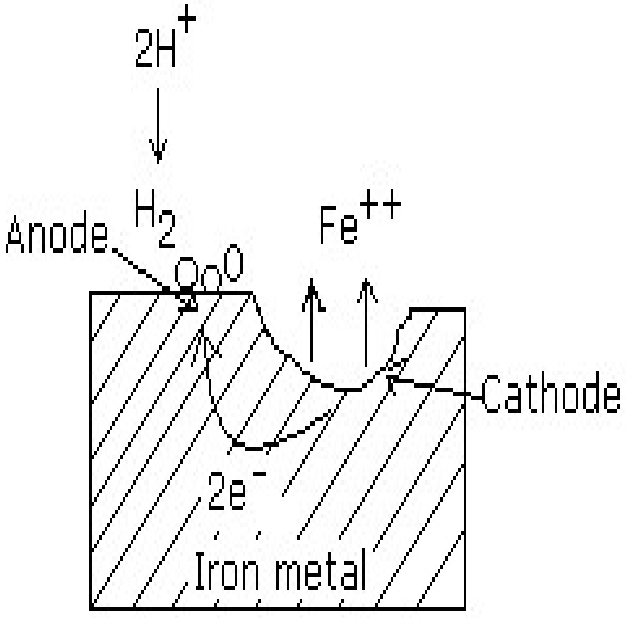

Fig. 1: Electrochemical mechanism of corrosion

Reaction at anode: Fe on the iron leaves two electrons to the metal and itself becomes Fe^{++} ion. Fe^{++} ion is soluble in water, so it is released in the medium. Thus the iron surface is corroded.

Reaction at cathode: The released electron is conducted through the metal piece into cathode region. Two electrons are supplied to two protons (H^+) to form two atoms of H. Hydrogen atoms are unstable, hence two H atoms will combine to form a molecule of stable H_2. In the absence of acid, water itself dissociates to generate H^+ ion.

$2H^+ + 2e^- \rightarrow H_2\uparrow$, Hydrogen ($H_2$) forms bubbles on the metal surface. If the rate of hydrogen formation is very slow then a film of H_2 bubbles will be formed that will slow down the cathode reaction, hence the rate of corrosion will slow down. If the rate of hydrogen production is very high then hydrogen molecules cannot form the film on the surface. So the corrosion proceeds rapidly.

2. Corrosion Reactions between Metals

If two metals come in contact with a common aqueous medium then one metal will form anode and the other will form cathode. Now if both the metals are connected with a wire the reaction will proceed. Anode metal will be corroded and hydrogen will form at the cathode.

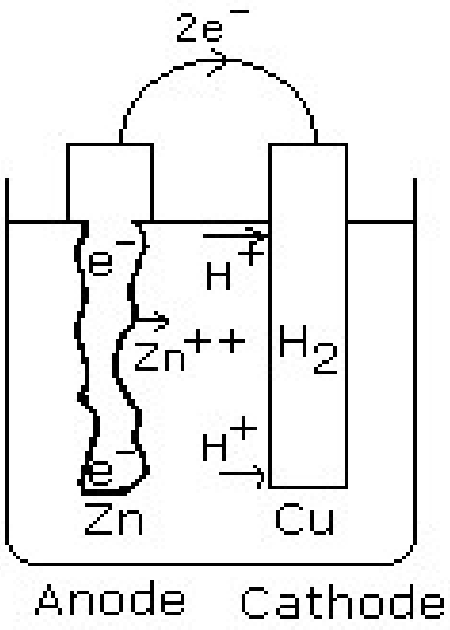

Fig. 2: Galvanic mechanism of corrosion

For example if a zinc and a copper plate is immersed in an acidic medium then zinc will form anode and will be corroded while hydrogen will be formed at copper plate.

Anode reaction: $Zn \rightarrow Zn^{++} + 2e^{-}$.

Cathode reaction: $2H^{+} + 2e^{-} \rightarrow H^{2}\uparrow$

So anode will be corroded and hydrogen will be evolved at cathode.

3. Corrosion Involving Oxygen

The oxygen dissolved in the electrolyte can react with accumulated hydrogen to form water. Depletion (reduction) of hydrogen layer allows corrosion to proceed.

At cathode: $O_2 + 2H_2 \rightarrow 2H_2O$

The above reaction takes place in acid medium. When the medium is alkaline or neutral oxygen is absorbed. The presence of moisture promotes corrosion.

FACTORS INFLUENCING CORROSION

1. pH of the Solution

Iron dissolves rapidly in acidic pH. Aluminium and zinc dissolves both in acidic and alkaline pH. Noble metals are not affected by pH e.g. gold and platinum.

2. Oxidizing Agents

Oxidizing agents may accelerate the corrosion of one class of materials whereas retard another class.

- e.g. O_2 reacts with H_2 to form water. H_2 is removed, corrosion is accelerated. Cu in NaCl solution follows this mechanism also.
- e.g. Oxidizing agents forms a surface oxide (like Aluminium oxide) and makes the surface more resistant to chemical attack.

3. Velocity

When corrosive medium moves at a high velocity along the metallic surface, the rate of corrosion increases because of:

- Corrosion products are formed rapidly and washed away rapidly to expose new surface for corrosion reaction.
- Accumulation of insoluble films on the surface is prevented.
- The corrosion is rapid in the bends of the pipes, propellers, agitators and pumps.

4. Surface Films

- Thin oxide films are formed on the surface of stainless (rusting). These films absorb moisture and increase the rate of corrosion.
- Zinc oxide forms porous films. Fluid medium can enter inside and thus corrosion continues. Nonporous films of chromium oxide or iron oxide prevent corrosion.
- Grease films protect the surface from direct contact with corrosive substances.

TYPES OF CORROSION

1. Fluid Corrosion: General

When corrosion is generally confined to a metal surface as a whole, it is known as general corrosion. This corrosion occurs uniformly over the entire exposed surface area. e.g. swelling, cracking, softening etc. of plastic materials.

2. Fluid Corrosion: Localised

a. **Inter-granular corrosion**:

During heat treatment or welding, some components get precipitated at the grain boundary of the metal.

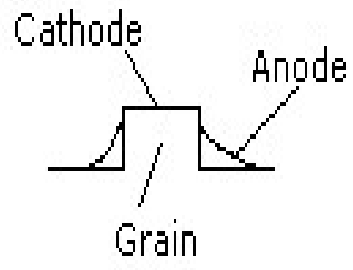

Fig. 3: Inter-granular corrosion

These boundaries act as anodes and grains as cathodes. So corrosion of anode region occurs.

b. **Pitting corrosion**:

On metal surface small holes or pits are created due to local corrosion and these pits increase in size rapidly. In the pits the metals dissolve rapidly especially by chlorine and chloride ions.

c. **Stress corrosion**: Certain area of metal may be subjected to thermal, mechanical or chemical stresses. The surface area becomes anode and acts as corrosion area.

d. **Fretting corrosion**: Equipment showing high vibrations destroys the surface of metal (e.g. steels balls in ball-bearing) by mechanical hitting.

e. **Corrosion fatigue**: Cyclic stress breaks the protective film, so corrosion increases.

3. Fluid Corrosion: Biological

Metabolic action of micro-organisms can either directly or indirectly cause deterioration of a metal by:

- Creating electrolyte concentration cells on the metal surface.
- Influencing the rate of anodic / cathodic reactions.
- Sulphates are converted in to hydrogen peroxide (H_2S) because of action of reducing bacteria on them. This reacts with iron to produce ferrous sulphide (FeS). Thus the iron gets corroded.

PREVENTION OF CORROSION

Following methods may be adopted for preventing or reducing corrosion:

1. Material Selection

- Pure materials have less tendency towards pitting, but they are expensive and soft. Therefore, only aluminium can be used in pure form.

- Improved corrosion resistance can be obtained by adding corrosion resistant elements. For example inter-granular corrosion occurs in stainless steel. This tendency can be reduced by addition of small amount of *titanium*.
- Nickel, copper and their alloys are used in non-oxidizing environment, whereas chromium containing alloys are used in oxidizing environment.
- Materials those are close in electrochemical series should be used for fabrication.
- Corrosive materials are taken with suitable material of construction:

Table 1: List of materials of construction that can withstand the respective corrosive materials

Corrosive material	Suitable material
Nitric acid	Stainless steel
Hyfrofluoric acid	Monel metal
Distilled Water	Tin
Dilute sulphuric acid	Lead
Caustic	Nickel

2. Proper Design of Equipment

Corrosion can be minimized in the following conditions:

- Design for complete drainage of liquids.
- Design for ease of cleaning.
- Design for ease of inspection and maintenance.
- A direct contact between two metals should be avoided. They may be insulated from one another.

3. Coating and lining: The metals are more prone to corrosion. To combat corrosion in metals, non metals coating or lining should be used. Electroplating, cladding, organic coating can also be used. Galvanic corrosion can be controlled by applying barrier coatings or insulating both the anodes and cathodes to prevent the flow of electrons across the joint. Organic coatings are also used as lining of tanks, piping and shipping containers. Cladding is the bonding of dissimilar metals. It is achieved by rolling of two sheets of metal together. Cladding is also done for steel with an alloy is another approach to combat corrosion.

4. By changing the environment: Corrosion can be prevented by removing air from boiler feed water which prevent steel from the corrosive effect of water. In case of nickel based alloy the

pumping of inert gas reduce air or oxygen content. The corrosive effect of acidic media on stainless steel alloys can be minimized by aeration. Corrosion can also be reduced by decreasing the temperature, by reducing the moisture and also by decreasing the exposure time.

5. Use of Corrosion Inhibitors: Corrosion inhibitors are used to decrease corrosion of metals. The inhibitors are used in critical amount (less than 0.1% by weight). For example: Chromates, phosphates and silicates are used to protect iron and steel in aqueous solutions. Organic sulphides and amines are used to protect iron and steel in acidic medium. Copper sulphate is used to protect stainless steel from corrosion in hot diluted solution of sulphuric acid.

6. Cathodic and Anodic protection: Cathodic protection is achieved by two methods as follows.

a. **Sacrificial anode methods:** As the name indicates, anodes are kept in contact with protected metal (cathode), this cause scarification of anode. For example: zinc, aluminium, magnesium and their alloys are used as sacrificial anode for protection of iron and steel tanks.

b. **Impressed emf methods:** In this method, external voltage is applied between tanks and electrodes. The anode is maintained always at positive. The natural galvanic effect is avoided. Thus anode is non-consumed. So any metal or non corrodible alloys are used. For example: in case of sulphuric acid and deionised water, anodes are buried in ground while graphite and high silicone steel are compressed. The advantage of this method is: simple, most effective, inexpensive and used to store mild corrosive liquors.

In contrast to cathodic protection, anodic protection is one of the more recently developed methods for controlling corrosion. In anodic protection, predetermined potential is applied to metal. At initial stage, as current increases, metal dissolution or corrosion occur. At critical point passivation occurs. The potential develop at critical point is called passivating potential. Above the passivating potential, current flow decrease to minimum value. This is called passivating current. The main advantage of anodic protection is that it requires small current. This is used in transportation of concentrated sulphuric acid.

CLASSIFICATION OF MATERIALS FOR PLANT CONSTRUCTION

The material used for construction of plant is classified as metals (ferrous and non ferrous) and non metals (organic and inorganic).

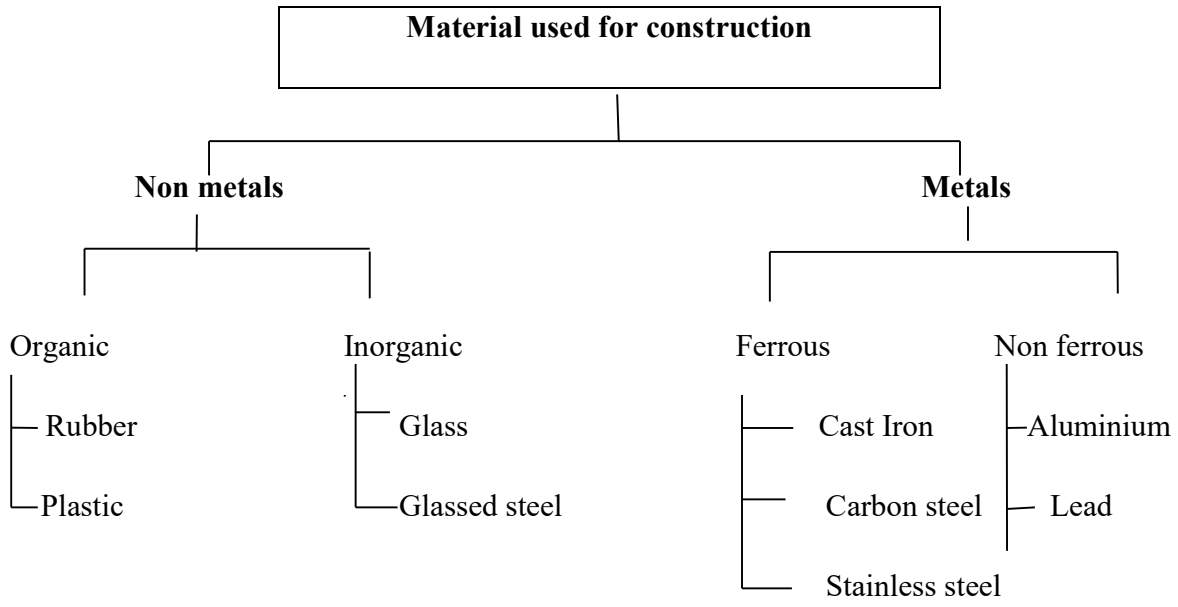

Fig. 4: Classification of materials used for construction

1. Non Metals-Organic

a. **Rubber**

It is used as a lining material

- **Latex:**

Advantages: The latex is ready to use directly outside the container. Latex is economical, exhibits good abrasion resistance and is an elastic mouldable rubber. Latex moulds are also good for casting wax and gypsum.

Disadvantages: Low-cost latex products generally shrink. Making moulds with latex rubber is slow and time consuming. Latex moulds are generally not suitable for melting resins.

- **Polysulfide rubbers:**

Advantages: Polysulfide moulds are very soft, elastic and long lasting, even some have a useful life of 40 years.

Disadvantages: It has an offensive smell. The polysulfides must be accurately mixed by weight otherwise they will not work. Polysulfide rubber costs more than latex.

- **Silicone rubbers:**

Advantages: Silicone rubber has the best release properties of all mold rubbers. The combination of good release properties, chemical resistance and heat resistance makes silicone the best choice for the production of resin castings.

Disadvantages: The silicones generally have a high cost.

- **Polyurethane rubbers**:

Advantages: Polyurethanes are easy to use. They are less expensive than silicones and polysulphides.

Disadvantages: As silicone rubber has the best release properties, urethane rubber has the worst release properties and adheres to almost anything. They have limited shelf life after opening.

b. **Plastic**

Plastic is commonly used material. It is light in weight. In plastic there are no chances of contamination as in metallic containers. They are available in variety of shapes. But plastic is not preferred in case of higher temperature. Generally pipes and tubing are made of plastic material. They are used for storage of inorganic salt and weak acid. They can be easily cut as per requirement. Plastic do not corrode in air or water. It is also used as insulating material.

Types:

- **Thermoplastic**: They get softened with application of pressure and heat but regain their original shape on cooling.

Table 2: Different type of thermoplastics and their uses

Thermoplastics	Uses
polyethylene	Cables, buckets, pipes
polypropylene	Milk, carsons, ropes
Teflon	Gaskets, coating
Polyvinyl chloride (PVC)	Manufacturing of gloves

- **Thermosetting**: They are permanently shaped to rigid structure when pressure and heat is applied. e.g. Phenol-formaldehyde. They cannot withstand on severe abrasion.

2. Non Metals-Inorganic

a. **Glass**

Glass container is widely used in daily life. It is composed of sand (pure silica), soda ash (sodium carbonate), limestone (calcium carbonate), and cullet (broken glass). Cullet acts as fusion agent for whole mixture. Glass is its solid state is considered as super cooled liquid.

Types:

There are different varieties of glasses used such as

- **Soft glass**: They are made of sodium silicate and calcium silicate. It is used for making glass bulbs and window glasses.
- **Hard glass**: They are made of potassium silicate and calcium silicate. They are used for making glass apparatus.
- **Flint glass**: They are made of potassium silicate and lead silicate.
- **Quartz glass**: They are made of pure silica. They are used for making silica crucible.
- **Pyrex glass and Jena glass**: They are generally used for laboratory glasswares. The iron oxide is added to give amber colored glass but iron oxide could leach into stored products.

There are 4 types of glasses used in pharmaceutical industries according to I.P.

- **Type1 (Borosillicate glass**): It is highly resistance to alkali leaching. In this alkali and earth cations are replaced by boron. They are less brittle. Easy to clean and sterilize.
- **Type II (Treated soda lime glass**): In this type of glass, surface alkali is neutralized by sulfur dioxide vapors. They are used for making containers for buffered aqueous solution having pH below 7.
- **Type III (Soda lime glass):** It release 10 times more alkaline than type1 and type II. It offers moderate hydrolytic resistance. It is used for dry powder and oleaginous solutions.
- **Type IV (General purpose soda lime glass**): It is not used for parenterals. It is used as container for tablets, oral solutions, suspensions, ointment and liquid for external use.

When glasswares are stored over a month in damp atmosphere having variation in temperature, it leads to Blooming or weathering. As a result salt leach out of glass and appear as fine crystals. In this case salt is washed off with water and acid. Pharmaceutical glass containers should comply with official test for hydrolytic resistance.

Advantages of glass container:

<u>Physical aspect</u>

- They are quite strong and rigid.

- They are transparent which allows the visual inspection of the contents; especially in ampoules and vials.
- They are available in various shapes and sizes. Visually elegant containers attract the patients.
- Borosilicate (Type-I) and Neutral glasses are resistant to heat so they can be readily sterilized by heat.
- Glass containers can be easily cleaned without any damage to its surface e.g. scratching or bruising.

Chemical aspect

- Borosilicate type of glass is chemically inert. Treated soda lime glass has a chemically inert surface.
- As the composition of glass may be varied by changing the ratio of various glass constituents the proper container according to desired qualities can be produced.
- They do not deteriorate with age, if provided with proper closures.
- Photosensitive drugs may be saved from UV-rays by using amber colour glass.

Economical aspect

- They are cheaper than other packaging materials.

Disadvantages of glass container:

Physical aspect

- They are brittle and break easily.
- They may crack when subject to sudden changes of temperatures.
- They are heavier in comparison to plastic containers.
- Transparent glasses give passage to UV-light which may damage the photosensitive drugs inside the container.

Chemical aspect

- Flaking: From simple soda-lime glass the alkali is extracted from the surface of the container and a silicate rich layer is formed which sometimes gets detached from the surface and can be seen in the contents in the form of shining plates – known as ‘flakes’ and in the form of needle*s* – they are known as ‘spicules’. This is a serious problem, especially in parenteral preparations.

- Weathering: Sometimes moisture is condensed on the surface of glass container which can extract some weakly bound alkali leaving behind a white deposit of alkali carbonate to remain over there, further condensation of moisture will lead to the formation of an alkaline solution which will dissolve some silica resulting in loss of brilliance from the surface of glass – called weathering. To prevent weathering, the deposited white layer of alkali carbonates should be removed as early as possible by washing the containers with dilute solution of acid and then washing thoroughly with water.

b. **Glassed steel**

It is an organic product of fusion. It is cooled to rigid condition without crystallizing. They are used in heavy vessels. It has excellent resistant to all acids. This is suitable in case of transparent pipes.

3. Metals-Ferrous

They are widely used as construction material because it is mechanically strong, easily available and economical.

a. **Cast iron**

It is the combination of iron with carbon content greater than 2%. It is cheap and available easily so greater in demand. It is resistance to concentrated sulfuric acid, nitric acid and dilute alkalis. It has low thermal conductivity. The main disadvantages of cast iron are hard and brittle. Gray cast iron contains carbon, silicone, manganese and selenium. It is easy to mould into any shape. Gray cast iron prevents material from corrosion but it is not preventive against dilute acids. Malleable iron (white cast iron with carbon content 2.5%) is also available and it is also corrosion resistant. Nickel resistant cast iron has also superior toughness, easy to weld, corrosion and as well as heat resistant. A number of cast iron alloys like Duriron and Durichlor are available in market.

Uses:

- It is used to jacketed steam pans.
- It is used as lining material with plastic.

b. **Carbon steel**

It is an iron alloy having low percentage of carbon content. It is cheapest and easy fabricate. It is most versatile metal used in industry. It is easily weldable and excellent ductility. But carbon steel has limited resistant to corrosion and it also react with caustic soda. Low alloy steel has

high mechanical strength. It contains 0.4% Carbon, 0.7% Manganese, 1.85% Nickel, 0.8% Chromium and 0.25% Molybdenum. The properties of carbon steel can be altered by alloying with nickel, chromium and silicone. Carbon steel-Nickel alloy is tough and corrosion resistant. Carbon steel-chromium alloy increases hardness and more resistant to corrosion. At elevated temperature strength of carbon steel can be enhanced by preparing carbon steel-Molybdenum alloy.

Uses:

- It is used for construction of pipes and plates.
- It is used as supporting structure for plant vessels.
- It is used as fabricating material for large storage tanks for water, sulfuric acid and organic solvents.

c. **Stainless steel**

It is an alloy of iron. It contain 12 to 30 % Chromium, 0 to 2% Nickel, low percentage of Carbon, Columbium, Copper, Molybdenum, Selenium, niobium, titanium. It is widely used in industries because it is heat resistant, corrosion resistant, easily fabricated, and has high tensile strength.

There are different types of stainless steel available

- **Martensitic (type 410):** It contains 12 to 20% chromium, 0.2 to 0.4% carbon and 2% nickel. It is mild resistant to corrosion and organic exposure. It is less ductile. It is used to prepare sinks, bench tops, storage tanks and mixing elements.
- **Alpha-Ferritic (type 430**): It contains 15 to 30% chromium and 0.1% carbon. It is better resistant to corrosion. It also resistant to oxidation and temperature. It is easy to machine. It is not good against reducing agents and hydrochloric acids. It is used in tower lining, baffles, beat exchangers, tubing, condensers, pump shafts and furnace parts.
- **Austenitic**: It contain 13 to 20% chromium, 0.1% is less than to 0.25% carbon and -22% nickel. It is highly corrosion resistant, east to weld, easily clean and sterilized. It can be easily weld. It is used in fomenters, evaporators, storage vessels, and extraction vesssels.
- **Others**: Type 316, 316L and 317 with 2.5 to3.5% Molybdenum are most corrosion resistant.

4. Metals-Non-Ferrous

a. **Aluminium**

It is available in large number of alloys. Aluminum is cheap and light in weight. It has adequate mechanical strength. Their maintenance and cleaning is easy. Thermal conductivity of aluminium is 60% of pure copper. Its tensile strength is 10000 lb/sq. in. It is resistant to corrosion. It can also used for concentrated nitric acid and acetic acid. It is used in wide variety of chemical equipments. But mechanical strength of aluminium decreases greatly above 150 ^{0}C. For food and pharmaceutical uses super grade of aluminium is used. It is used as container for storage of meat. It is used in heat transfer applications. Aluminium alloy with improved mechanical properties and qualities are available which is also corrosion resistant. Aluminium-clad alloy is used for greater mechanical strength. Hot dipped aluminized steel is preferred when sulfur is present. Aluminium is used in biosynthetic processes because it is non toxic to microorganism.

Uses: It is used for manufacturing of container (tank), rail tankers and barrels.

b. **Lead**

In pharmaceutical industry, Lead is used in less percentage because in large amount it produces toxicity. It is cheap. It is generally used for non food products. The addition of silver (Ag) and copper (Cu) makes lead corrosion resistant and fatigue resistant. Lead has poor structural quality due to low melting point. Therefore antimony is added to harden the lead. Lead pipes are used for solution containing sulfuric acid. The main disadvantage of lead is high coefficient of expansion which may cause permanent deformation.

c. **Others**

Copper and its alloy are also used in chemical processing because it has high temperature resistance properties. Nickel and its alloy are also used for handling alkalis and storing and shipping of high purity caustic soda and potash. It is also used to store chlorinated solvents and phenols. Titanium is also used as construction material due to strong, corrosion resistant, resistant to hot chloride solutions and nitric acid. But it is costly.

BASICS OF MATERIAL HANDLING SYSTEMS

INTRODUCTION

Material handling is the movement, protection, storage and control of materials products during manufacturing, storage, distribution, consumption and disposal. As a process, material handling incorporates a wide range of manual, semi automated and automated equipment. Conveying is the process of transport of materials from one place to another. If there is delay in raw material movement as per production schedule, then manufacturing process will be slowed down. Conveyors are used in the production of tablets, capsule and liquid orals dosage form.

OBJECTIVES OF CONVEYING

The objectives of conveying are

- To decrease product cost.
- To decrease manufacturing cycle time.
- To decrease manufacturing capacity.
- To decrease raw material cost.
- To lower processing time.
- To avoid contamination and dust formation.
- High degree of uniformity and productivity at low manufacturing cost.
- To provide better quality product without any damage.
- To increase storage capacity.
- To provide better working condition.

APPLICATIONS OF CONVEYING

Conveyors have variety of applications

Ergonomics: Because they do the work of the movement of the load, the conveyors eliminate the possibility of the operator being injured by pushing or pulling.

Process flow: The conveyors can be used as part of an assembly or manufacturing process.

S**afet**y: due to the fact that conveyers move loads along a fixed path, the conveyor belts eliminate the possibility of collisions associated with the movement of the forklift truck of the manual product.

Speed: The conveyor speed can be adjusted as per requirement.

Transportation: The conveyors facilitate the internal movement of containers or boxes with a minimum or no labour force.

TYPES OF CONVEYORS

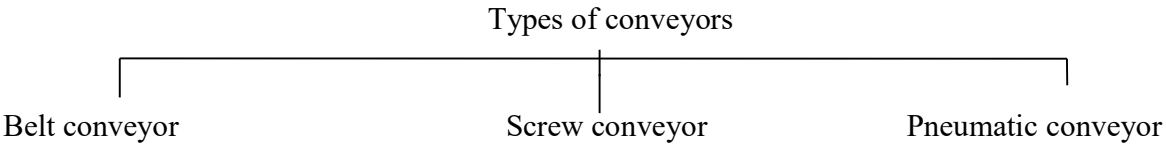

Fig. 5: Classification of conveyors

1. Belt Conveyors

Principle:

Belt conveyors are used to transport solid materials and bulk objects at high speed. The belt conveyors are based on the principle of material transport from the point of feeding to the point of discharge by rotating belt driven by motor in pulleys.

Construction:

The basic element of belt conveyors are belt and belt tightening system, belt drive and power supply, roller support, feeding arrangement and discharge arrangement. The belt consists of core of carcass of various plies of cotton duck in which each layer impregnated and bonded with rubber. The carcass is also coated with thin rubber layer that join plies with each other. The belt runs either in horizontal or inclined position. The belt runs continuously because both ends of belts are joined to each other.

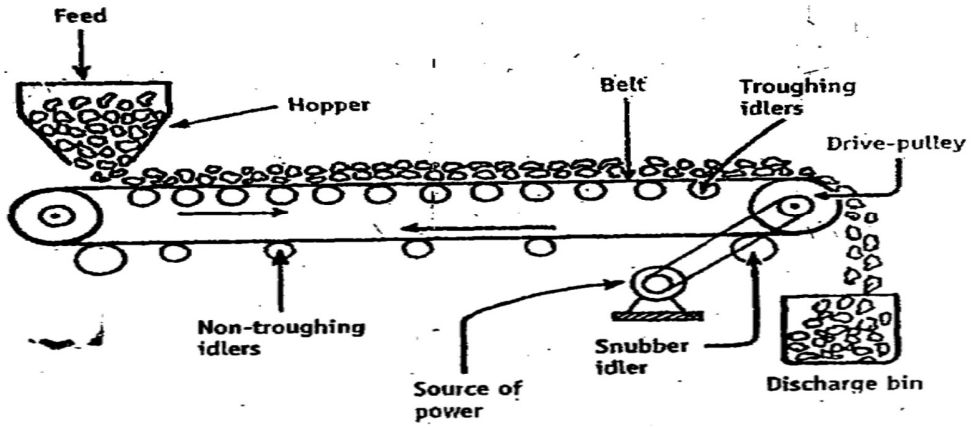

Fig. 6: construction of belt conveyors

To handle highly abrasive material, special grade of rubber belts are preferred. The belt of superior quality is made of neoprene and Teflon. Cord belts are also available. The belt should not be too thin or too thick because if belt is too thin for its width it will sag between idlers and if belt is too thick then it will not trough properly.

Due to temperature and humidity the length of belt is increased. Therefore tighteners are attached to maintain uniform stress on belt in all conditions. Belt drive is used to move the belt. The simplest device used to drive belt is bare steel pulley actuated with power source. The area of contact between belt and pulley can be enhanced by introducing snubber idlers below the pulley. Rollers which are arranged on shaft are used to support belt and these are called idlers. There are a significant number of idlers on conveyor. The selection of the correct type of idlers is very much important with respect to the optimum load carrying capacity of a conveyor and the environment in which the conveyor is to operate. The idlers are troughed to rise belt at edges and depress from centre.

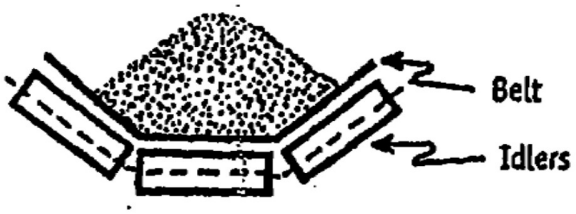

Fig. 7: Construction of troughed idler on 20 ^{o} idlers

Feed hopper is also attached at one end. Hopper is used to load feed at centre of the belt. To remove sticky material from belt, revolving brushes and rubber scrapper blades are used. The material at other side is collected in discharge bin.

Working:

When a rotor rotates, the conveyor belt will also rotate due to intense friction between the rotor wheel and the belt. This rotating movement of the rotor causes one side of the belt to move in one direction, while the other side moves in the opposite direction. There should be close contact between pulley and belt. Therefore snubber idlers are used to maintain close contact between them. The material or feed with the help of the hopper is loaded from the one side to the centre of the belt as the belt moves continuously in the forward direction. This also allows the material to travel over the belt in same direction. The material is collected in the discharge bin from the end of the belt, either mechanically or manually.

The selection of belt conveyor depend on speed of belt, width of belt, power required, mechanical and tensile strength of belt system, troughability of belt and also on material size.

Applications:

- During production of dosage form (such as injections, liquid orals and ointments), belt conveyors are used to transport container for filling, capping, labeling etc.

- Stripes are conveyed through moving belt for strip and blister packing of tablet and capsule.

Advantages:

- Simple structure.
- Easy to maintain.
- Low energy consumption.
- Large load capacity. Belt conveyors run at speed of 1000 fpm and load 5000 tons per hr.

Disadvantages

- Costly equipment.

2. Screw Conveyors

Principle:

Screw conveyors are based on the principle of material transport from the point of feeding to point of discharge by rotation of helical screw driven by motor.

Construction:

The basic element of screw conveyors are trough system, feeding arrangement, flight and power supply and discharge arrangement. It consists of U shaped trough which is made of steel. Spiral blade which act as screw element, also known as flight, is attached to the equipment. Power is transmitted through shaft to the flight or screw element.

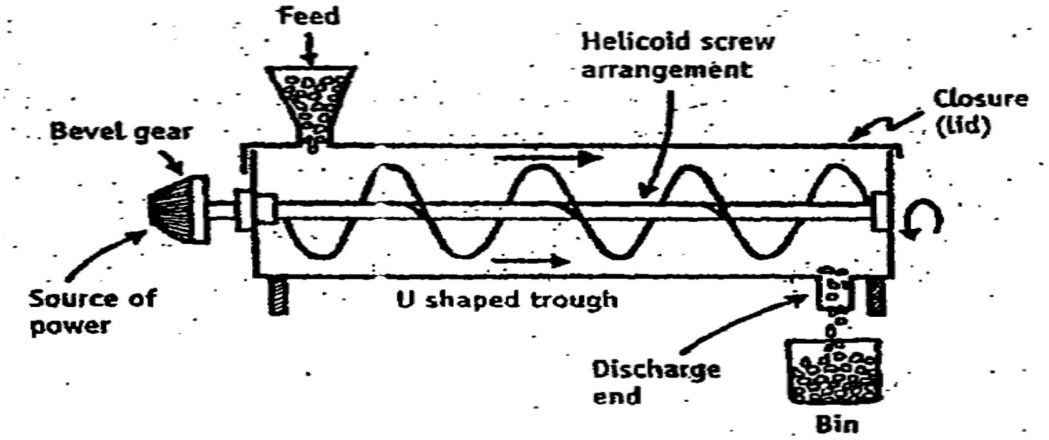

Fig. 8: construction of screw conveyor

The equipment is attached to helicoids screw arrangement which consist of one long ribbon twisted and wrapped into spiral shape. Flights are welded in to central shaft through hanger. Bevel gears are also installed at the drive end and used for maintaining speed and rotation for shaft. Hopper is used for feed arrangement. The drive end and discharge end are jointly called

box ends. Various feed and discharge arrangements are available. Feeding arrangement such as plain spout, rotary van feeder and rack and pinion gates are available while different discharge arrangements are open end through, open bottom trough, flat bottomed rack and pinion gates, curved side gate, enclosed rack and pinion gates.

Working

Switch on the power system. Bevel gear maintains speed of rotation of shaft which rotates axially. The flight or spiral blade also rotates. Feed is introduced through hopper. Material gets trapped within the scrapper. Material move forward as a flight moves. The material is received in discharge bin using open end trough.

Applications:

- It is used to convey fine, pasty solids, abrasive and non abrasive materials.
- It can transport material with capacity of 280 m^3/hr.
- Incorporated for *in situ* devices for mixing, heating, cooling etc.

Advantages:

- Operated at positive as well as negative pressure.
- It occupies less space.
- Material can be conveyed horizontally as well as vertically.

Disadvantages:

- High power consumption.
- High speed cause abrasive problem.

3. **Pneumatic Conveyors**

Principle:

In pneumatic conveyors, the transport of material from one place to another occurs due to the high velocity of the air stream that suspends individual particles in the air. This is known as fluidized bed system.

Construction:

The equipment consists of Air supply system, Air slides, pipelines, feed arrangements, discharge arrangement etc. The system is attached to a pump. The conveying system consists of fans or cycloid blowers. The feed supply is connected to air slide through rotary feeder valve. The other

end of pipeline is also attached to cyclone separator. The material is collected from other end of equipment and air is passed out.

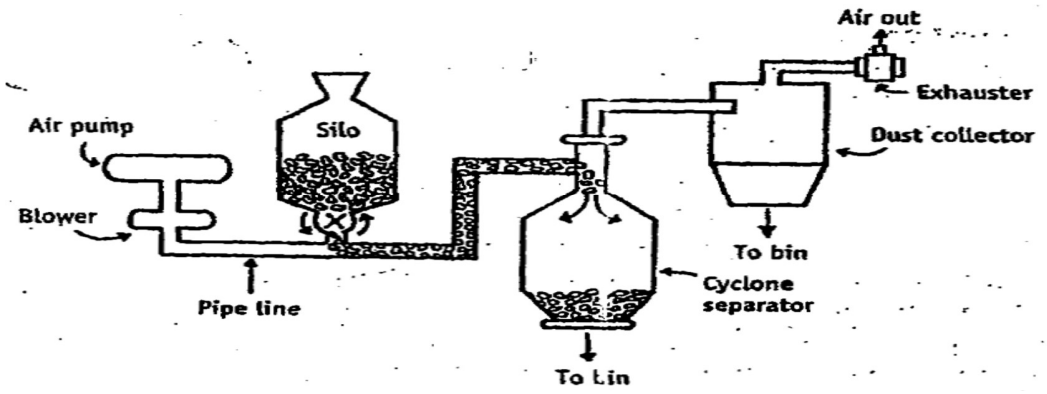

Fig. 9: Construction of pneumatic conveyors

Working:

The air through cycloid blower generate at the pressure of 7 kilopascals. The cycloid blower produce air which pass through air slide. As a result rotary feed valve rotates and feed enters in to the pipeline. The solids are suspended in air stream. The suspension is then admitted to a cyclone separator where the separation of large and fine particles occurs. Large particle are collected in bin while fine particles removed in bag filters. The gas is recycled. Pneumatic conveyors are classified as pressure type, vacuum type, pressure vacuum type, fluidizing type and blow tank type.

Applications:

- It is used for transferring powders, granules, and other dry bulk materials through enclosed pipelines.
- It is used to move lightweight material quickly from one place to another without vessel.
- As it is a closed system, therefore also used to handle poisonous material.
- Fine powder having bulk density 1 to 200 lb/ft^3 can be handled by pneumatic conveyors.

Advantages:

- The material travel from few meters to several hundred meters.
- It consists of simple, small diameter pipeline to transfer material.
- The system is totally enclosed and typically has few moving parts.
- Friction losses are small.

Disadvantages:

- A pneumatic conveying system requires more horsepower than other conveyor system.

- In case of large particle size and extremely sticky material there are chances of total pipeline blockage.
- Sometime attrition of solid occurs.
- Chances of erosion of internal surface.