17

Materials of Construction

Factors Influencing the Selection of Materials
Classification of Materials for Plant Construction
Ferrous Metals
Non-Ferrous Metals
Nonmetals—Inorganic
Nonmetals—Organic

A number of equipment are used in the manufacture of pharmaceuticals, bulk drugs, antibiotics, biological products etc. In addition, several accessories such as containers for processing and packing of finished products are essential. A wide variety of materials can be utilised for the construction of equipment. The success or failure of a new chemical plant or in the improvement of an existing facility depends on:

1. Design of equipment
2. Selection of material
3. Technique of fabrication

The design (construction) and working of equipment employed in unit operations have been discussed vividly in various chapters. The knowledge on the properties of materials is essential for selecting the right kind of materials.

The purpose of this chapter is to provide a working knowledge on some of the major types of materials available for construction. This will determine whether a process is expensive or complex. It also decides the profit and utility of the end product. The technical details on the fabrication are not within the scope of this chapter, because it needs special expertise, which may not be relevant.

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

1. Chemical resistance
2. Structural strength
3. Resistance to physical shock i.e., operating pressure

4. Resistance to thermal shock i.e., operating temperature
5. Ease of fabrication
6. Cost
7. Maintenance

Selecting satisfactory materials for the construction of plant encounters problems involving chemical, physical and economic factors.

FACTORS INFLUENCING SELECTION OF MATERIALS

Chemical Factors

The container or equipment should protect the integrity of the contents. At the same time, the contents should not alter the properties of the material with which the vessel is made. When these are in contact with each other, the effects may be understood in two ways:

(a) The contents may react and thus get contaminated with the material of the plant.

(b) The drugs and chemicals may destroy the material of the plant.

Contamination of the product : The impurities in chemical substances or bulk drugs may be from different sources. The solvent action may cause corrosion, so that the traces of metal ions used in construction tend to pass into solution and contaminate the product. Substances such as glass, silica, lead, cast iron, steel, tinned iron and a variety of alloys are used in the construction of a chemical plant and most of them produce contamination.

Even though impurities are present in traces, these may cause the product to decompose. For example, heavy metals inactivate penicillin. The appearance of the product may also be effected by changes in colour. Glass vessels may give up traces of alkali to the solvent, though this is unlikely, if the vessels are of hard glass. Sometimes, product contamination may be innocuous and non-toxic.

Influence of chemicals on the material of the plant : The solutions that come into contact with the equipment are generally corrosive in nature. In addition, equipment are exposed to extremes of pH, temperatures and pressures. As a result, the material gets corroded, losing its strength and durability. Therefore, the life of the equipment is reduced.

The knowledge of materials of plant construction assists greatly in providing a plant that will be resistant to attack of acids, alkalis, oxidizing agents, tannins etc. New alloys having special physical and chemical properties have been developed to meet the problems of chemical reactions.

Physical Factors

Strength : The material should have sufficient strength so that it can withstand the stresses or rigours to which the material is subjected in the production. Iron and stainless steel can satisfy these properties. For example, in the compression of tablets, the dies and punches should have sufficient mechanical strength to transmit the applied pressure, otherwise tablets are poorly formed. Glass satisfies the property of strength, but is breakable.

Generally tablets, capsules and vials are preserved in blister packing. The packing materials should withstand the rigors of handling, shipment and transportation. Plastic materials are used, because these offer sufficient mechanical strength.

Aerosol containers must withstand pressure as high as 960 kPa to 1.20 MPa at 55°C. Tin plate containers can satisfy this condition, while plastic containers cannot be used due to its poor mechanical strength.

Mass : Many times, the equipment should be transported or moved from one place to another. This is possible when the material is light in weight, when other factors are satisfactory. Similarly, plastic material is employed for the manufacture of containers for use of pharmaceuticals and cosmetics on account of its light weight. As a result the cost of transportation reduces.

Wear properties : These properties become important, when there is a possibility of friction between the moving parts. For example, during milling and grinding, the grinding surfaces wear off and these materials will be incorporated into powder as impurities. Such type of mills should be avoided, when drugs of high purity are required. The risk of contamination is more due to wear of ceramic or iron equipment (sieves etc.).

During tabletting operations, the upper and lower punches rotate continuously. In this process, the wearing of these punches is high.

Thermal conductivity : In chemical industries, several equipment such as evaporators, dryers, stills and heat exchangers are used. The material employed for their fabrication should have good thermal conductivity. However, the resistant films greatly retard the process of heat transfer. For example, iron, glass or graphite tubes are used in the fabrication of heat exchangers, so that effective heat transfer is possible.

Thermal expansion : If the material has high coefficient of expansion, the design of plants may be greatly complicated. This increases stresses and the risk of fracture when temperature changes. The material should be able to maintain size and shape of equipment at working temperatures.

Ease of fabrication : During fabrication, the materials undergo various processes such as casting, welding, forging and machinisation etc. For example, glass and plastics can be easily moulded into containers of different shapes and sizes. Glass can be used as a lining material for reaction vessels used in the chemical industry. Iron and steel undergo various rigours of processing during fabrication.

Cleansing : Smooth and polished surfaces allow the process of cleansing easy. Materials that can be obtained with such a finishing are ideal, when scrupulous cleanliness is necessary. For example, stainless steel and glass are suitable for this purpose.

Sterilisation : In the production of parenterals, ophthalmic products, antibiotics and biologicals, sterilisation is an essential step, which is obtained by autoclaving. The material should be capable of withstanding the necessary treatment, usually steam and pressure. In most cases, cleansing is a preliminary step to the sterilisation of apparatus and plant. For example, equipment and vessels are made of stainless steel, because they can be sterilised.

Transparency : Transparency may be a useful property because it permits the visual observation of the changes during a process. For this reason, borosilicate glass has been increasingly used in the construction of reactors, fermentors etc.

Economic factors : Initial costs and maintenance of the plant must be economical. Here the main concern is not simply to obtain the least cost material. Low wearing qualities and lower maintenance may well mean that a higher initial cost is more economical in the long run.

CLASSIFICATION OF MATERIALS FOR PLANT CONSTRUCTION

Materials of pharmaceutical plant construction can be classified as shown in Figure 17-1.

Different materials and their properties are discussed so that right kind of materials can be selected for the desired purpose and function.

FERROUS METALS

Iron metal is one of the widely used materials for the construction of plants because of its mechanical strength, abundant availability and lower cost. Some varieties of iron are discussed.

CAST IRON

Cast iron consists of iron with a proportion of carbon (beyond 1.5%). The properties of iron depend on the amount of carbon present in it. Cast iron is abundantly available, inexpensive and therefore widely used. A number of types of cast iron are available (Table 17-1).

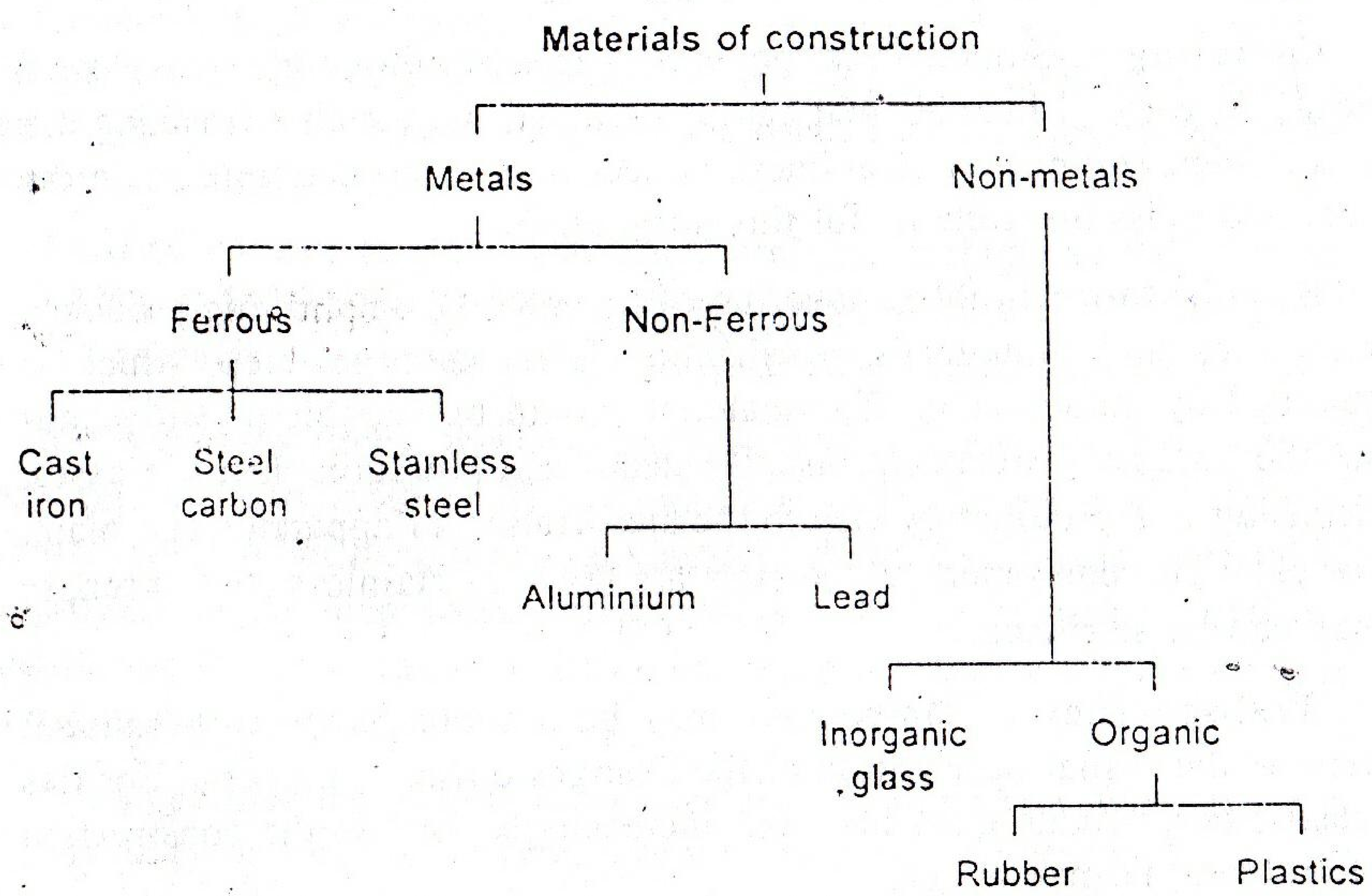

Figure 17-1. Classification of materials used for the construction of plant.

Advantages : (1) Cast iron is cheap. Therefore, it is used in place of expensive plant material with coatings or linings of enamel or plastic.

(2) It is resistant to concentrated sulphuric acid, nitric acid and dilute alkalis.

(3) Since cast iron has low thermal conductivity, it is used for the construction of outer surface of jackets of steam pans.

Disadvantages : (1) Cast iron is very hard and brittle. Therefore, it is difficult to machine. This disadvantage can be overcome by the addition of different materials to improve its performance.

(2) Cast iron is attacked by dilute sulphuric acid, dilute nitric acid and dilute as well as concentrated hydrochloric acid.

(3) Since cast iron has low thermal conductivity, it cannot be used for heat transfer in stills.

Uses : It is commonly used for the construction of:

(1) Supports for plant

(2) Jackets of steam pans

(3) Linings with enamel, plastic or suitable protective material

Modifications of cast iron : Cast iron is not considered corrosion resistant. The characteristics of cast iron can be altered by alloying with other elements such as silicon, nickel and chromium. (see Table 17-1)

Commercial Types : Duriron and Durichlor.

TABLE 17-1
Different Types of Cast Iron Alloys

Types of cast iron	*Composition*	*Properties*	*Disadvantages*
Gray cast iron	Carbon silicon	Low cost, easy to cast into intricate shapes and linings. For grinding balls, dies, impellers.	Brittle, poor resistance to impact and shock
Maleable iron	white cast iron carbon–2.5%	Corrosion resistant . Type I easy to machine	Type II less easy to machine
High silicon cast iron	Silicon-13-16% cast iron	Resistant to corrosion, oxidising environment, reducing environment. Used in sulphuric acid services.	Not easily machined and welded
Nickel resistant cast iron		Superior toughness, impact resistant, easy to weld and machine. Corrosion resistant and heat resistant.	Oxidising agents such as nitric acid are highly detrimental. There is little attack from neutral or alkaline solution

CARBON STEEL OR MILD STEEL

Carbon steel is an iron alloy, which contains only a small percentage of carbon. **Advantages** of carbon steel are:

(1) Carbon steel is cheapest. Therefore, it is preferred.

(2) It is easily weldable and is frequently used in fabrication.

Disadvantages of carbon steel are:

(1) Carbon steel has limited resistance to corrosion. This property can be improved by preparing alloys.

(2) It reacts with caustic soda, brine and sea-water. Alloying it can reduce this reactivity.

Uses : Carbon steel is used for the construction of bars, pipes and plates. It is used to fabricate large storage tanks for water, sulphuric acid, organic solvents etc. It is used for supporting structures such as grinders and bases for plant vessels.

Variants of carbon steel : The properties of carbon steel can be altered by alloying it with other metals. Some of the metals and their properties are:

Nickel (Ni) – improves toughness, corrosion resistance and low temperature properties.

Chromium (Cr) – increases hardness, more abrasive resistance and resistance to oxidation.

Silicon (Si) – increases hardness, more abrasive resistance and resistance to oxidation.

Molybdenum (Mb) -- provides strength at elevated temperatures

The types of alloys of carbon steel are given in Table 17-2.

TABLE 17-2
Different Types and Alloys of Carbon Steel

Variety of carbon steel	*Composition*	*Advantages*
Low alloy steel	Low concentration of iron, carbon, manganese, nickel, chromium and molybdenum	– High mechanical strength – Corrosions resistant to environments. – Walls of plant can be thin.
Alloying with nickel	nickel	– Increased hardness – High corrosion resistance – Improved low temperature properties.
Alloying with silicon chromium	nickel chromium	– Abrasion resistant – Corrosion resistant – Resistant to oxidation

STAINLESS STEEL

Stainless steel is an alloy of iron. Usually, it contains chromium and nickel, which make the steel corrosion resistant. Stainless steel is stabilised by the addition of titanium, niobium or tantalum. Minor amounts of other elements such as copper, molybdenum and selenium are added. Stainless steel also has the advantage of ease in fabrication.

The abundant use of stainless steel is due to the properties such as:

- heat resistance
- corrosion resistance
- ease of fabrication
- cleaning and sterilisation
- tensile strength

Depending on the composition, stainless steel alloys are available in three groups, viz., martensitic, ferritic and austenitic. These are given in Table 17-3.

TABLE 17-3
Different Types of Stainless Steel

Composition	*Advantages*	*Disadvantages*	*Uses*
Martensitic (e.g: Type 410)			
Chromium : 12-20% Carbon : 0.2- 0.4% Nickle upto 2.0%	Mildly corrosion resistant, atmospheric and organic exposures	Ductility is poor	Sinks, bench tops, storage tanks, buckets, mixing elements etc.
Ferritic (α-form) (e.g: Type 430)			
Chromium : 15-30% Carbon : 0.1% Nickel : nil	Better corrosion resistant; easy to machine; resistant to oxidation and temperature. (upto 800°C)	not good against reducing agents, hydrochloric acid	Tower linings, baffles, separator, tower, heat exchanger, tubings, condensers, furnace parts, pumps shafts, valve parts.
Austenitic (γ-form)			
Chromium : 13-20% Nickel : 6-22 % Carbon : 0.1% < 0.25%	Highly corrosion resistant; readily cleaned; sterilizable; easy to weld; non-magnetic	Not easy to machine	Fermentors, storage vessels, evaporators, extraction vessels, small apparatus (funnels, buckets etc.)

NON-FERROUS METALS

ALUMINIUM

A number of aluminium items are used in regular day to day life. Aluminium is cheap, light in weight and offers adequate mechanical strength. In addition, aluminium equipment can be easily fabricated. Further, aluminium can be strengthened by cold working. Their maintenance and cleaning is also easy. Hence, its utility is mostly recommended. However, the use of aluminium in the construction of plant and equipment is limited.

Advantages : (1) High resistance to atmospheric conditions, industrial fumes, vapour and fresh or salt waters. Aluminium can be used with concentrated nitric acid (above 82%) and acetic acid.

(2) Thermal conductivity of aluminium is 60% that of pure copper.

Disadvantages : (1) The mechanical strength decreases greatly above 150°C.

(2) Aluminium cannot be used with strong caustic solution.

(3) Many mineral acids attack aluminium.

(4) Oxide and hydro-oxide films are formed rapidly, when its surface is exposed. Normally this film is thickened by chemical and electrolytic means. These provide so called anodised finishes.

Uses : A super grade is preferred for food and pharmaceutical use. It is used in many heat transfer applications. These are used as meat storage containers.

Aluminium alloys and modifications : A number of aluminium alloys are available with improved qualities and mechanical properties. Aluminium alloys are used in the construction of equipment producing medicinal substances, since aluminium does not affect the salts.

Aluminium is non-toxic to microorganisms. It has considerable use in biosynthetic processes such as the production of citric acid gluconic acid and streptomycin by deep culture methods. It is most useful for the construction of containers namely drums, barrels, rail tankers etc.

LEAD

Lead has the lowest cost and is used as collapsible tube material particularly for non-food products such as adhesives, inks, paints and lubricants. Lead tubes with internal linings are sometimes used for fluoride tooth-paste. Lead chamber process is used in the manufacture of sulphuric acid.

Disadvantages : (1) Lead has low melting point and hence possesses poor structural qualities.

(2) It has high coefficient of expansion. Therefore, temperature strain results in permanent deformation.

In pharmaceutical practice, lead has little use, because of the risk of contamination even in traces produces toxicity and of cumulative nature. It is used for the construction of cold water pipes, waste pipes and dilution tanks for laboratories.

Lead alloys and modifications : Lead alloys with superior performance qualities have been established. For example, acid lead and copper lead are used in chemical industries. Some metals are added to lead for altering properties.

Silver and copper	- improves corrosion resistance.
	improves creep and fatigue resistance.
Antimony, tin, arsenic	- hardens, still melting point is low.

Lead-lined steel structures are used for the construction of pipes, valves, vessels designed for operations at high temperatures, fluctuating temperatures or vacuum.

NONMETALS—INORGANIC

GLASS

A number of glass articles are used in daily life. Glass has the advantages of superior protective qualities, attractiveness and low cost. It is chemically inert to a large extent and available in a variety of sizes, shapes and colours. Glass containers practically offer excellent barrier against every element except light. UV rays and sunlight are harmful to certain ingredients and bring about chemical deterioration. Protective action against light can be achieved by amber-coloured glass. Protection against IR rays can be obtained by using green glass. The disadvantages are its fragility and weight.

Glass is considered as a super-cooled liquid, though it is seen in solid state. The constituents are present in amorphous state. Glass is composed of the following constituents.

Sand	- silica pure (silicon dioxide, SiO_2)	- base material
Soda ash	- sodium carbonate (Na_2CO_3)	- improves the properties
Lime stone	- calcium carbonate ($CaCO_3$)	- improves the properties
Cullet	- broken glass	- fusion agent

Silicon dioxide is having a tetrahedron structure. The glass that is prepared by silicon dioxide alone is the most resistant, but relatively brittle. It can be melted and moulded at high temperatures. Therefore, cations such as sodium, potassium, calcium, magnesium, aluminium, boron, iron etc., are added. These cations (available as oxides) modify the physicochemical properties of glass, so that it is suitable for the manufacture of glass with desired characteristics. However, this glass has low chemical resistance. Some varieties of glasses are given in Table 17-4.

TABLE 17-4
Some Varieties of Glasses

Type of glass	*Composition*	*Advantages or uses*
Soft glass (soda glass)	Sodium silicate Calcium silicate	Making glass bulbs and window glasses
Hard glass (potash glass)	Potassium silicate Calcium silicate	Glass apparatus, which resists the action of acids
Flint glass (Potash lead glass)	Potassium silicate Lead silicate	Optical instrument because of its refractive index
Jena glass	Zinc silicate Barium borosilicate	Laboratory glassware, because of its resistance to acids and alkali
Pyrex glass	Silicon dioxide Boron oxide Sodium oxide Small amounts of potassium calcium magnesium	Laboratory glassware and reactor vessels, because of its resistance to heat
Quartz glass	Pure silica	Silica crucibles, distilled water stills (for high purity), because of its low coefficient of expansion. It withstands temperature shock upto 1000°C.

Glass containers used for pharmaceutical purposes are given in Table 17-5. These types are classified into four groups. These have varied degree of chemical resistance. The reasons for the low chemical resistance are as follows. Most of the alkali oxides such as Na_2O, K_2O, MgO and CaO enter the spaces within the structures and reduce the strength of inter-atomic forces between silicon and oxygen. The oxides decrease the melting point of glass and are comparatively free to migrate. This behaviour creates a number of problems in their use. These are:

(a) Oxides leach into the solution, raises the pH, hydrolyse or catalyse chemical reactions.

(b) Some times, glass flakes are formed in the solution.

However, boron oxide enters into the structural configuration of glass and does not leach out and hence is used in parenteral packings.

TABLE 17-5
Types of Glass used in Pharmaceutical Industry IP

Types	*General description*	*Properties*	*Uses*
I	Highly resistant Borosilicate (Alkali and earth cations are replaced by boron)	Resistant to alkali leaching, less brittle, low thermal expansion easy to clean and sterilise.	Containers for buffered and unbuffered, aqueous solutions and injectables
II	Treated soda-lime glass.	Surface alkali is neutralised by sulphur dioxide vapours. Glass surface is resistant to water.	Containers for buffered, aqueous solution with pH below 7.0, dry powders, oleogenous solutions.
III	Soda-lime glass	It releases comparatively more alkali. It offers moderate hydrolytic resistance.	Dry powders, oleogenous solutions.
IV	General purpose soda lime glass		Not for parenterals, used as containers for tablets, oral solutions, suspensions, ointments and liquids for external use.

GLASSED STEEL

Glassed steel is an inorganic product of fusion, which is cooled to a rigid condition without crystallising. It requires special considerations in its design and use. These surfaces are applied to heavy vessels. Normally, several coatings are fused in a furnace. Glassed steel combines the corrosion resistance of glass with the working strength of steel.

Advantages of glassed steel are:

(1) It has excellent resistance to all acids except hydrofluoric acid and hot concentrated sulphuric acid.

(2) It can be attacked by hot alkaline solution. Particularly suitable for piping when transparency is desirable.

(3) It is brittle and gets damaged by thermal shock. Hence it is protected using glass lined with epoxy polyester fibre glass.

(4) A nucleated crystallised ceramic metal composite form of glass has superior mechanical properties compared with conventional glassed steel.

(5) Glass linings are resistant to:
   (a) All concentrations of hydrochloric acids upto 120°C.
   (b) Dilute concentrations of sulphuric acid up to the boiling point.
   (c) All concentrations of nitric acid upto boiling point.
   (d) Acid resistant glass with improved alkali resistance (up to pH 12).

Uses : Glass lined steel is used for handling of strong acids, alkalis and saline solutions. For small-scale manufacture and pilot plant work, glassed steel vessels are used.

NONMETALS—ORGANIC

RUBBER

Rubber is used as such or as lining materials for the construction of plants. Both natural and synthetic rubbers are used.

Natural Rubber : Rubber is a naturally occurring polymer, which is obtained as latex from rubber trees. It is a common example of an elastomer. *Elastomer* is a substance that can be stretched readily and when released, rapidly regains its original form.

Soft Rubber : The naturally occurring polymer is known as *soft rubber*. It is a polymer of monomeric isoprene (C_5H_8). Thus, rubber is a polyisoprene with a formula $(C_5H_8)_n$. Soft rubber has the advantages of being resistant to dilute mineral acids, dilute alkalis and salts. The disadvantage is that soft rubber can be attacked by oxidising media, oils and organic solvents. Soft rubber is used as lining materials for plants, as it can bond easily to the steel.

Addition of carbon black to the soft rubber gives hardened rubber. It is used for making tyres, tubes and conveyor belts.

Hard Rubber : When soft rubber is mixed with sulphur, warmed and set into a given shape, it retains its form. The sulphur combines with the polymeric chains of rubber and cross-links between them. This

process is called *vulcanisation*. Soft rubber with 25 % or more sulphur, is known as *hard rubber*. Hard rubber has the advantages of hardness and strength. So it is used for making gloves, bands, tubes and stoppers.

Synthetic Rubber : Synthetic rubber has taken greater importance over natural rubber due to its superiority in properties such as resistance to oxidation, solvents, oils and other chemicals. Some synthetic rubber materials with their properties are reported in Table 17-6.

TABLE 17-6 :
Some Varieties of Rubber

Synthetic rubber	*Properties*	*Uses*
1. Neoprene (polychloroprene)	• Does not burn readily like natural rubber. • Stable at high temperature.	Insulating material in electric cables; conveyor belts in coal mines, making hoses in the transportation of oils. Rubber stoppers, cap-liners, dropper assemblies for eye drops etc.
2. Nitrile rubber	• Resistant to oil and solvents.	
3. Butyl rubber	• Resistant to – mineral acids & alkalis concentrated acids (except nitric and sulphuric acid)	Used for closures of freeze dried product containers because of its low water vapour permeability.
4. Silicon rubber (polysiloxanes)	• Resistant to – high & low temperatures. – attack to aliphatic solvents, oils and greases	
5. Polyisoprene	• Stable at high temperature, translucent, flexible.	

Synthetic rubber is thermoplastic, but when mixed with sulphur, warmed and set into a given shape, it retains its form. *Vulcanization* of rubber is possible. It is used for making gloves, bands and tubes, caps for vials.

Rubber is a soft material, but can be hardened by adding carbon black. Hardened rubber is used for making tubes, tyres and conveyor belts.

PLASTICS

Plastic materials have been in common use in various ways in our daily life. These are light in weight so that transportation is easy and cheap. These are available in a variety of shapes implying that it can be easily fabricated. Plastic containers are used for storing a number of substances such as inorganic salts and weak mineral acid. In machines, plastic materials are preferred wherever moving parts are present indicating that it offers less friction. These have better resistance to environmental factors. In a similar manner, plastic materials also used in the construction of plants.

Plastics are synthetic resins containing long chains of atoms linked to form giant or macromolecules (polymers). They have high molecular weight (10^3 to 10^7).

Plastics have several **advantages**. These are:

(1) Low thermal and electrical resistance.
(2) Excellent resistance to weak mineral acids.
(3) Unaffected by inorganic salts.
(4) Resistance to slight changes in pH.

Plastics have **disadvantages** also. These are:

(1) Low mechanical strength
(2) High expansion rates

Basically, two types of plastics are used in pharmaceutical industry.

Thermosetting plastics : *Thermosetting plastics* can be formed under heat and pressure. But these cannot be softened or remoulded, once hardened. Some thermosetting plastics are made of phenolic and urea resins.

Thermoplastic plastics : *Thermoplastic plastics* are formed by the application of heat and pressure and can be softened and remoulded. This is a specific advantage. Scrap and rejected articles can be worked again to get new materials.

Some thermoplastic materials and their uses are given below:

Polyethylene – cables, buckets, pipes
Polypropylene – milk cartons, ropes
Polyvinyl chloride – gloves, water proof garments
Teflon – gaskets, coatings

Based on the *utility* of plastics in plant construction, these can be categorised as:

1. Rigid materials
2. Flexible materials
3. Metallic surfaces
4. Plastic cements
5. Special case plastics

1. Rigid materials : These are phenolic resins with various inert fillers. These are used in the fabrication of a number of items. For example, Keebush is a rigid material (phenolic plastic) and is used for gears, bearing etc. It is light in weight. Some of its applications are:

– Gears	– Bearing	– Vessels
– Pipes	– Fittings	– Valves
– Pumps	– Ducts	– Filter presses

Disadvantages : These are resistant to corrosion except oxidising substances and strong alkalis.

2. Flexible materials : These are thermoplastic materials. These materials can be rigid or flexible depending upon the amount of plasticizer added. These are used in the fabrication of:

– Tanks	– Pipes	– Ducts
– Funnels	– Buckets	

3. Metallic surfaces : Plastics of polyethelene or polyvinyl chloride types are used along with plasticizers for the coating of metallic surfaces. These are used to protect the metal from corrosion. These linings are applied on:

– Tanks	– Vessels
– Stirrers	– Fans

4. Plastic cements : These are used for spaces between acid resistant tiles and bricks

5. Special cases : Plastics are used as guards for moving parts of machinery. Nylon and PVC fibres are woven into filter cloths and are used for aseptic screening.

QUESTION BANK

Each question carries 2 marks

1. Write the usefulness of glass lined equipment in the pharmaceutical plant.

Each question carries 5 marks

1. Explain the importance of stainless steel in pharmaceutical industry.
2. Write a note on the utility of glass and stainless steel in pharmaceutical industry.
3. Describe steel as a material of plant construction.
4. Name five important classes of plastics. Mention their applications in pharmaceutical industry.
5. Describe the steel alloys used in pharmacy practice.
6. What are the properties of glass? What are its applications as material of construction?
7. Describe various types of iron as materials of construction.