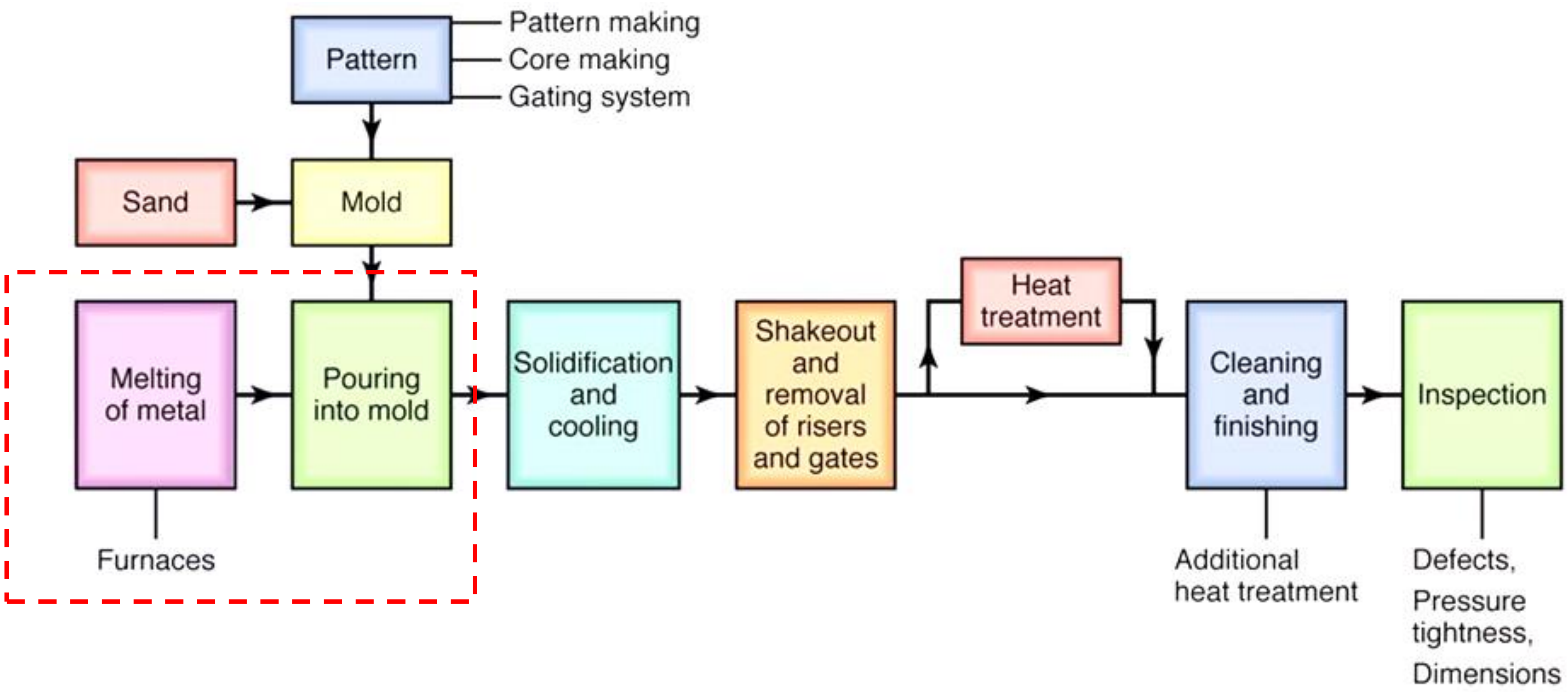
Melting and Pouring in Casting

Basic requirements of casting process



Melting is a process of preparing the **molten material for casting**. The molten metal is transported to the pouring area by **ladles** wherein the molds are filled.

Melting and pouring

- The quality of casting depends on the **method of melting**
- The melting technique provides the molten metal **required temperature**, which **ensure flow of material** in every corner of the mould cavity and maintain the quality of the product
- Molten metal should **prevented from oxidation** by **covering it with fluxes** or by performing melting and pouring in vacuum
- Pouring temperature and pouring rate should be maintained properly
- At higher temperature, **fluidity of molten metal** is more but **dissolved more gases**
- The fluidity of the material able to fill the whole cavity
- **High temperature damages the mould walls** and causes poor surface quality of the casting
- In ferrous metals, the dissolved hydrogen and nitrogen are removed by passing CO.
- In non-ferrous metals, Cl, He, or Ar gases are used.
- The optimum pouring temperature decided on the basis of fluidity requirement.

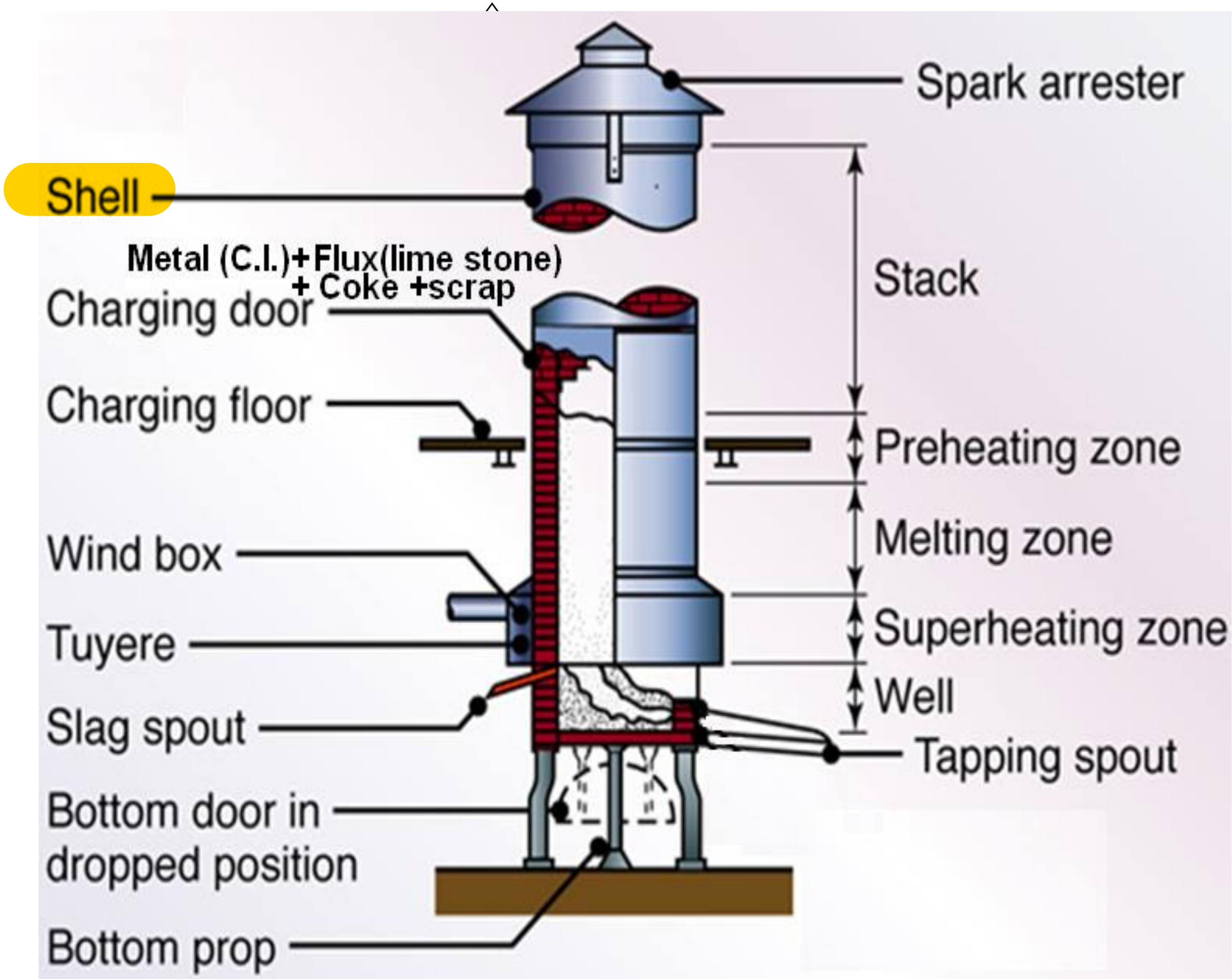
Furnaces

The choice of furnace depends on the type of metal to be melted.

- Cupola
- Electrical arc furnace
- Induction furnace
- Crucible furnaces (Indirect fuel-fired furnace)
- Direct fuel-fired furnaces
- Reverberatory furnace

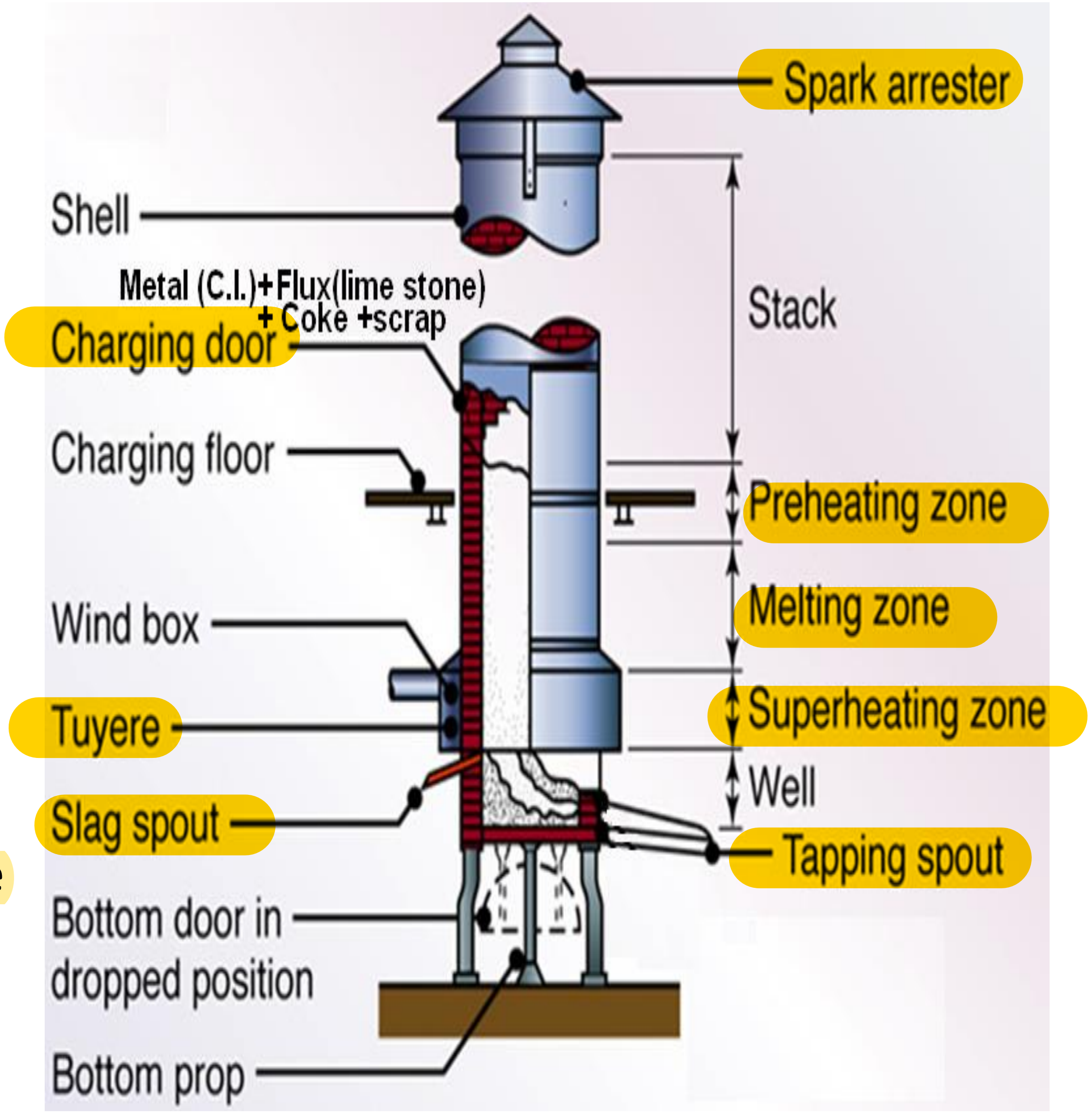
- Furnaces are charged with stock consisting of solid **metal**, alloying elements, and various other materials such as **flux** and slag forming constituents and **fuel** to generate heat.
- Fluxes have several functions:
  - React with impurities and form slag (Slag are lighter and float on the surface of molten metal and prevent further oxidation).
  - Act as an alloying and refining element.
  - Lime stone is widely used as flux.
- Coke or electric arc or other chemicals used as fuel.

Cupola

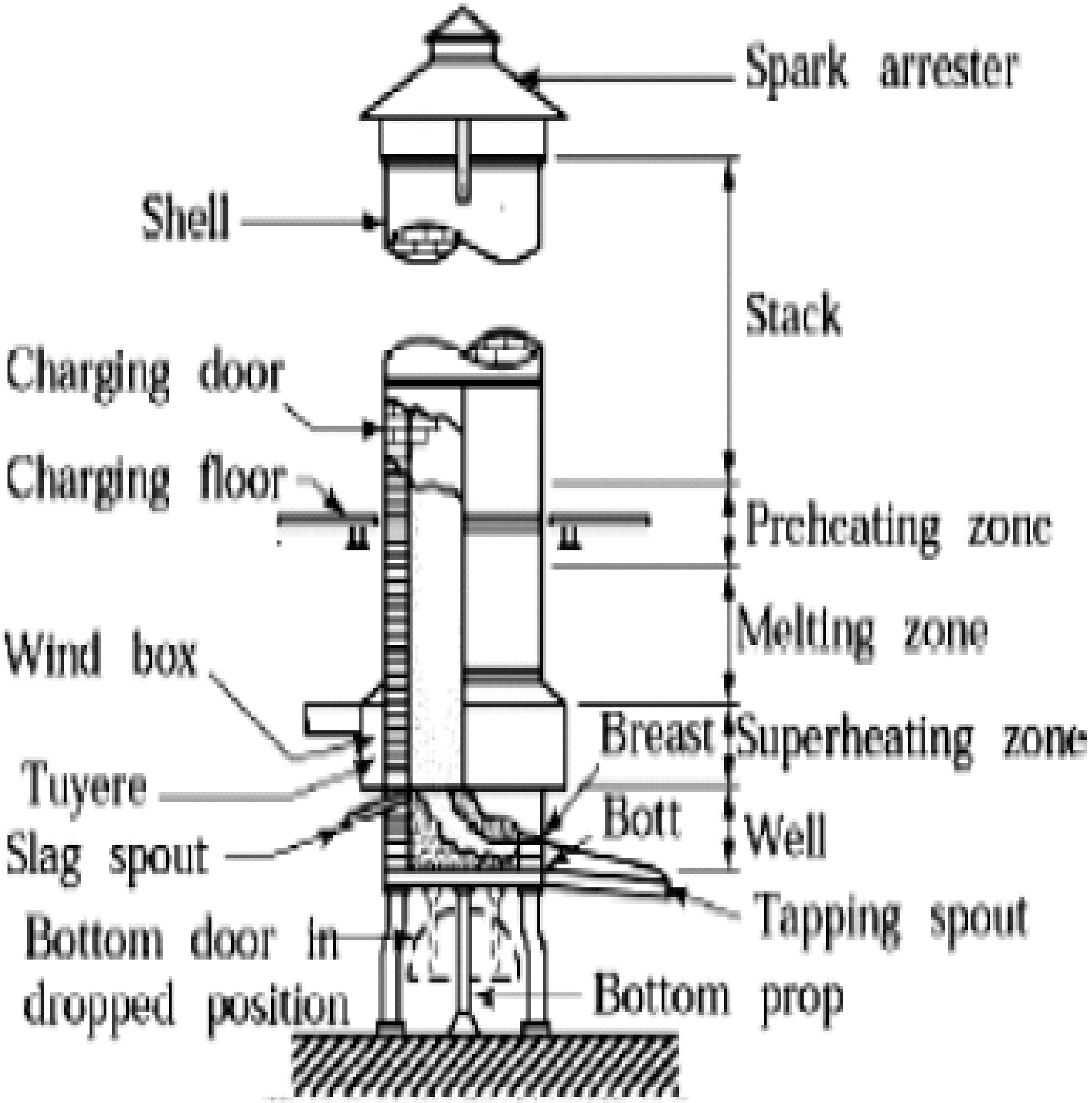

Spark arrester
Shell
Metal (C.I.)+Flux(lime stone)
+ Coke +scrap
Charging door
Charging floor
Stack
Preheating zone
Melting zone
Wind box
Tuyere
Superheating zone
Well
Slag spout
Tapping spout
Bottom door in
dropped position
Bottom prop

Cupola

- The cupola consists of a vertical cylindrical steel sheet, lined inside with refractory bricks. The lining is thicker in the lower portion (temperatures are higher than upper portion)
- **Charging door**: through which coke, pig iron, steel scrap and flux (lime stone) is charged
- The hot air is blown through the **tuyeres**, are arranged in one or more row around the periphery of cupola
- Hot gases ascends from the bottom (combustion zone) preheats the iron in the **preheating zone**
- **slag hole** is provided to remove the slag
- Through **tap hole** molten metal is poured into ladle
- **spark arrest** (top conical cap) is provided to prevent the spark emerging to outside



Cupola



The cupola is a shaft type furnace for producing molten cast iron.

It is a vertical cylindrical shell made of 6 to 12 mm thick steel sheets or plates riveted and lined inside with refractory bricks.

Diameters vary from 1 to 2 meters.

The lining is generally thicker in the lower region, where the temperatures encountered are very high than in the upper region.

The shell is mounted either on a brick work foundation or on a steel column.

The bottom of the shell is provided with drop-bottom doors, through which debris consists of slag, coke etc. can be removed at the end of the melt.

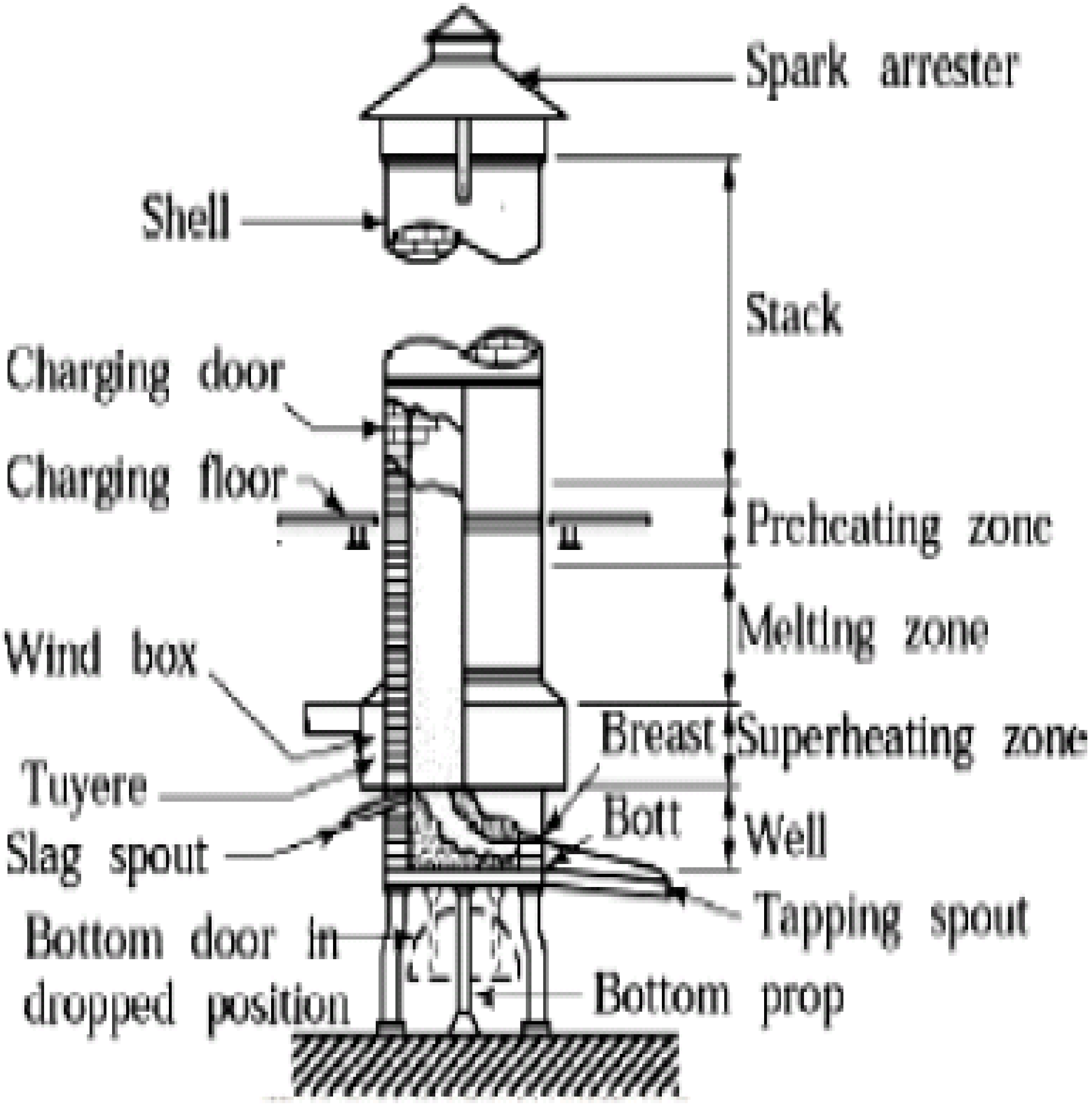
In cupolas the working bottom is built up with molding sand, which covers the drop doors.

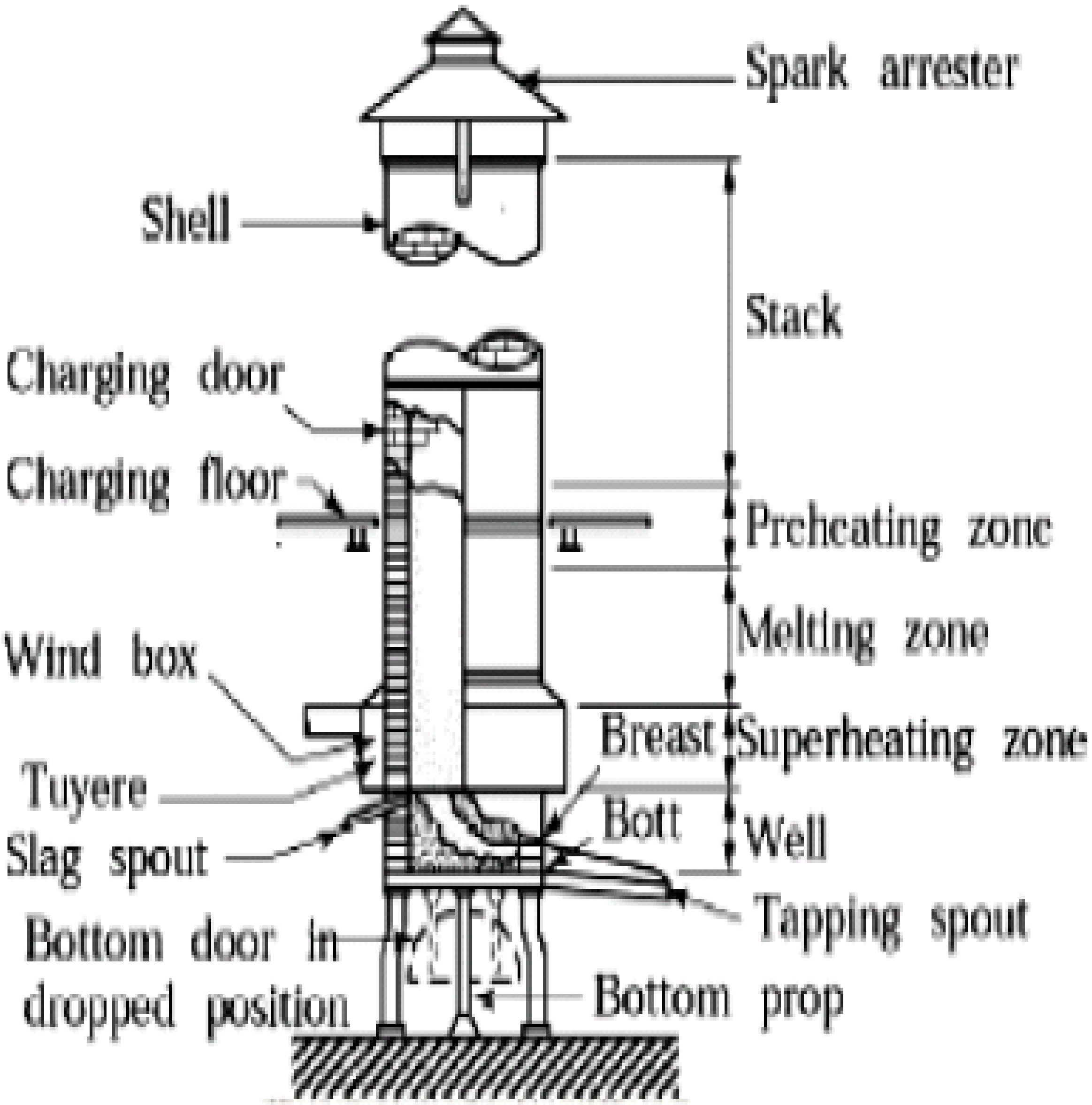
This bottom sand slopes towards the metal tapping hole situated at the lowest point at the front of the cupola.

The tap hole is used to tap molten metal.

Opposite to this tap hole, and slightly above, is another hole, called the slag hole, which enables the slag to be taken out.

The air for combustion is blown with the help of a motorized blower, through a pipe called wind pipe to a circular jacket wound around the shell called wind box. And finally the air goes in to the shell through a number of openings called tuyeres, which are provided at above the bed of the cupola.





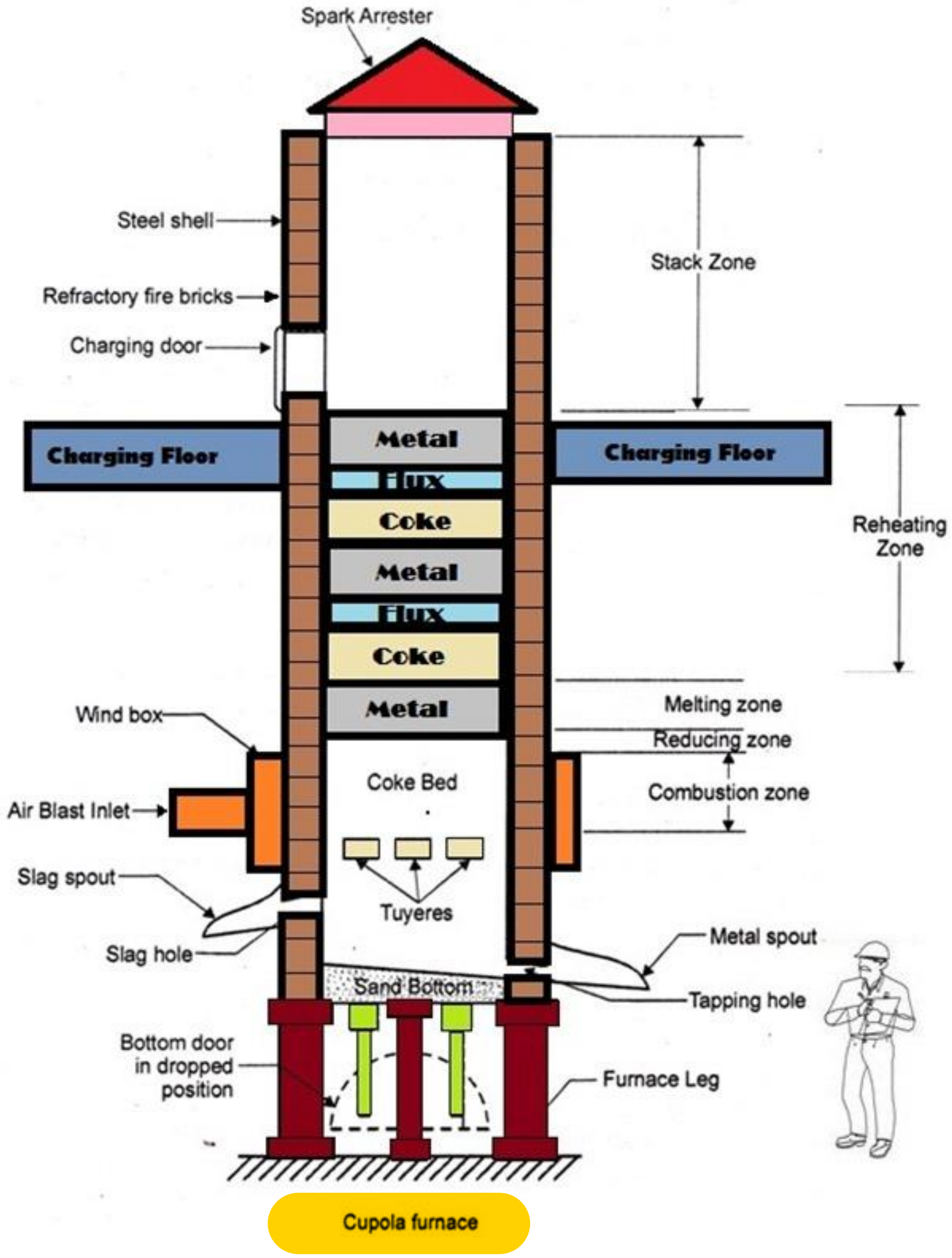
The tuyeres are generally 4,6, or 8 in numbers depending on the size of the cupola. They may be fitted in one or more number of rows.

A charging door is provided through which metal, coke and flux are fed into the furnace, and this is situated 3 to 6 m above the tuyerers, according to the size of the cupola.

At the top of the furnace a conical cap called the spark arrester, prevents the sparks from emerging outside.

The spark arrester cools down the sparks and allows only smoke to escape from the opening.

Cupola Furnace



Zones in Cupola

Crucible Zone: It is between the top of the sand and the bottom of the tuyeres. The molten metal comes here.

Tuyeres Zone: It is between the bottom of tuyeres to the top of tuyeres.

Combustion or oxidizing Zone: This zone is located above the tuyeres where the combustion of the fuel occurs by oxygen of the air blast and produces lot of heat in the cupola. Heat is also evolved due to oxidation of silicon and manganese. The chemical reactions which occurs in this zone are:

- $C + O_2 \longrightarrow CO_2 + \text{Heat}$
- $Si + O_2 \longrightarrow SiO_2 + \text{Heat}$
- $2Mn + O_2 \longrightarrow 2MnO_2 + \text{Heat}$

Preheating Zone or Charging Zone: It is located above the melting zone to the charging door. Iron and coke are preheated in this zone.

Reduction Zone: This zone extends from the top of the combustion zone to the top of the coke bed. CO2 produced in combustion zone comes in contact with hot coke and is reduced to CO. The reaction taking place in this zone is:

- $CO_2 + C\text{ (coke)} \longrightarrow 2CO - \text{Heat}$

Melting Zone: It is the first layer of iron above the coke bed. The temperature in this zone is as high as 1700 ºC . Iron is meted in this zone. A considerable carbon is picked up by the molten metal in this zone according to the following reactions;

- $3Fe + 2CO \longrightarrow Fe_3c + CO_2$

Stack zone: This zone carries gases from preheating zone to atmosphere and arrests sparks.

Working of Cupola

Preparation of Cupola:

After each heat, the slag and refuse are cleaned as soon as the patching of the lining is completed; the bottom doors are raised and held in position by metal props. The sand bottom is made such that it slopes towards the tap hole.

Firing the Cupola:

Small pieces of wood are ignited on the sand bottom when the wood burns well. Coke is then added. Air necessary for combustion is fed from the tuyeres. Coke is added until the desired height is reached

Charging of the Cupola:

After the coke bed is properly ignited, coke and pig iron are charged in alternative layers until the cupola is full.

In addition of iron and coke, a certain amount of limestone is added to first metal charge. Besides that fluorspar (CaF2) and soda ash (Na2CO3) are also used as fluxing materials. A flux removes the impurities in the iron and protects the iron from oxidation. Limestone reduces the meting point of the slag and increases fluidity. Sometimes ferro-manganese is also used as deoxidizer.

Soaking of Iron:

After the cupola is fully charged up to the charging door, the charge should soak in the heat for about 45 minutes. The charge gets slowly heated since the air blast is kept at a lower than normal blowing rate during this time. This causes the iron to get soaked

Opening the air blast:

At the end of soaking full blast is turned on. After the blast has been on for a few minutes, molten metal starts accumulating in the hearth.

Tapping and Slagging:

The first tapping can be made 40 to 50 minutes after the full blast is turned on. Slag is first removed through the slag hole and then the molten metal is collected in ladles and is carried to the moulds for pouring.

Closing the Cupola:

When the operation is over, the blast is shut off and the prop under the bottom door is knocked down so that the bottom plates swing open. This enables the cupola remains to drop on the floor or in to a bucket. They are then quenched and removed from underneath the cupola.

Charge calculation ??

- Final composition of the metal obtained from cupola furnace is important
- The elements in the final analysis are essentially the total of what is contained in each of the charge ingredients, with some losses or pickup in the cupola.
- Out of the various elements, **carbon, silicon, manganese and Sulphur** are most relevant.
- As the charge comes through the coke bed, some amount of **carbon is picked up** by the metal depending on the temperature and the time when the metal is in contact with the coke. **(0.15% carbon)**
- **Silicon is likely to get oxidized** in the cupola and therefore, a loss of **10%** of total silicon contained in the charge is normal. Under the worst conditions, it may go as high as 30%.
- **Manganese is also likely to be lost** in the melting process. The loss could be of the order of **15 to 20%.**
- **Sulphur is also likely to be picked** up from coke during melting. The pick up depends on the sulphur content of the coke. **(0.03 to 0.05%).**

Example- Estimate the final composition of the cast iron produced with following charge compositions and proportions

	Carbon	Silicon	Manganese	Sulphur	Phosphorus	% in charge
Pig iron 1	3.5	2.5	0.4	0.01	0.4	40
Pig iron 2	3.2	1.5	1.0	0.02	0.6	35
Gray iron scrap	3.2	2.5	0.5	0.10	0.4	25

Analyse the total amount of elements present in 1 ton (1000 kg) of charge, assuming carbon pickup 0.15%, sulphar pickup 0.05%, Silicon loss as 10% and Manganese loss as 20%.

Charge materials	kg	%	Carbon, % in material	Carbon, % in charge
Pig iron 1	400	40	3.50	$3.5 \times 0.40 = 1.40$
Pig iron 2	350	35	3.20	$3.2 \times 0.35 = 1.12$
Grey iron scrap	250	25	3.20	$3.2 \times 0.25 = 0.80$
Total	1000	100		
Total in charge, %				3.32
Change in cupola				+0.15
Estimated composition, %				3.47

Charge materials	kg	%	Silicon, % in material	Silicon, % in charge
Pig iron 1	400	40	2.50	$2.5 \times 0.40 = 1.00$
Pig iron 2	350	35	1.50	$1.5 \times 0.35 = 0.525$
Grey iron scrap	250	25	2.5	$0.25 \times 0.25 = 0.625$
Total	1000	100		
Total in charge, %				2.15
Change in cupola				−0.215
Estimated composition, %				1.935

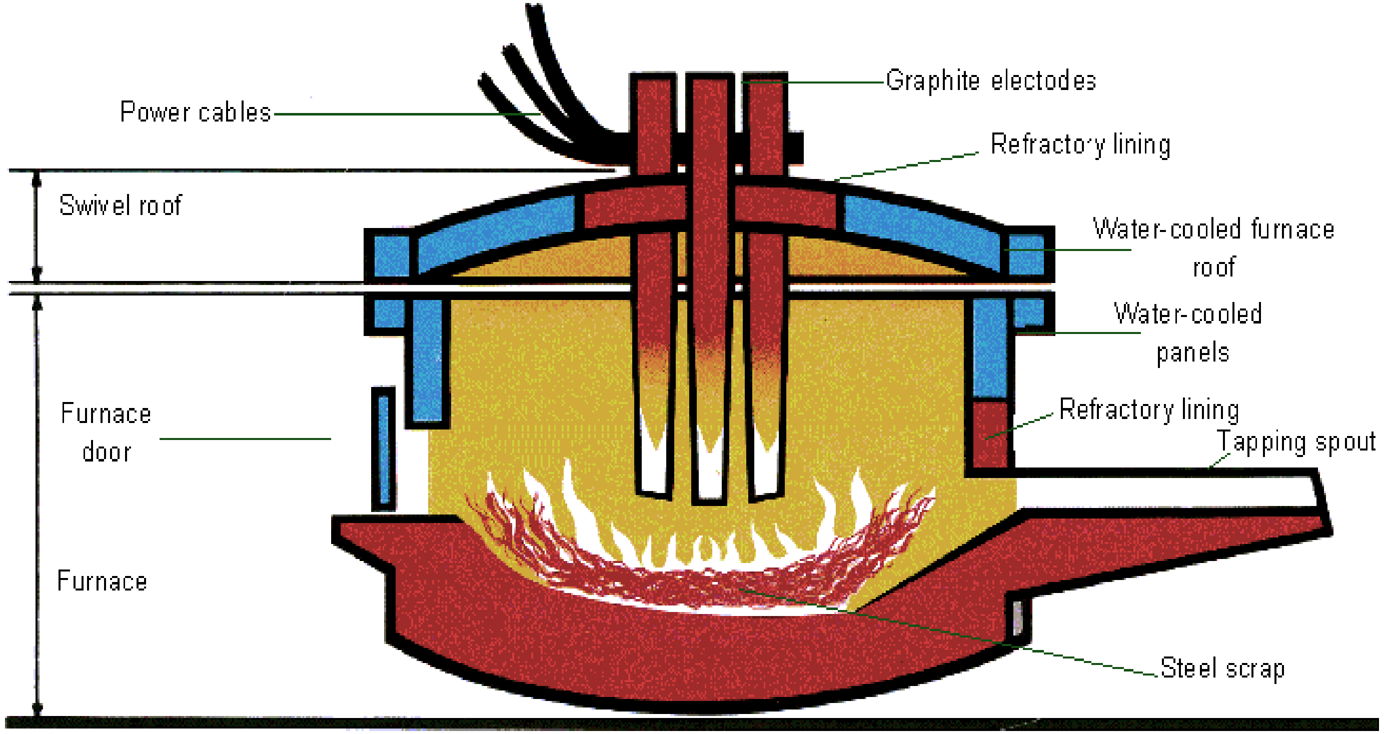
10% of Si present in charge

Charge materials	kg	%	Carbon, % in material	Carbon, % in charge	Silicon, % in material	Silicon, % in charge	Manganese, % in material	Manganese, % in charge	Sulphur, % in material	Sulphur, % in charge
Pig iron 1	400	40	3.50	3.5 × 0.40 = 1.40	2.50	2.5 × 0.40 = 1.00	0.40	0.4 × 0.40 = 0.160	0.01	0.01 × 0.40 = 0.004
Pig iron 2	350	35	3.20	3.2 × 0.35 = 1.12	1.50	1.5 × 0.35 = 0.525	1.00	1.00 × 0.35 = 0.35	0.02	0.02 × 0.35 = 0.007
Grey iron scrap	250	25	3.20	3.2 × 0.25 = 0.80	2.5	0.25 × 0.25 = 0.625	0.50	0.50 × 0.25 = 0.125	0.10	0.10 × 0.25 = 0.025
Total	1000	100								
Total in charge, %				3.32		2.15		0.635		0.036
Change in cupola				+ 0.15		− 0.215		− 0.127		+ 0.050
Estimated composition, %				3.47		1.935		0.508		0.086

Electric Arc Furnace

Direct arc furnace(Open-hearth)

Three-phase Direct arc furnace is the most popular one for melting steel in the foundry. In operation, scrape steel is placed on the hearth of the furnace. An arc is drawn between the electrodes and the surface of the metal charge by lowering the electrodes down till current jumps. Slag is maintained on the molten metal to reduce oxidation. Before pouring liquid metal into the ladle, the furnace is tilted back and the slag is removed from the charging doors. Now the furnace is tilted forward to pour the molten metal into ladle.



Advantages:

- The main advantage of this furnace over cupola furnace is that purer production is obtained and composition can be exactly controlled during refining process.
- This furnace can operate on 100% scrape steel which is cheaper than pig iron.

Disadvantage:

- This furnace involves high initial cost

Indirect arc furnace:

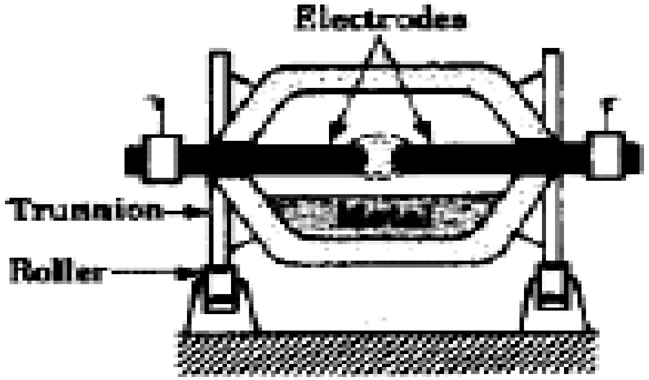
This is a single-phase electric furnace. This differs from the direct arc furnace that the electrodes do not come in contact with the molten metal, but form an arc above the molten metal. The furnace is mounted on rollers, which is driven by rocking unit to rock the furnace back and forth during melting. When the furnace rocks, liquid metal washes over the heated refractory linings and absorb heat from them. Thus the life of the refractory linings is also increased as the metal takes some of its heat and prevents it from high temperatures. The charge is heated by radiation from the arc and conduction from the lining.

Advantages:

The chamber being closed, and the atmosphere above the metal being arc, there is less loss of metal due to oxidation.

This furnace gives higher production per ton of molten metal.

Due to rocking action and absence of combustion gases, the molten metal is free from blow holes, inclusions etc. As a result, this molten metal gives sound castings.



Disadvantage:

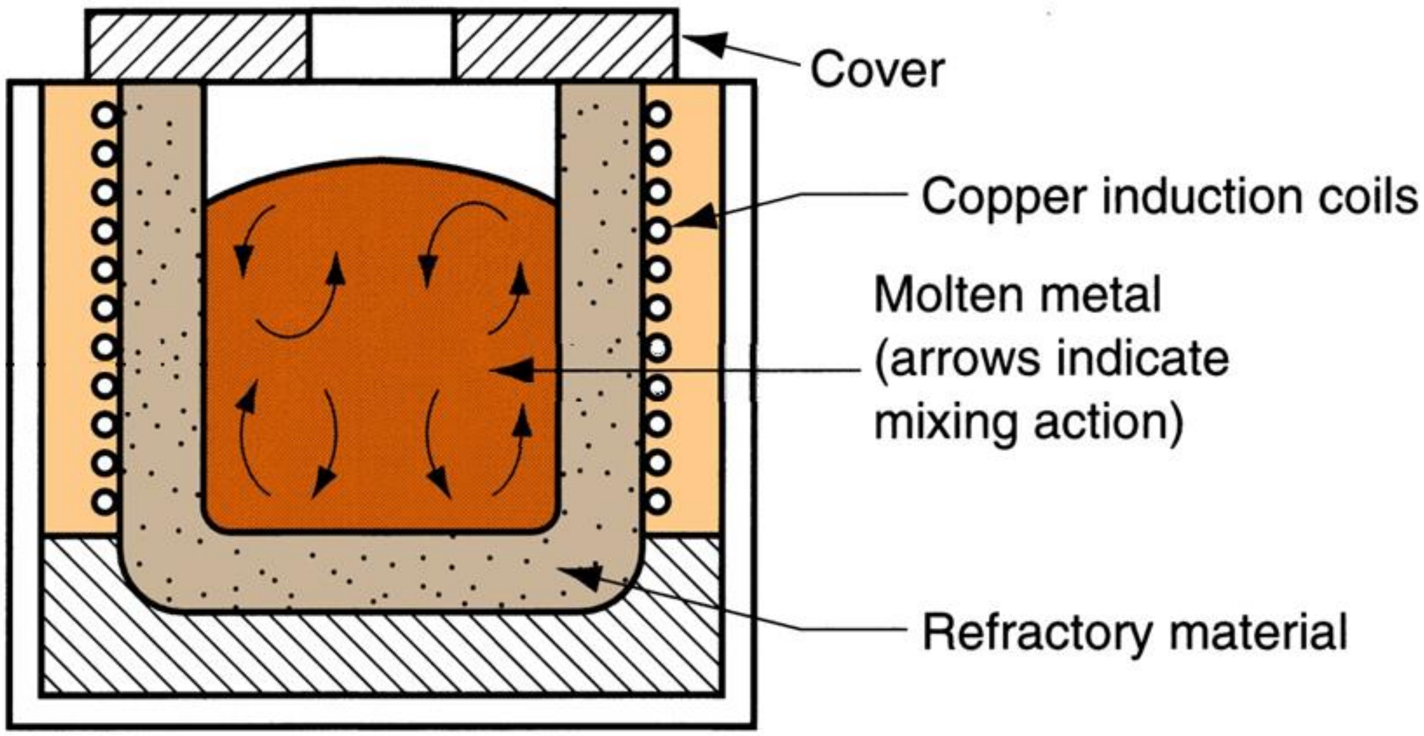
Due to indirect heating the furnace is suitable for metal having low melting temperatures. Thus this furnace is suitable for non ferrous metals only.

Induction Furnaces

- Uses alternating current passing through a coil to develop magnetic field in metal
- Induced current causes rapid heating and melting
- Electromagnetic force field also causes mixing action in liquid metal

•Since metal does not contact heating elements, the environment can be closely controlled, which results in molten metals of high quality and purity

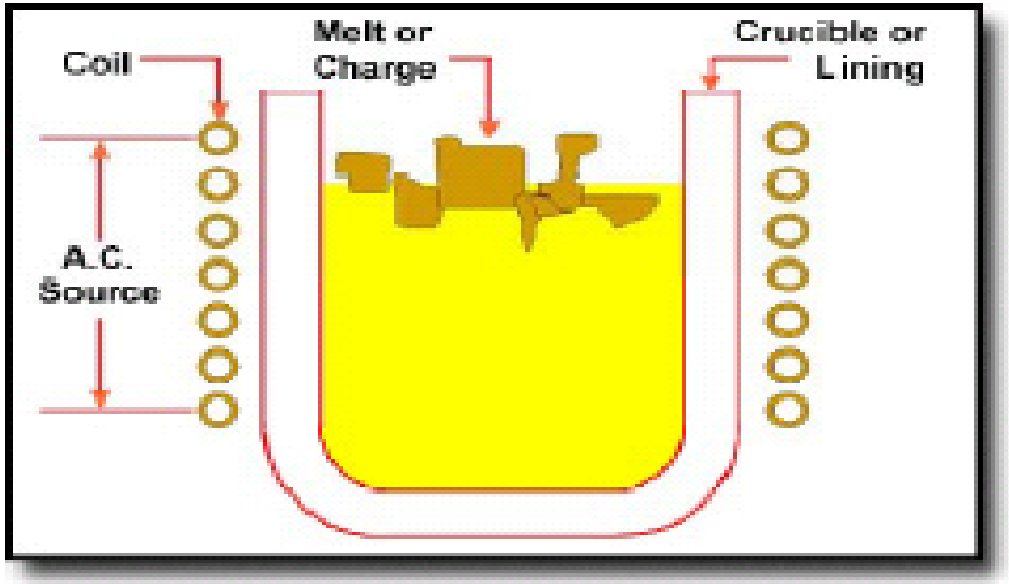
•Melting steel, cast iron, and aluminum alloys are common applications in foundry work



High Frequency or coreless induction furnace:

This furnace consists of a crucible surrounded by water cooled coil of copper tubing. A very high frequency electrical current passes through the coil, creating an alternating magnetic field, inducing secondary current in the metal being melted, which bring about a rapid rate of heating.

This furnace provides a good control of temperature and composition. Because there is no contamination from the heat source, they produce pure metals.



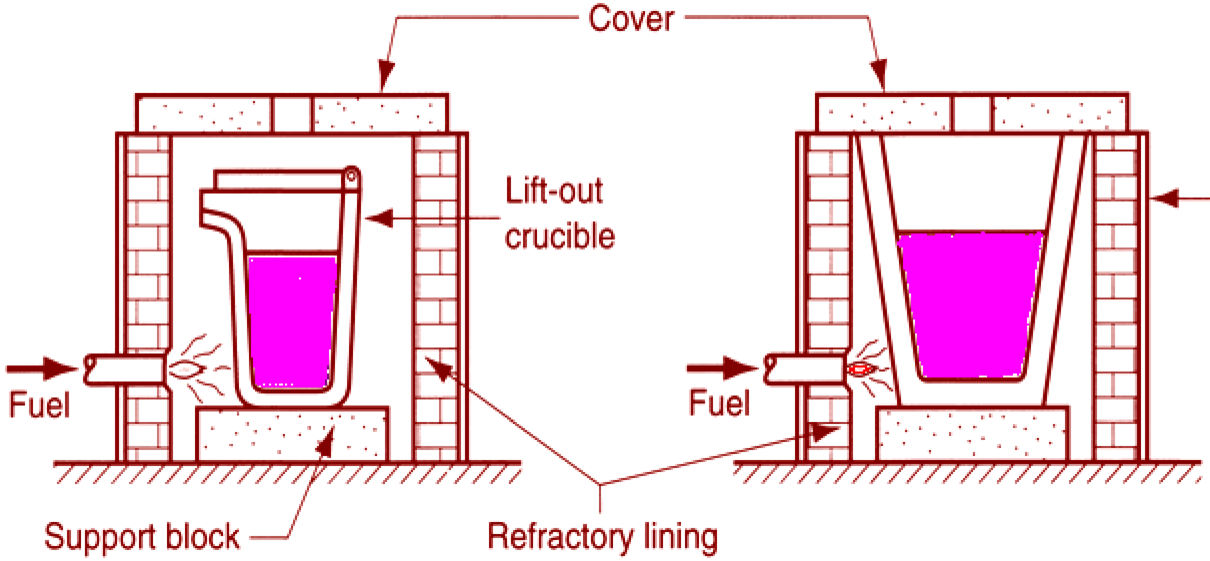
Low frequency or channel type:

In this a small channel is surrounded by primary coil (which has laminated steel core). A secondary core is formed by channel of molten metal which contains the metal to be melted. The metal while circulating through the channel gets heated.

As temperature in the furnace can be easily controlled, this type of furnace are used as holding furnace, where molten metal is maintained at constant temperature for an extended period of time.

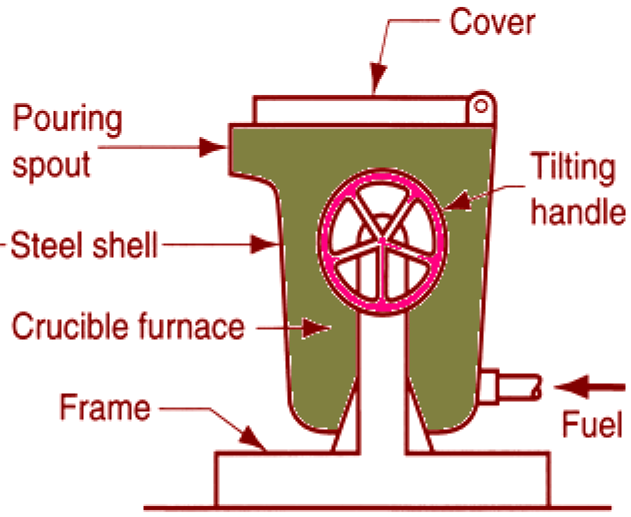
Crucible Furnaces

- Metal is melted without direct contact with burning fuel mixture
- Heated with commercial gases, fuel oil, fossil fuel, electricity.
- Sometimes called *indirect fuel-fired furnaces*
- Container (crucible) is made of refractory material or high-temperature steel alloy
- Used for nonferrous metals such as bronze, brass, and alloys of zinc and aluminum
- Three types used in foundries: (a) lift-out type, (b) stationary, (c) tilting



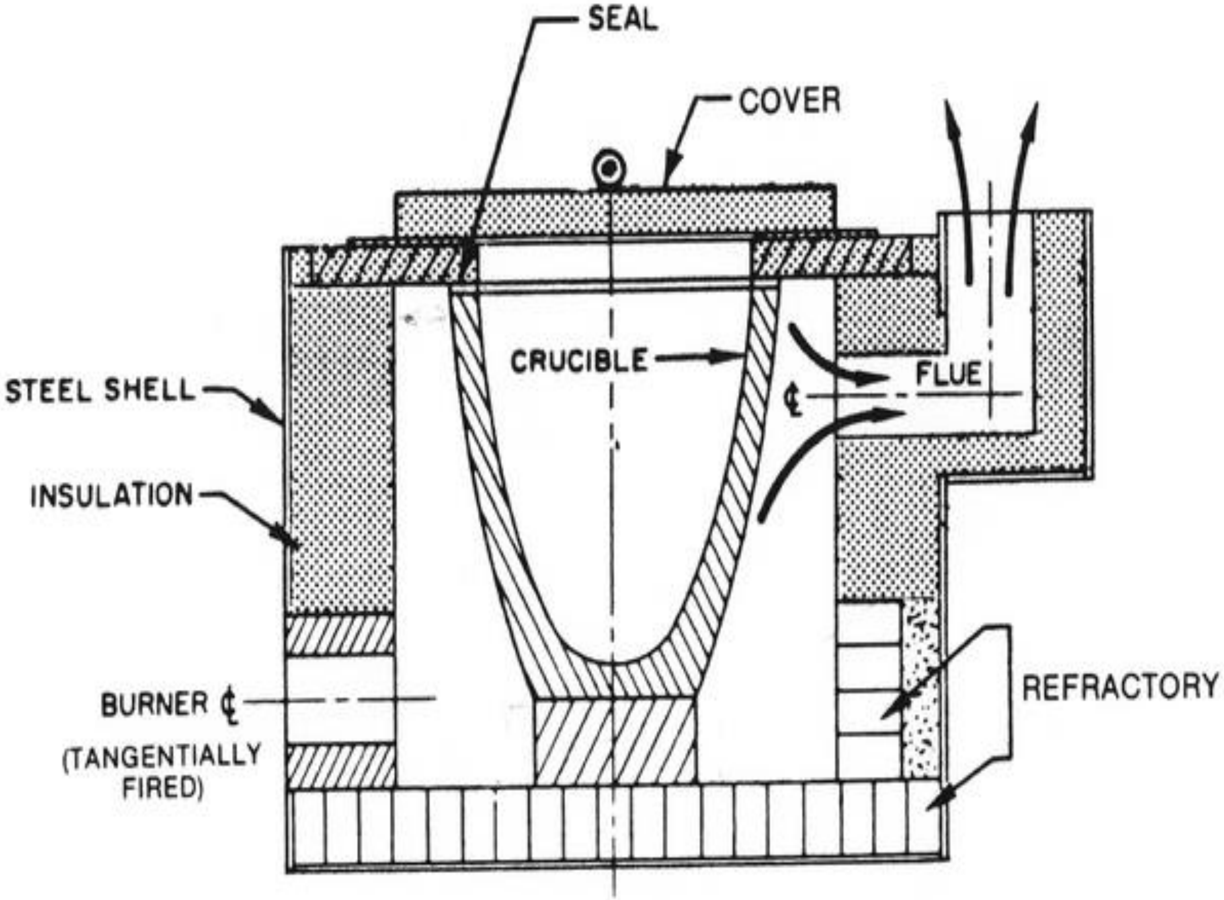
Lift-out crucible

Stationary pot



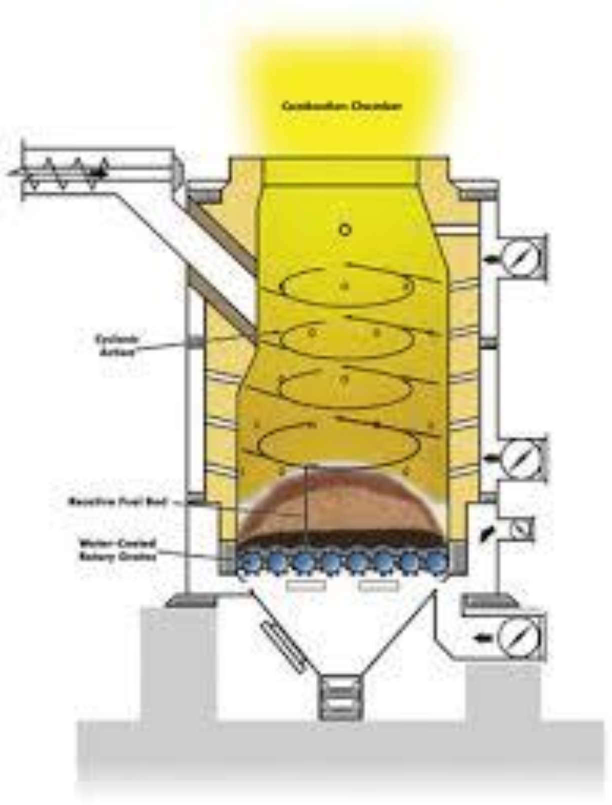
Tilting-pot furnace

Crucible Furnace



Direct Fuel-Fired Furnaces

- Small open-hearth in which charge is heated by natural gas fuel burners located on side of furnace
- Furnace roof assists heating action by reflecting flame down against charge
- At bottom of hearth there is a tap hole to release molten metal
- Generally used for nonferrous metals such as copper-base alloys and aluminum



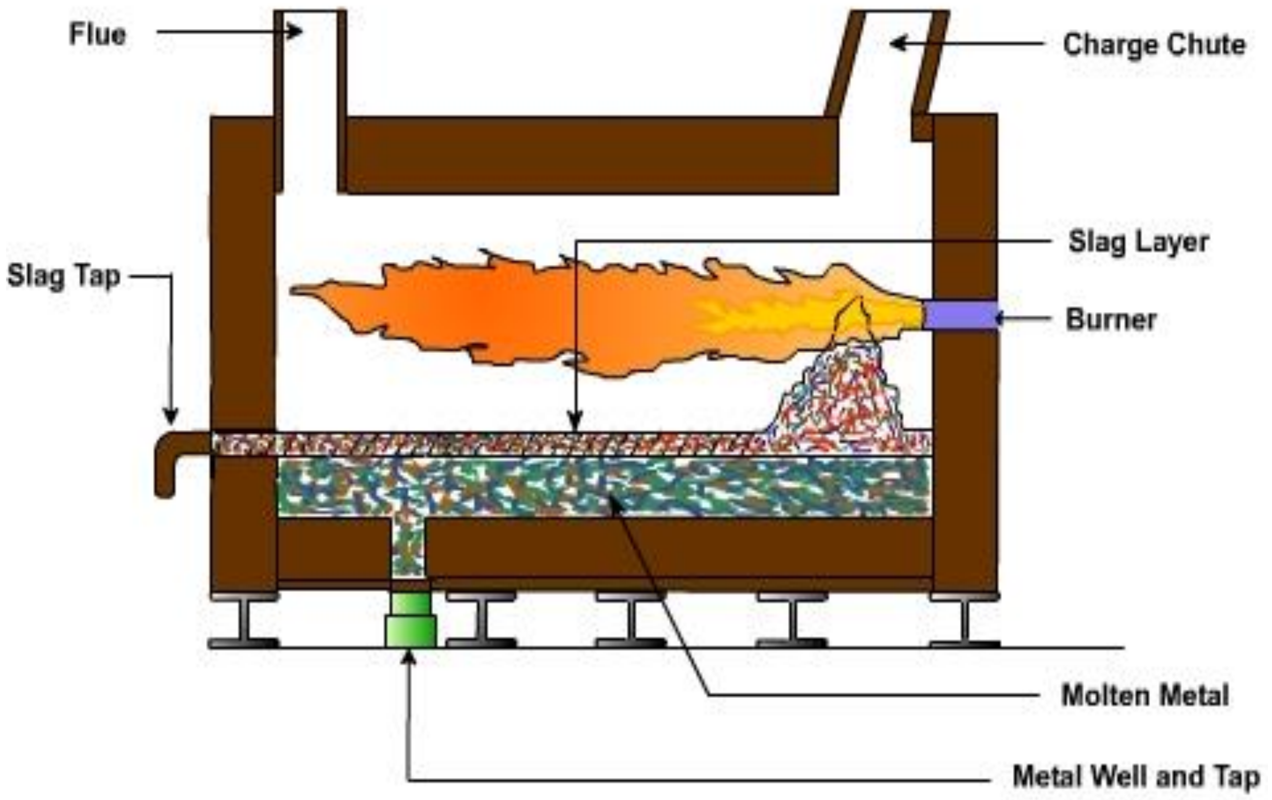
Reverberatory furnace

- Material is heated indirectly by means of a flame deflected downward from the roof.
- Used in copper, tin, and nickel, aluminum.
- Heat transfer is through radiation from the refractory brick walls to the metal
- Convective heat transfer also provides additional heating from the burner to the metal.

Advantages :

- High volume processing rate,

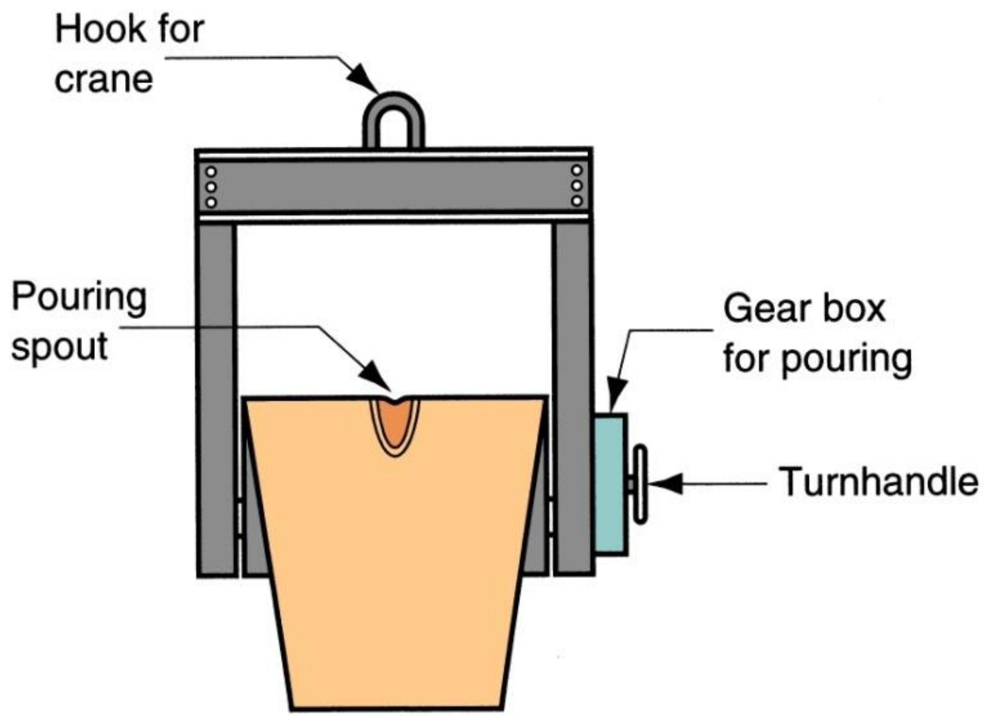
and low operating and maintenance cost.



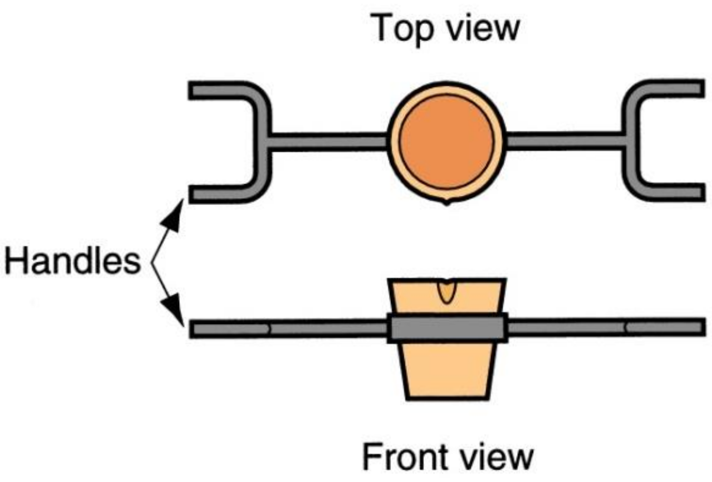
Ladles

- Moving molten metal from melting furnace to mold.
- Sometime done using crucibles
- More often, transfer is done by ***ladles***

•As per movement, ladles are two types



(a) crane ladle



(b) two-man ladle

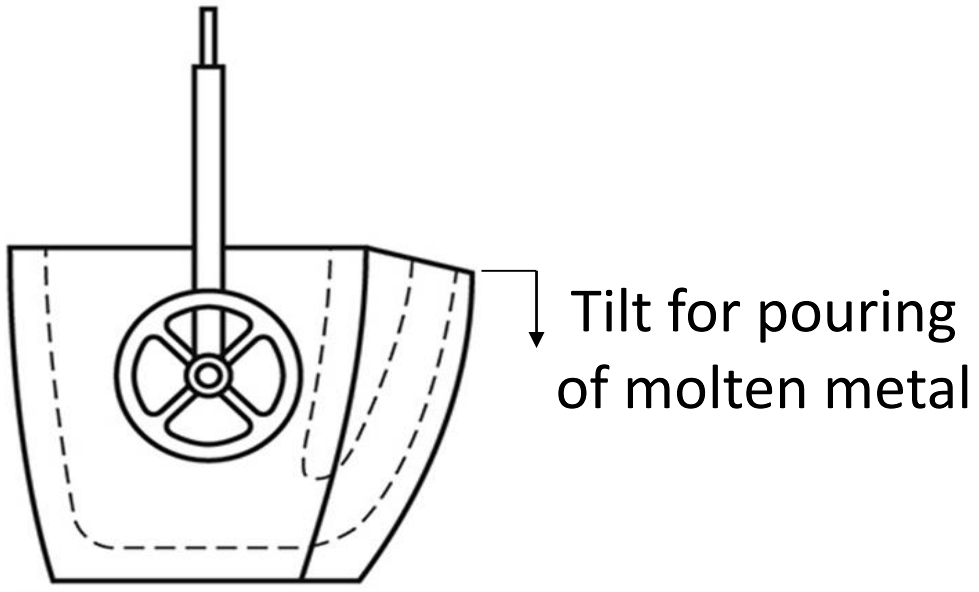
•Molten metal is **poured by two type** of ladles:

a) Top pouring type, b) Bottom pouring type

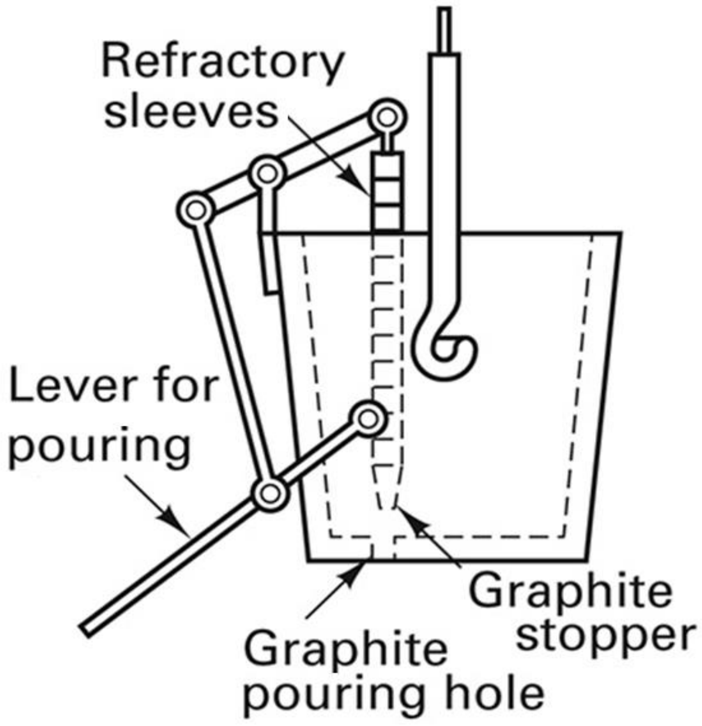
•Molten metal react with oxygen to from metal oxides (slag) and these must be separated before entering mould cavity.

• Slag can be easily separated out from molten cast iron so top pouring leads are used for CI.

•For steel, bottom pouring ladies are generally used.



(top pouring ladle)



(Bottom pouring ladle)