

IRON MAKING

MM-15020

5th SEM B TECH

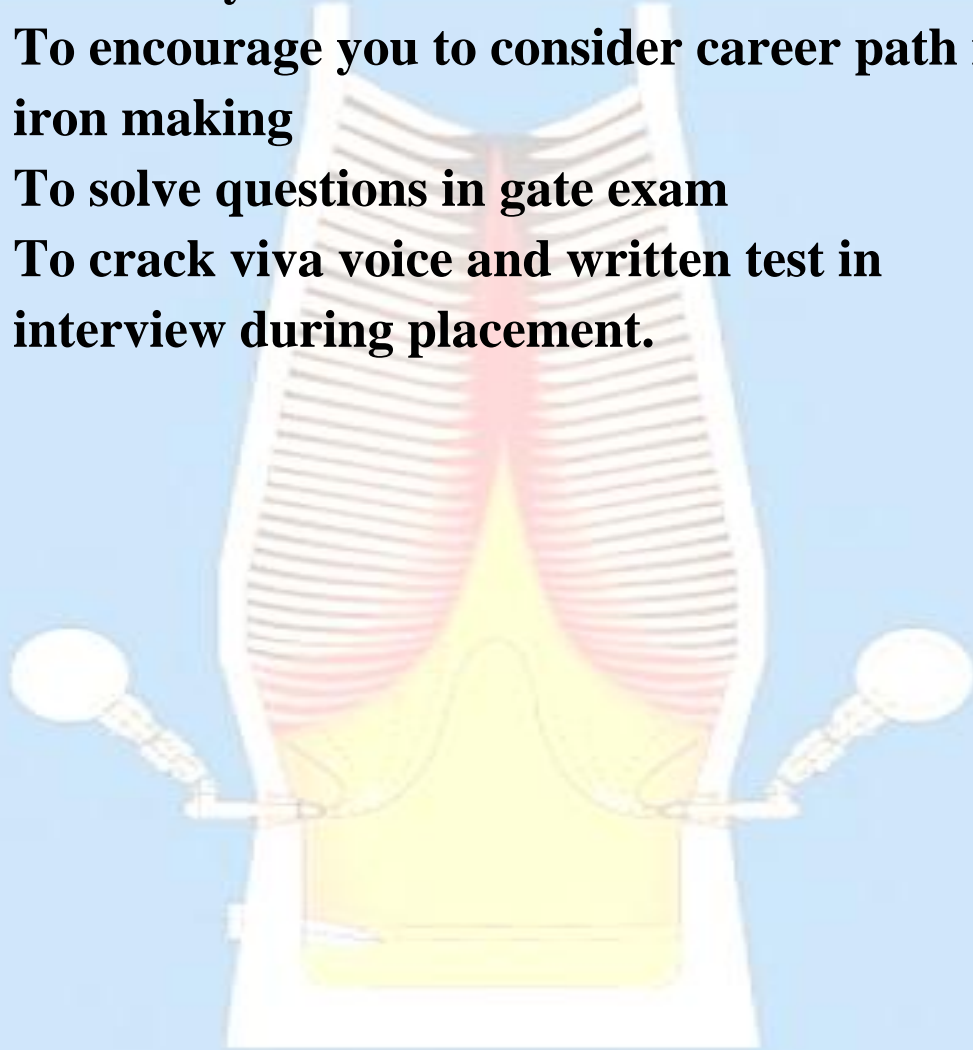
DEPARTMENT OF METALLURGY
AND MATERIALS ENGINEERING

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GOAL OF THIS SUBJECT

- 1- To impart knowledge about Iron Making which can be implemented while working in steel plant.**
- 2- To teach you to think rather than cook.**
- 3- To encourage you to consider career path in iron making**
- 4- To solve questions in gate exam**
- 5- To crack viva voice and written test in interview during placement.**



CONTENT

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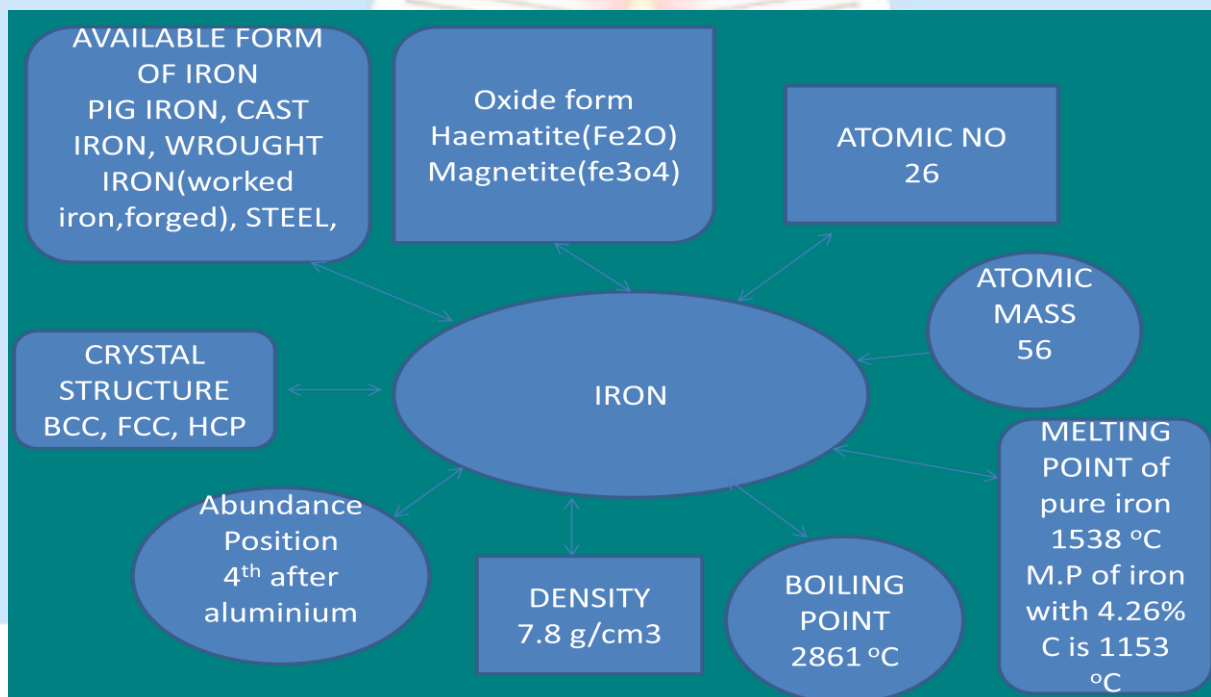
Desulphurization

Irregularities in B/F and remedies

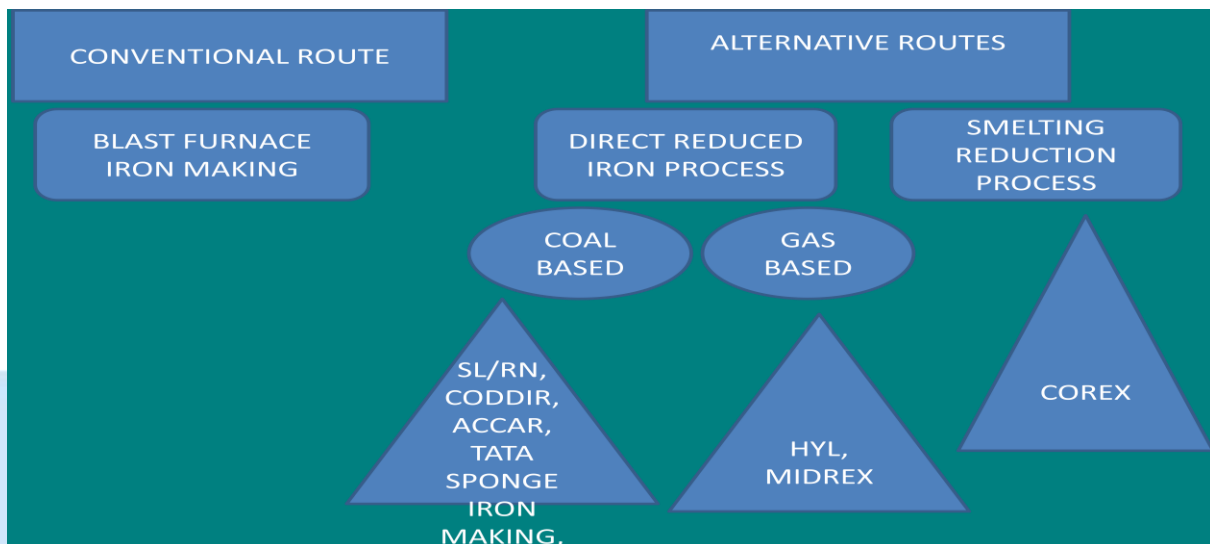
Alternate routes of iron making advantages of these process and ferro alloys

MODULE -1

IMPORTANT DATA ABOUT IRON

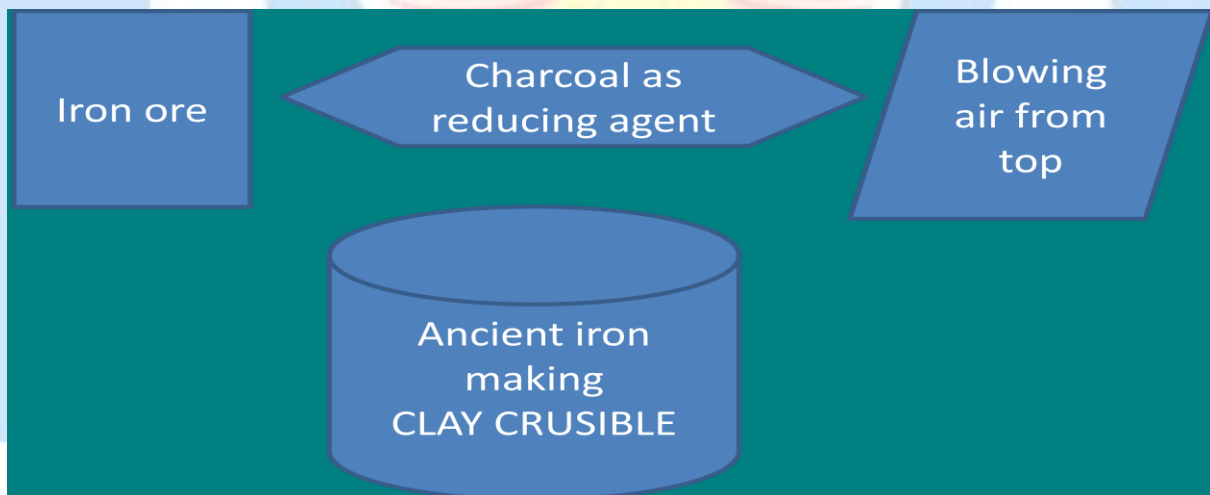


ROUTES OF IRON MAKING



ANCIENT IRON MAKING

Iron –carbon –phosphorus ternary system has lower m.p then iron –carbon binary system.



to study the physical and chemical examination from different zones a blast furnace is quenched by supplying nitrogen through tuyers .(1950)

(1880-1950) developing blast furnace :

THE DEVELOPMENT UPTO 1950 LEAD TO FOLLOWING CHANGES IN B/F IRON MAKING

- (A) More power full blowing engine.
- (B) High temperature blast
- (C) Bigger furnace
- (D) Better charging equipment
- (E) Improved raw materials storage
- (F) Screening of raw materials to eliminates fines
- (G) More efficient cleaning of balst furnace gas
- (H) Use of better refractories and improved design of the furnace lining
- (I) More versatile facilites for handling iron
- (J) Accurate and quick measurement of the composition and temperature of inputs and out puts.

CHANGES IN THE BLAST FURNACE

Table 1.1 Historical developments of blast furnace ironmaking

Year	Furnace size, m		Average production of iron, t**pd	Coke rate, kg coke per tonne hot metal (kg/thm)
	Working height*	Hearth diameter		
1880	20	3.4	110	3400
1901	22	4.5	415	2500
1950	25	8	1500	1000

* Working height is from tuyere to stock level; ** 't' means tonne, i.e. a metric ton = 1000 kg.

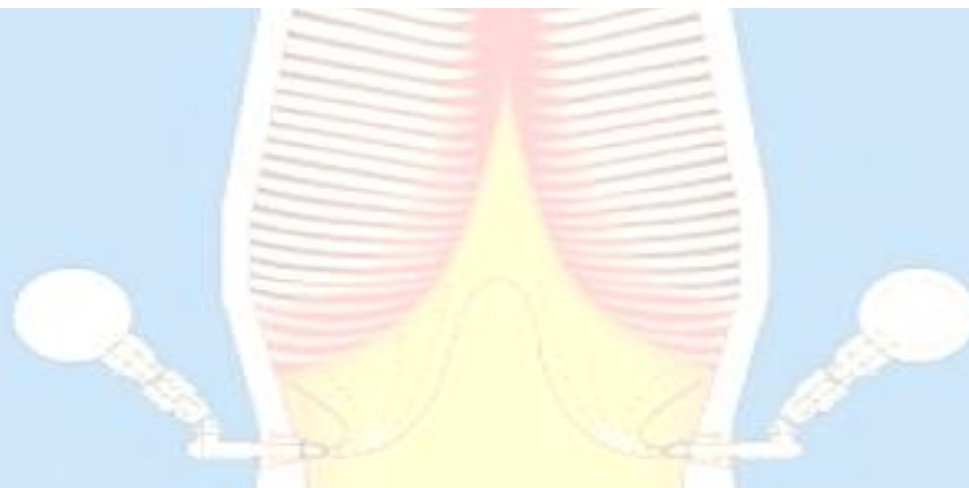
DEVELOPMENT AFTER 1950

- (A) Use of sinter and pellets in burden material
- (B) Better and proper sized coke
- (C) Injection of pulverized coal, liquid and gaseous hydrocarbon through tuyers.
- (D) Large furnace volume
- (E) Higher blast temperature
- (F) Oxygen enrichment of air blast
- (G) High top pressure
- (H) Better burden distribution –bell less top
- (I) Computer added process control.

Table 1.2 Comparison of performance indices of blast furnaces of 1960 with those of 1990–2000 for the best operating practices

Parameters	Year	
	1960	1990–2000
Working height, m	25	25
Inner hearth diameter, m	9	15
Working volume, m ³	2000	5000
Production of iron, tpd	2000	13000
Productivity, thm/day/m ³	1	2.6
Fuel rate, kg/thm	800	450–500
Campaign life, years	4–6	above 10
Silicon in hot metal, weight %	1	0.2

'hm' denotes hot metal, which is the terminology used popularly for liquid iron produced in ironmaking.



ALTERNATE ROUTE OF IRON MAKING

Alternative process of iron making classification
on basis of state of iron obtained as final product

Process in which iron is
produced as a solid by
solid state reduction

Dri

Process in which iron is
produced as a liquid by
combination of solid and
liquid state reduction

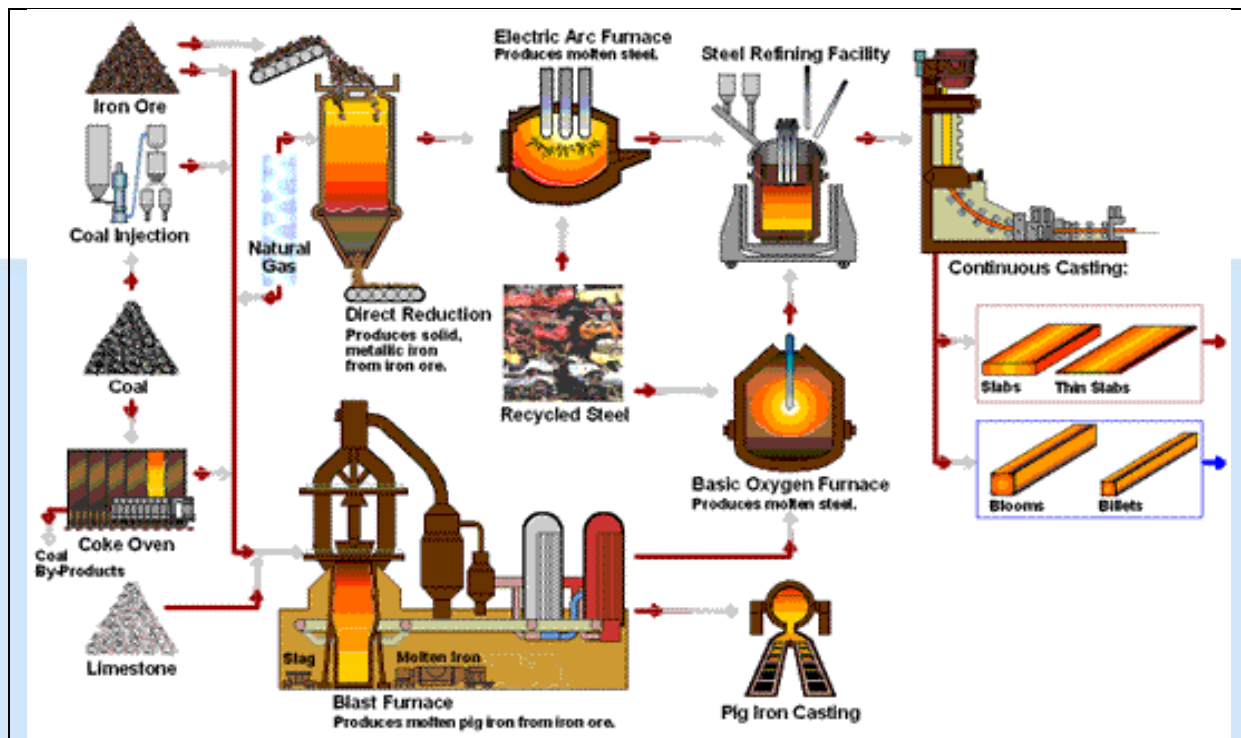
SR
process



Table 1.3 Basic features of some alternative ironmaking processes

Process	Basic features				Year	Country
	Reductant	Ore form	Reactor	Product		
Hoganas	Coke breeze	Fines	Retort	Powder	1910	Sweden
Wiberg	Coke	Pellet	Shaft	Sponge	1952	Sweden
HyL I	Natural gas	Pellet	Retort	Sponge	1953	Mexico
Nu-Iron	Natural gas	Fines	Fluidised bed	Powder	1962	USA
SL/RN	Coal lump and fines	Lump	Rotary kiln	Sponge	1964	Canada
Midrex	Natural gas	Pellet	Shaft	Sponge	1967	USA
Fastmet	Coal fines	Fines	Rotary hearth	Sponge	1974	USA, Japan
Corex	Coal lump	Lump and pellets	Smelter	Liquid	1989	Germany and Austria
ITmk3	Coal fines	Fines	Rotary hearth	Solid (liquid)	1996	Japan

FLOW SHEET OF IRON MAKING



RAW MATERIALS FOR BLAST FURNACE IRON MAKING

Iron ore for b/f

(A) haematite (Fe_2O_3), magnetite (Fe_3O_4), with size more than 10 mm.

(b) Sinter or pellets from fines (less than 8 mm) iron ore.

Fuel (thermal requirement) and reductant (chemical requirement)

(a) Coke from top

(b) Coal from tuyers

©oxygen

Flux

lime stone/dolomite/lime

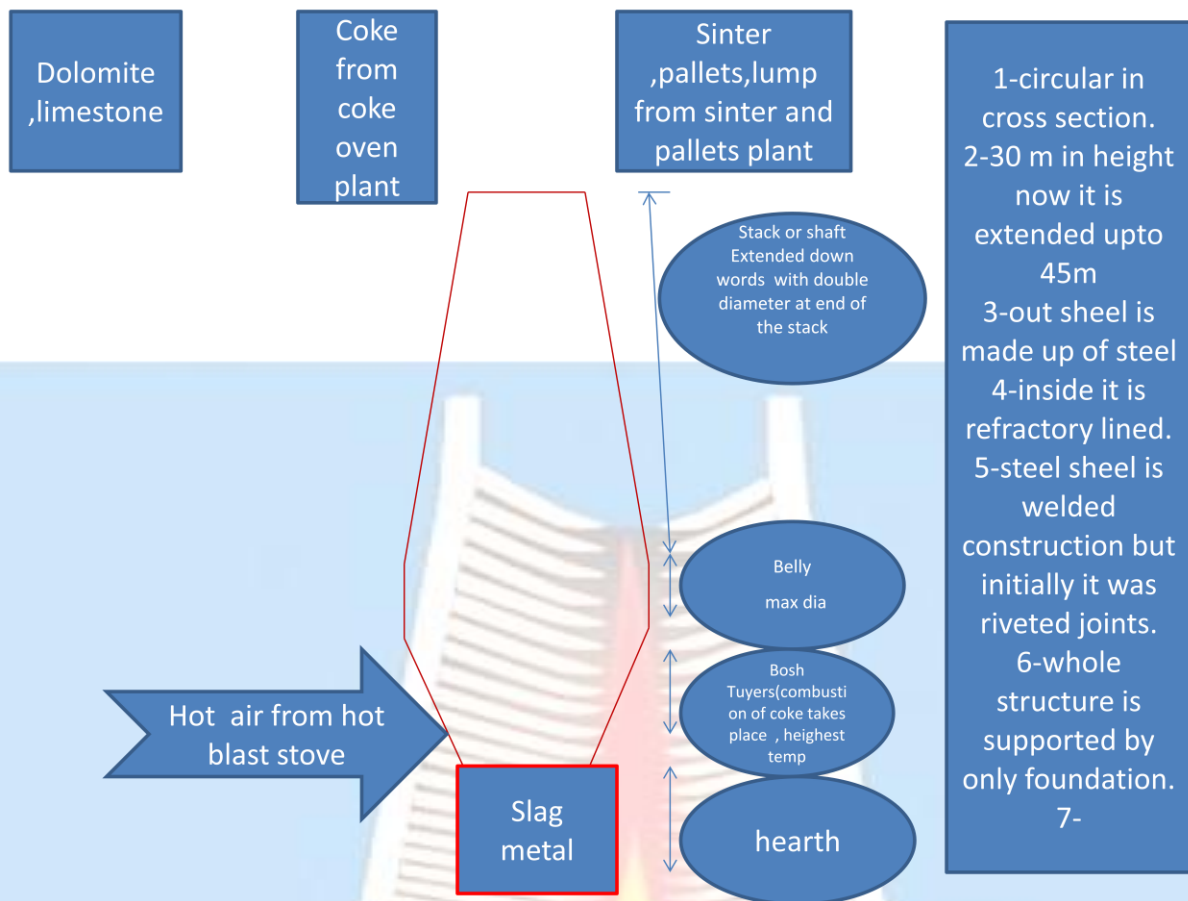
Which is charged independently and with sinter.

OXYGEN/AIR for combustion

IMPROVEMENT MADE IN BLAST FURNACE TECHNOLOGY

- 1-hot metal production rate -8000-10000tpd
- 2-fuel rate 450-470 kg/thm(270-275 coke and 175-225 kg of coal).
- 3-productivity levels of 2.5-3.0 t/m³/d(based on inner volume).
- 4-low silicon (<0.20)
- 5-campaign life 15years
- 6-better quality coke,Low ash coke
- 7-increased use of agglomerates (sinter,pellets)

BLAST FURNACE CROSS SECTION OVER VIEW INCLUDING RAW MATERIALS AND PRODUCTS



Stack or shaft

- 1-stock line to mantle level(dia becomes double).
- 2-here burden is completely solid
- 3-burden get heated from 200 -1200 degree centigrade at the end of the stack region.
- 4- the success of b/f process depends upon the efficiency of solid gas intercation occurs in the stack portion since . Max reduction occurs in stack portion.

Bosh

- 1-burden start to soften and get fuse except coke
- 2-slag starts forming (flux+gangue)
- 3-wall in this region is parallel then it is tapered down words and corss section reduces to 20-25% .

4-permeability is maintained by solid coke .

5- degradation of coke may leads to decrease in permeability and hinder normal operation

Tuyers zone

1-combustion of coke occurs and formation of each tuyers and formation of run way or race way occurs which like a flame it is firstly horizontal and then vertical when rises in the furnace

2- formation of co gas

3-except the central coke all the coke are burns and in entire burned is in molten state.

Hearth

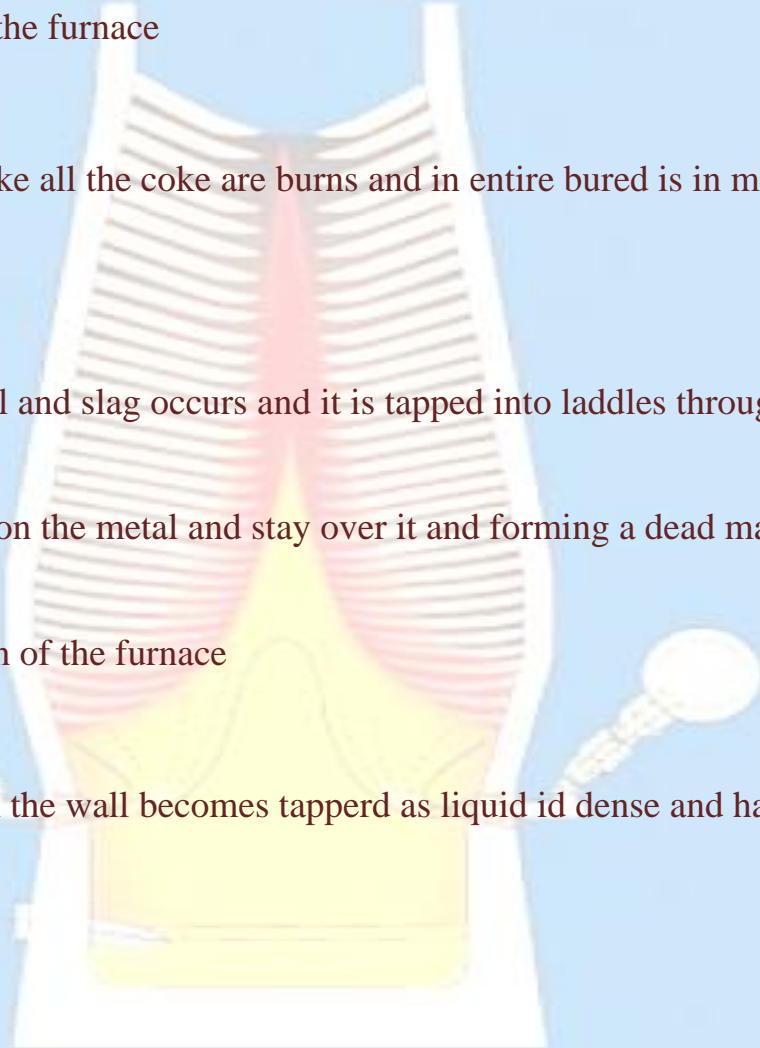
1-stratification of metal and slag occurs and it is tapped into ladles through tap holes

2- unburnt coke floats on the metal and stay over it and forming a dead man zone

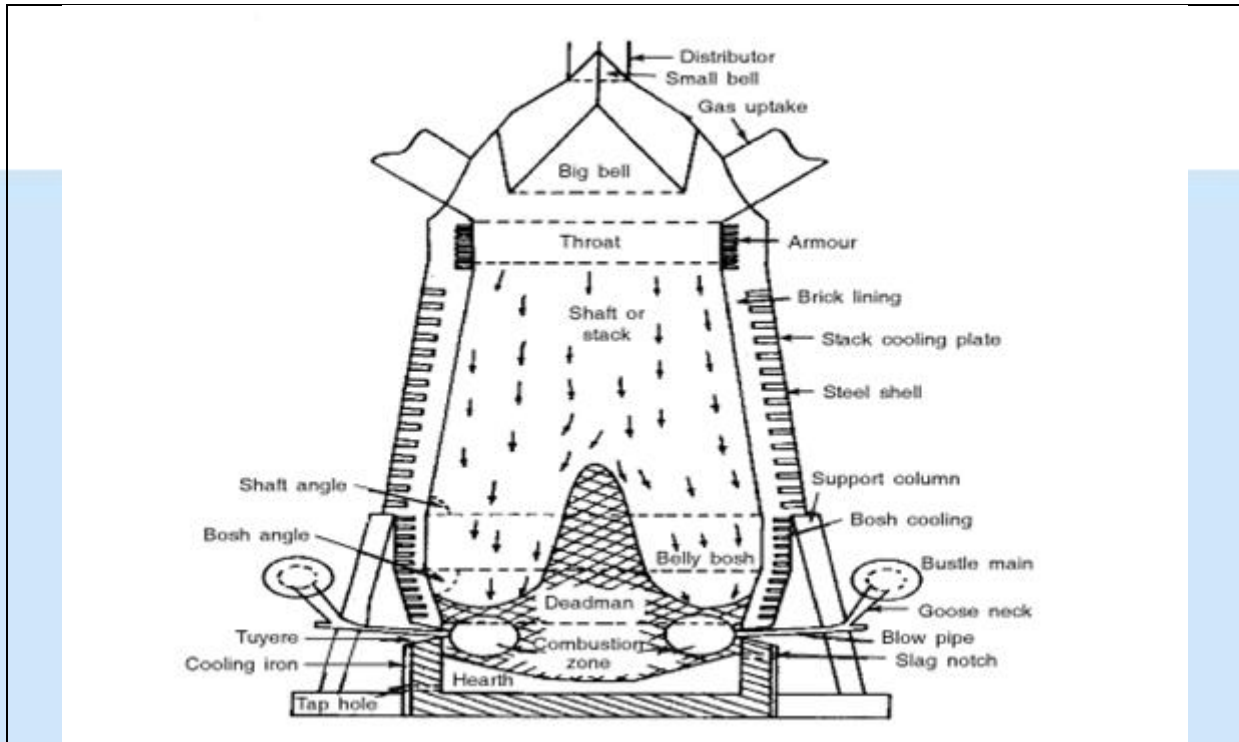
3-smallest cross section of the furnace

4- walls are parallel

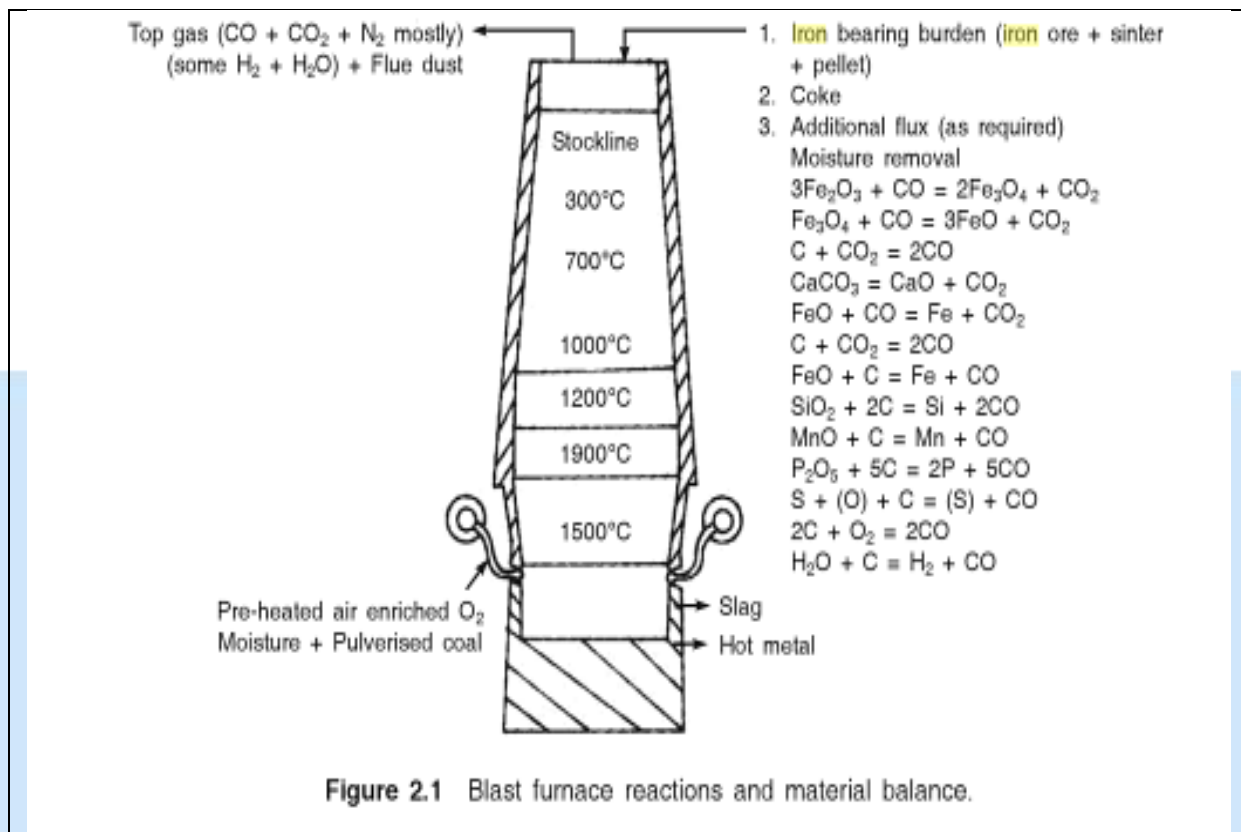
5-from tuyers to hearth the wall becomes tapered as liquid is dense and having no voids and pores.



CROSS SECTION OF BLAST FURNACE SHOWING DIFFERENT ZONES



BLAST FURNACE REACTIONS AND PROCESS IN A NUTSHELL



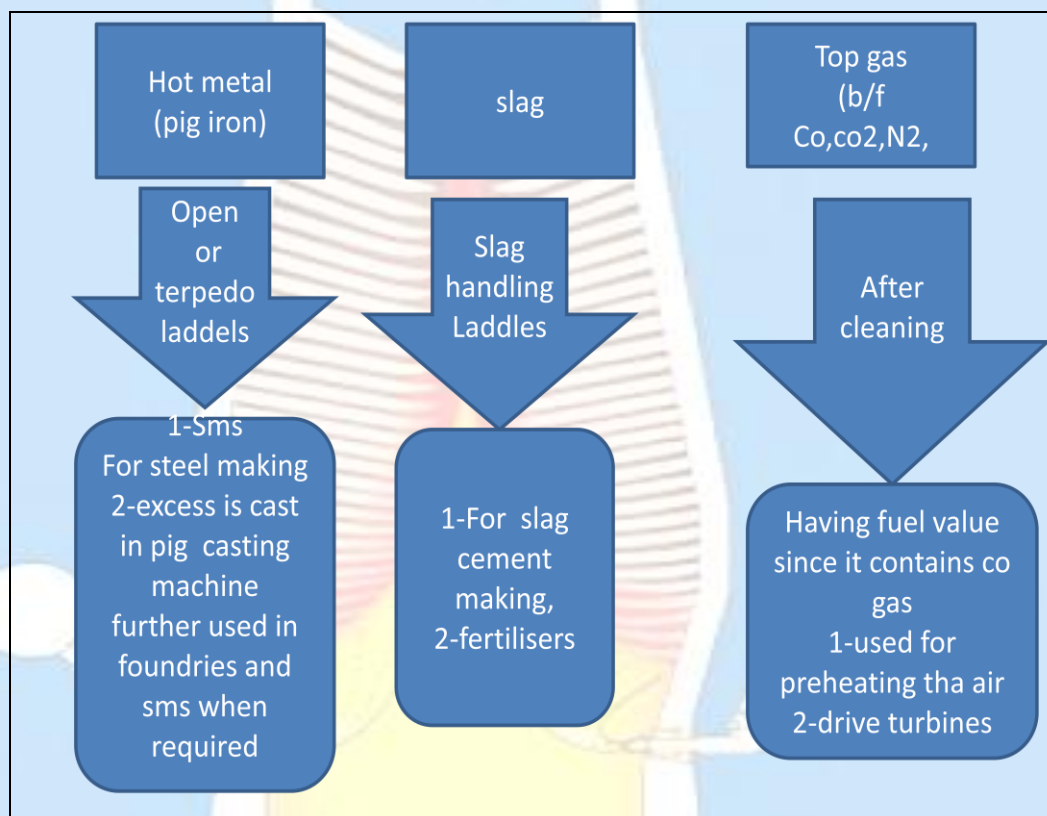
HERE THE MAJOR REACTION CAN BE CLASSIFIED INTO FOLLOWING:

- Removal of the moisture from the raw material
- Reduction of the iron oxide by Co
- Gasification of carbon by Co₂
- Calcinations of CaCo₃(where lime stone is added as raw material)
- Reduction of Feo By carbon
- Reduction of some other oxides present in ore like.
- Combustion of coke and coal in front of tuyers

BLAST FURNACE OUTPUTS OR PRODUCTS FROM THE BLAST FURNACE

- Molten iron (hot metal)
- Molten slag
- Gas at a temperature around 200°C containing Co , Co₂,N₂ moisture and some dust particles.

BLAST FURNACE PRODUCTS AND THERE USE



SIZE OF BLAST FURNACE

Design of blast furnace is evolved through experience . Calculation of blast furnace size is empirical in nature.

Hearth dia of possco b/f increases from 9.5-13.5

Hearth area increased from 1660 mtr sq -3800 mtr sq .

Now there are nearly 700 blast furnace available in world.

Largest b/f is having a working volume of 2300m³ (tata steel)G furnace .

Boashan china Gwangyang possco .

BLAST FURNACE REFRACTORY LINING

Campaigning life (starting of blast furnace to shutting down of blast furnace) depend on the life of refractory lining which liesa between the inside working volume to that of outer steel sheel, which protects the steel sheel.

Campaign life of furnca ehve increased from 5 yrs -10-20ye and more these days.

This is possible due to better furnace opeartion and better quality of refractories.

CAUSES OF FAILURE OF FURNACE LINING:

- 1-co attack
- 2-alkali vapour attacks
- 3-high temperature attck
- 4-abrasion by solid charge moving downward.
- 5- attack by molten slag and metal
- 6-furnace design and operation.

REFRACTORY USED IN B/F

1- Alumina silicates(fire clay)

A- low duty fire clay[40-45% alumina content](for upper stack)

B-high duty fire clay [60 % alumina content](lower stack, bosh, tuyers)

2-carbon block (hearth lining) carbon block is having high thermal conductivity compared to that of fire clay 3W/m/K amorphous carbon and 40W/m/K for graphite.) high thermal conductivity help is faster heat transfer which helps in keeping refractory cool .

For longer lining life water cooling is carried out, this water cooling not only helps in great amount of heat transfer that also helps in formation of protective coating of slag and metal on lining.

COOLING SYSTEM:

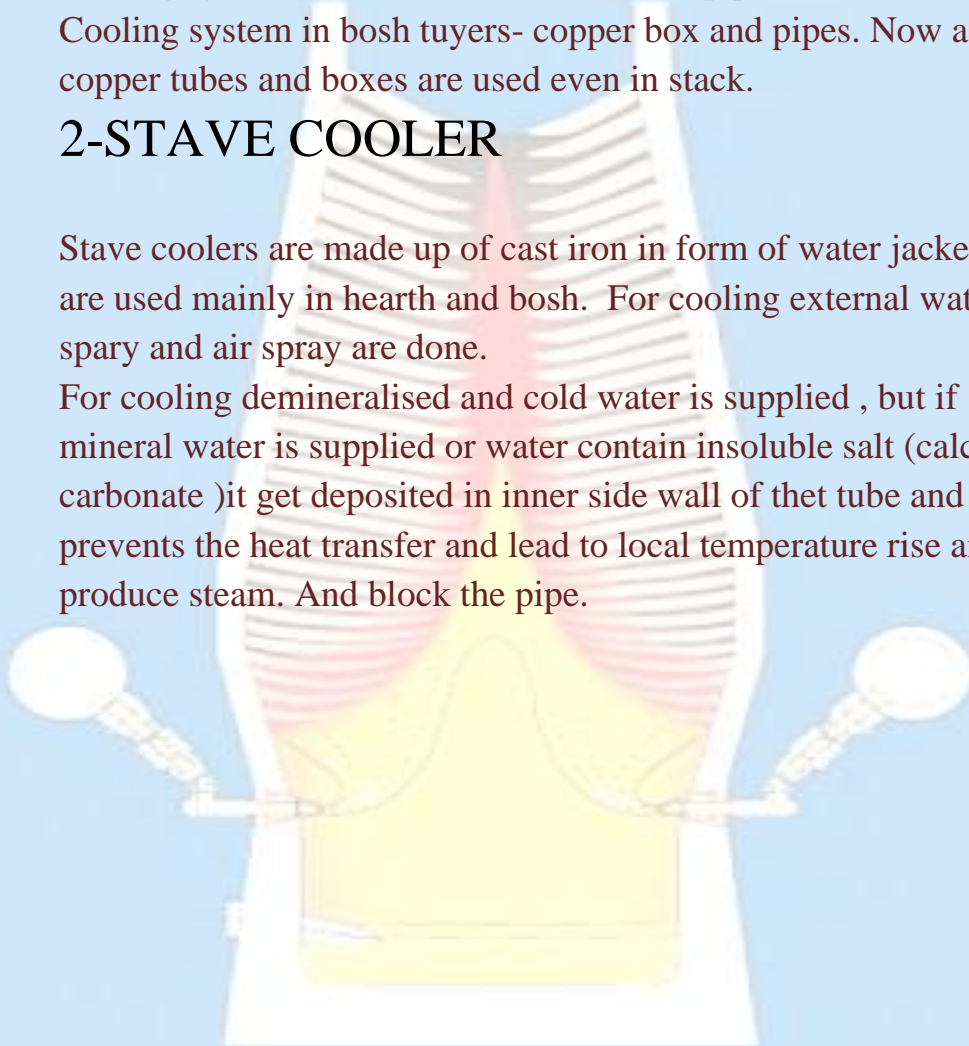
1-BOX COOLER

Cooling system in stack- cast iron box and pipes are used
Cooling system in bosh tuyers- copper box and pipes. Now a days copper tubes and boxes are used even in stack.

2-STAVE COOLER

Stave coolers are made up of cast iron in form of water jacket they are used mainly in hearth and bosh. For cooling external water spray and air spray are done.

For cooling demineralised and cold water is supplied, but if mineral water is supplied or water contain insoluble salt (calcium carbonate) it get deposited in inner side wall of the tube and prevents the heat transfer and lead to local temperature rise and produce steam. And block the pipe.



MODULE -2

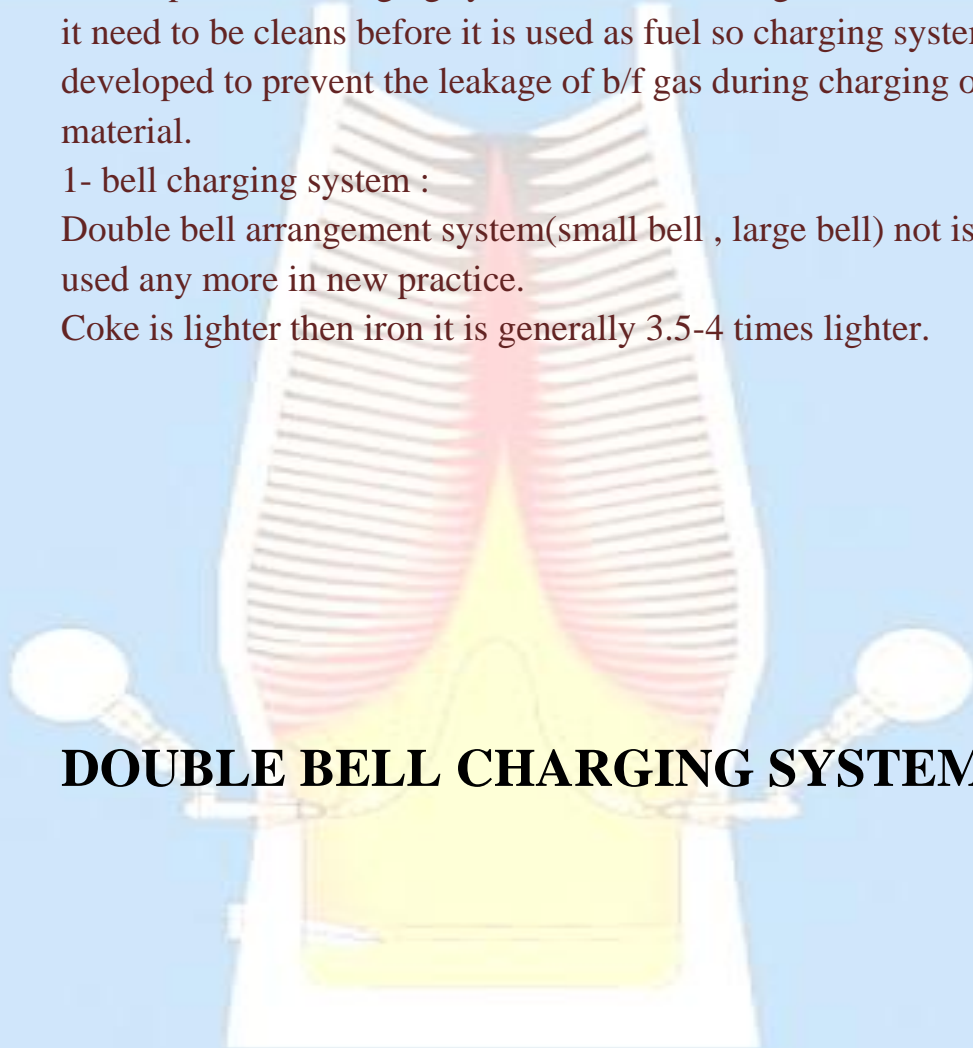
CHARGING SYSTEM FOR CHARGING OF RAW MATERIAL FROM THE TOP

Development of charging system. Since the b/f gas have fuel value it need to be cleans before it is used as fuel so charging system is developed to prevent the leakage of b/f gas during charging of raw material.

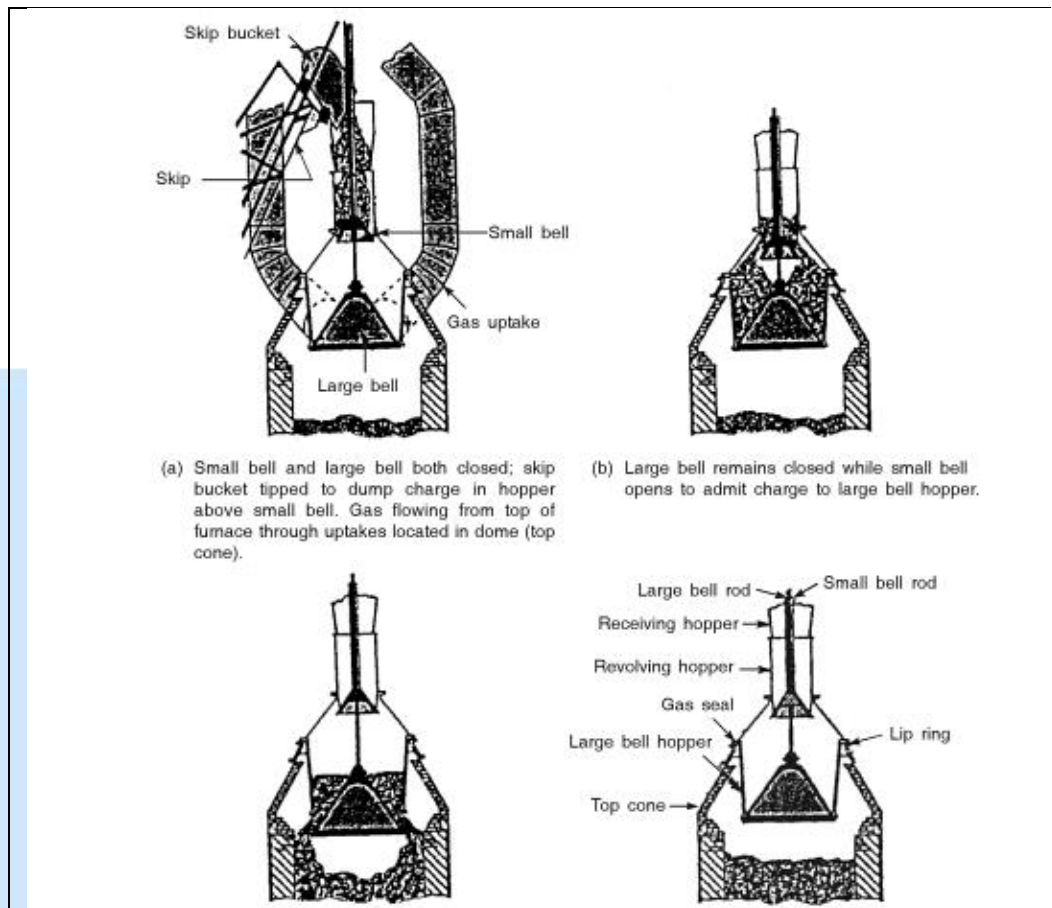
1- bell charging system :

Double bell arrangement system (small bell , large bell) not is not used any more in new practice.

Coke is lighter then iron it is generally 3.5-4 times lighter.



DOUBLE BELL CHARGING SYSTEM



FOR EFFECTIVE PRODUCTIVITY AND UNIFORM GAS FLOW IN B/F

- 1- screening of solid charge to prevents fines in the burden .
 - 2- agglomeration of fines (sintering , pelletising)
 - 3- proper charging device for better distrubution of charge in horizontal section.
 - 4- a revolving chute is used for uniform charge distribution of charge in horizonatl sec.
 - 5- revolving chute uniformly distribute the charge over small bell.
- But there is formation of two types of stockline profile in the furnace, due to seggregation of smaal and big size materials

segregation is due to different trajectories when they fall into the furnace upon opening of the big bell.

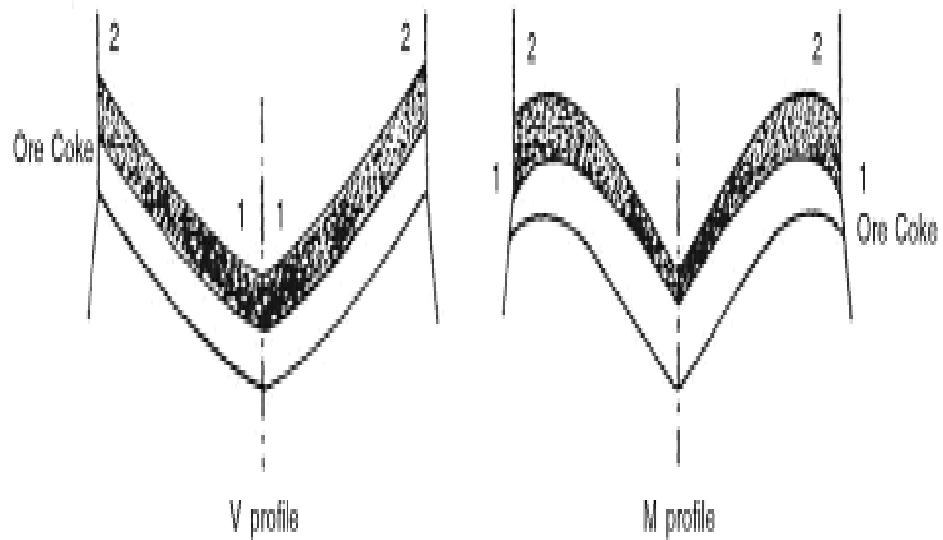


Figure 2.6 Typical burden profiles showing ore and coke layers, qualitative size segregation in ore layer (1 large and 2 small particles); iron ore includes sinter and pellets.

FURTHER MODIFICATION IN BELL CHARGING SYSTEM FOR BETTER BURDEN DISTRIBUTION:

1- Four bell charging system

2-bell type with movable throat armor.(here a movable deflector is introduced with the big bell so a the material coming out of big bell is uniformly distributed in horizontal cross section.

Separate charging of iron bearing martial and coke at different deflector setting as well as the proper distribution of fines .

BELL LESS TOP:

Invented by paul wurth in luxembourg in 1972. this system combines a hopper and gate. From various angle the raw materials are feed onto rotating chute through a system of sealed valve and flow control gate . Here in this case mathematical model and

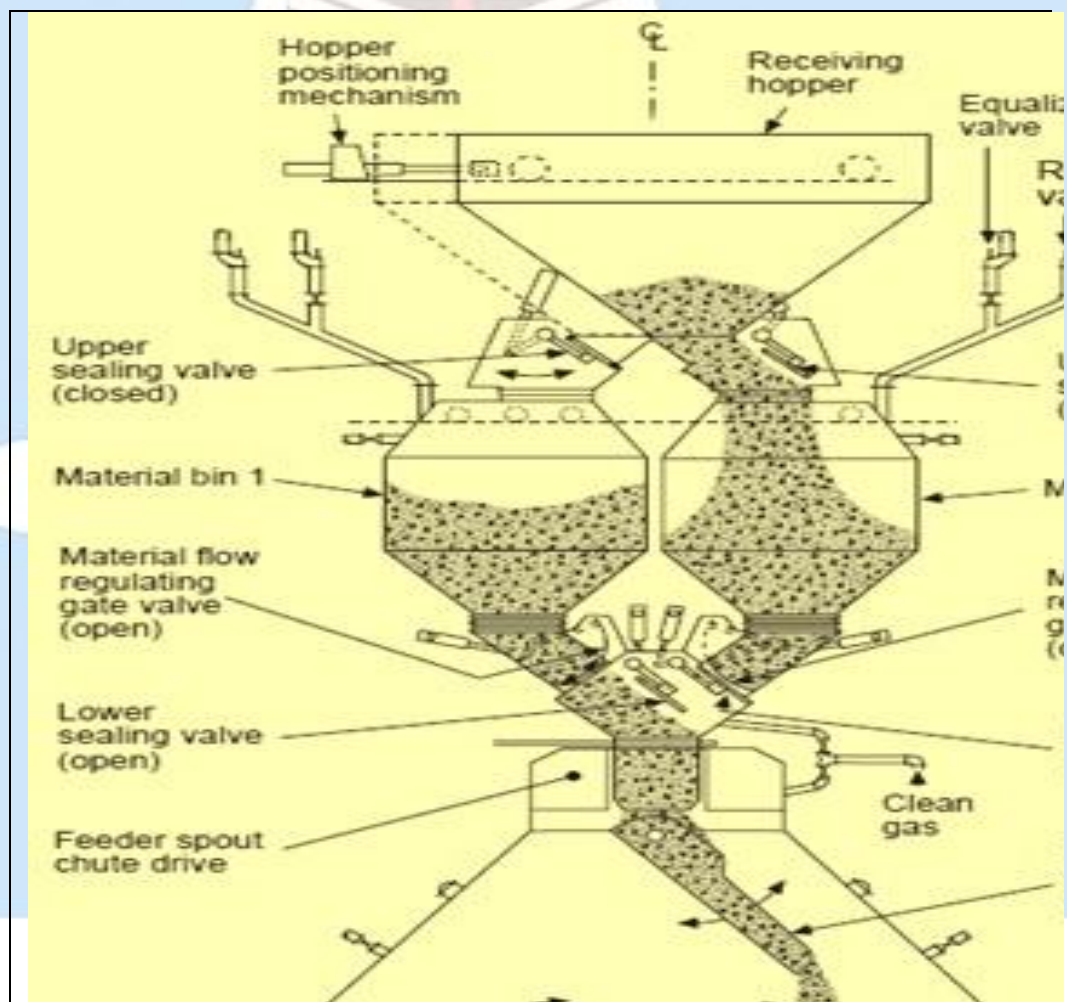
instrumentation system are provided to predict the stock line profile and to measure the effect of change in the distribution pattern. Now days all the furnace operates at high top pressure. Where the exit gas pressure is 1.5-2 atm gauge. The distribution is much more better in bell less charging.

the charge distribution monitoring system includes.:

1-heat flux monitoring equipment to measure the heat flow in the different zone(both above and under the burden.)

2-profile meter for measurement of surface profile.

3-thermocouples at different position like throat, stack, bosh for measurement of temperature.



Bell-Less Top Charging System

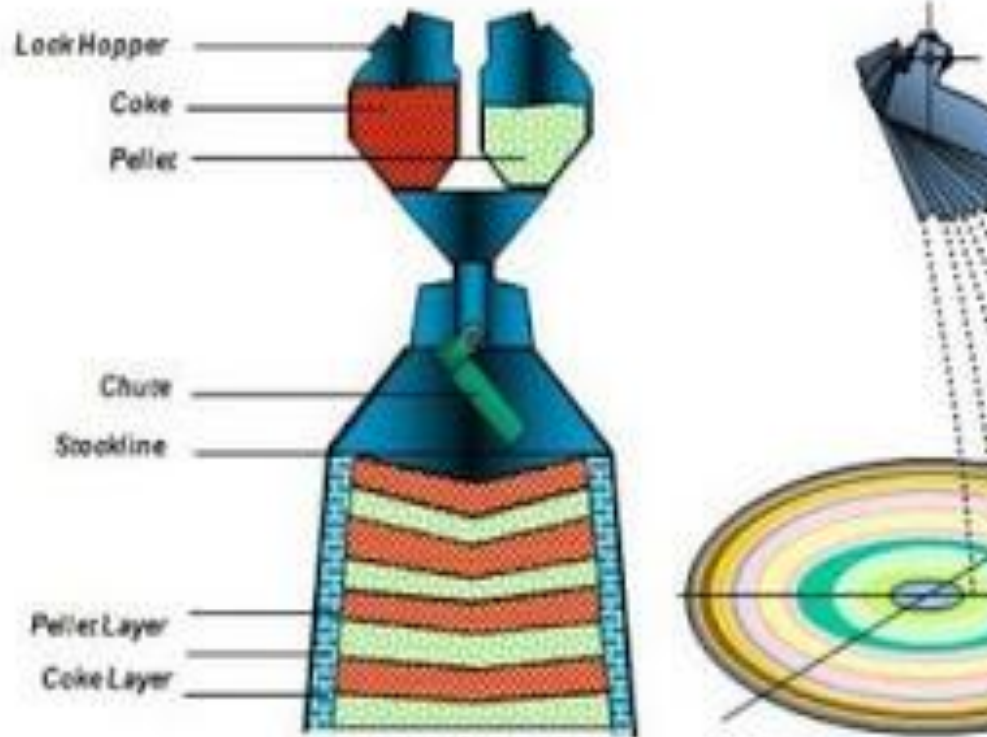


Diagram of bell less top system:

BLAST FURNACE LAYOUT



Figure 2.8 shows a schematic two-dimensional vertical section as illustration. Solid raw materials are stored in bins. Weighed quantities are loaded into the skip car, which goes up through inclined rail to the furnace top to off-load the charges.

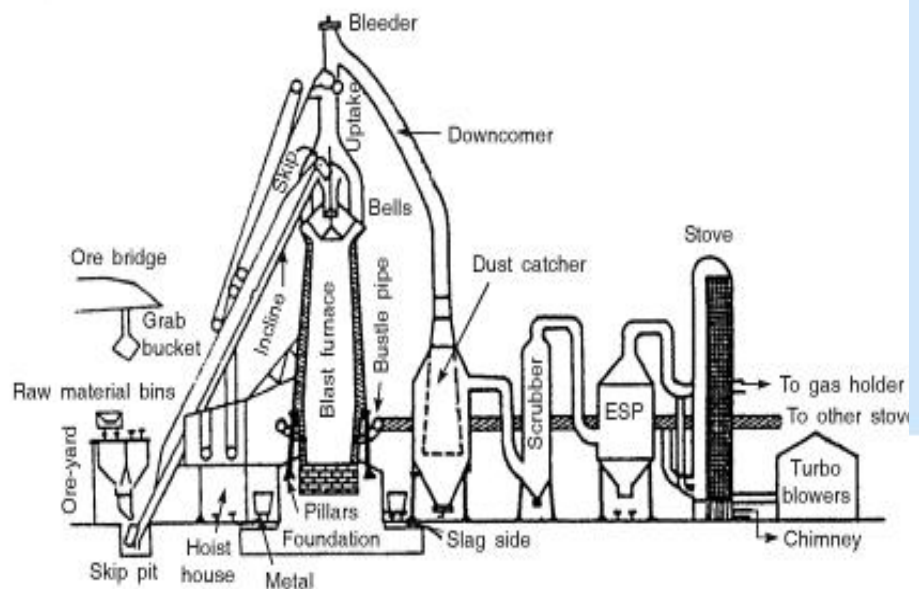


Figure 2.8 Elevation view of a blast furnace plant (schematic).

Blast furnace plant layout and its accessories

Apart from blast furnace proper blast furnace section includes many other accessories :

1-raw materials storage and handling .

2-gas cleaning system and gas storage.

3-hot blast supplying equipment , consisting of turbo blowers and Cowper stoves for preheating the air.

4-liquid product disposal and handling

5-pulverised coal injection system

6-process control equipment.

1-raw materials storage and handling [storage bins for different raw materials] .

2-gas cleaning system and gas storage[dust Catcher, scrubber, electrostatic precipitator].

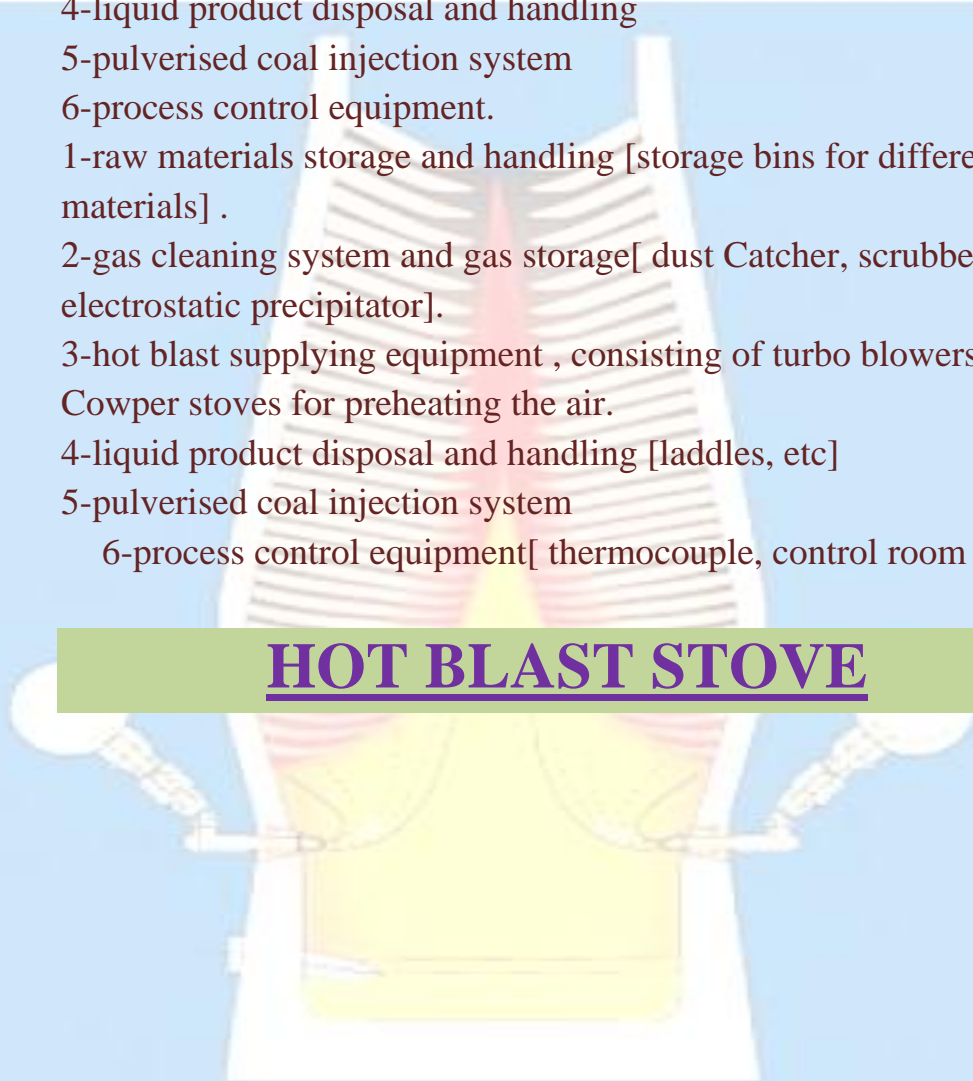
3-hot blast supplying equipment , consisting of turbo blowers and Cowper stoves for preheating the air.

4-liquid product disposal and handling [laddles, etc]

5-pulverised coal injection system

6-process control equipment[thermocouple, control room]etc

HOT BLAST STOVE



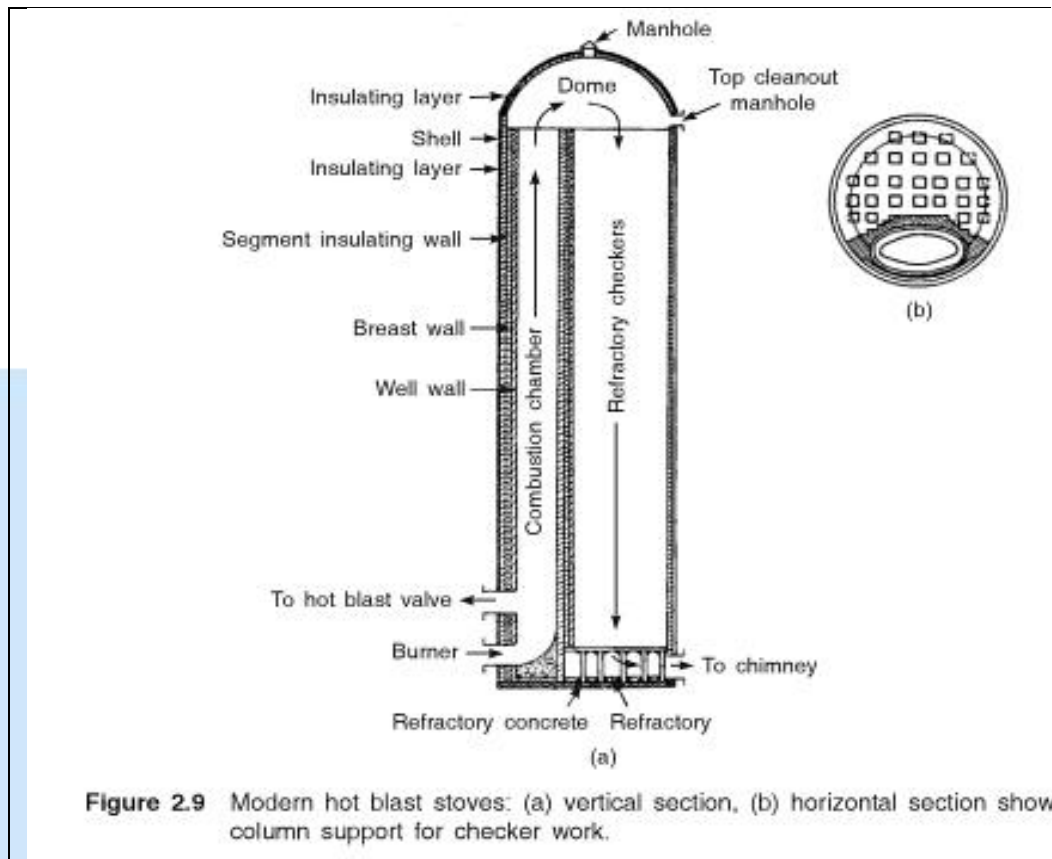


Figure 2.9 Modern hot blast stoves: (a) vertical section, (b) horizontal section showing column support for checker work.

The air blast which is supplied to blast furnace, it is heated to high temperature nearly up to 1200 degree centigrade. The blast furnace gas which is obtained it is cleaned first then 30-40 percent is used for preheating the blast in hot blast stove. The stove is

- 1- 20-36 m in height in form of cylinder made up of steel with dome shaped top .
- 2- 6-8 m in diameter
- 3- insulating bricks lined.
- 4- stove is divided into two parts one is combustion chamber and a regenerator unit (consists of refractory brick arranged in form of checker works). Gaseous flow through the checker works and exchange the heat.

Blast furnace stove works on cyclic manner. One cycle is on gas (that is also called heating cycle in this cycle the air and b/f gas is burnt in the combustion chamber and this heated air is allowed to heat the checker bricks. And in second cycle it is called on blast (also called cooling cycle in this case the cold air is allowed to pass

through the heated checker bricks to heat the cold air and this heated air then passed into blast furnace through tuyers. First cycle is of 3-4 hours and 2nd cycle is off 1-2 hours. Since cooling is faster than heating so maximum of three stoves is required for one b/f That is one for cooling and three for heating.

RAW MATERIALS DEPOSITS IN INDIA

DEPOSITS OF IRON ORE IN INDIA :

India is the 5th rank in iron ore deposit .
Maximum iron ore deposit are in jharkhand and odisha state [43 %].

- Jharkhand- singbhum dist
- Orissa- keonjhar, bolani, mayurbhanj, cuttack.
- C.G- bailadila of baster dist, Rajhara hills in durg dist Bailadila ore is the richest ore in india and in world.
- Maharastar- ratnagiri , chandrapur dist.
- Ap- anantapur
- Out of total ore deposit 80 per is hematite with goethite . and rest is magnetite .

RAW MATERIALS FOR IRON MAKING FOR 1 TONNE OF IRON

- Iron ore – lumps, sinter pellets (2000-2500)kg
- Metallurgical coke-, (450)kg
- Flux- dolomite or lime stone (300-400)
- Air- hot air (4000-5000)
- Pulverized coal-(.....)
- For 1 tonne iron you need 3.5-4 tonne of solid charge .

MINERALS OF IRON

- Oxide-hematite(red) magnetite (black)
- Sulphide ore- pyrite(FeS_2) pyrrhotite
- Hydroxide- limonite($2\text{FeO}\cdot 3\text{H}_2\text{O}$) goethite
- Carbonate ore- siderites , spathose iron
- Complex- ilmenite ($\text{FeO}\cdot\text{TiO}_2$),
- silicates

VALUATION OF IRON ORE

- Richness (percentage of iron) ,
- location, (how near to industry)
- composition of gangue,(SiO_2 , TiO_2 , Al_2O_3 ,etc)
- Treatment and preparation needed before smelting, (mineral beneficiation)
- end use.

RESERVES OF METALLURGICAL COALS IN INDIA

- Primary coking- jharia (88-91)
- Medium coking- jharia , ramgarh, rani gang, east and west bokaro, (86-88)
- Semi coking or Weakly coking- ranigang, jhilimili sonhat (83-85)

WHY COAL IS NOT USED AS FUEL AND REDUCING AGENT IN BLAST FURNACE IRON MAKING

- Coal : too dense and fragile so neither blast will penetrate it quickly for burning nor it is strong enough to stand nearly 25 m burden. And other properties are
- High volatile matter,
- High ash content ,(large volume of slag will produce)
- less fixed c, (low calorific value)
- High in moisture content
 - For iron making we need metallurgical coal also called coking coal which can be converted into coke .

CRITERIA OF COKE FOR IRON MAKING IN B/F-

- v.m < 2 %,
- ash content < 10 %
- fixed c =85 %
- cheap source of sulphur in b/f is coke.

EVALUATION OF FLUX:

- Flux- value of flux is expressed in terms of available base. Available base value depends upon the basicity of slag under operating condition. (ratio of base to acid content).
- Basicity of slag in b/f is = 1-1.3
- Basicity = $\frac{\text{cao+mgo}}{\text{sio}_2}$
- Available base : $\%(\text{cao+mgo}) - \%(\text{sio}_2) \cdot B$ where B is basicity.

DEPOSIT OF LIME STONE

Lime stone : odisha and mp

Size is -80 + 25

FUNCTION OF COKE IN IRON MAKING IN B/F-

- Act as a Fuel- smelting, melting and meeting endothermic reaction
- Generation of Reducing gas- co
- Provides Open permeable bed through which slag and metal passed down into hearth as it remains as solid in bosh region where as others are in liquid.
- Support burden as it has high strength
- Carburize the iron lowering the m.p of iron and working temp of b/f.

COKE MAKING –COKE OVEN PLANT

Equipment used-

A-beehive coke oven ,

B-by products oven (valuable by products are recovered (Tar)).

- Metallurgical Coal is converted into coke by process know as carbonization or destructive distillation (that is coal is heated in absence of air absence of air at a very high temperature).

what happen during carbonisation process :

- Due to carbonisation of coking coal results in

A-Removal of volatile mater—lead to porosity ,

B-and fusion of carbon partiles leads to high strength.

Quality of coal-

determines by the presence of amount of (VITRINITE) Chemically, it is composed of polymers, cellulose and lignin.^[1] in coal.

- Others are exinite, inertinite.
- This shows the rank of coal and its tendency toward coking.

COKE RATE : COKE REQUIRED TO PRODUCE A TONE OF HOT METAL.

- Csr and RI are important properties of coke .
- Coke oven is silica lined –
- wide-400-600mm,
- long-1300-1400mm,
- height 4-7 mts,
- (15-55 number of such batteries are there in a oven.
- Its is heated from 2 sides. Charging is done from top door and it is sealed after that, charging is in form of fine grounded coal -3mm size
- Time required for carbonistation is 16-20 hours , but now days it depends upon practice and amout of coal feed in the oven .
- After carbonistation the red hot coke is taken out and cooled or quenched with water and nitrogen Stream. Then it is crushed to required size(+50-80mm) for feeding into b/f .

VALUE OF COKE IS ASSESSED BY

- Room temp strength
- High temp strength
- Reactivity
- Ash content
- Chemistry

- Csr (coke strength after reduction)
- Mainly the quality of coke produced depend upon the quality of coal or coal blend.
- Main problem with Indian coal is it is having high ash content . so coke is also having high ash content.

COKE MAKING PRACTICE –STEPS

- Step in coke making :
- Washing ----- blending (prime coking coal(40-50%),medium coking coal 30-40%, semi or weakly coking coal—10-20%)----- stamp charging- carbonisation--- coke
 - For good coking:
- the reflectance of vitrinite should be in the rank of (1.15-1.25)
- Fluidity of coal blend should be at lest above (250ddpm) *dial divisions per minute (DDPM)* which is actually 100 times the rotational speed i n RPM are the standard Gieseler fluidity *units*.
- Csr- (58-65)

PROXIMITY ANALYSIS OF COKE FOR B/F-

- 1-Ash content max (20%)
- 2-V.M percent maximum (2%)
- 3-%sulphur(0.70)
- 4-%phosphorus(0.30)

CLASSIFICATION OF COKING COAL BY INDIA AND OTHER COUNTRIES (AUSTRALIA)

Coal type	India	Australia
1	Primary coking coal	HCC(hard coking coal)
2	Medium coking coal	SSCC(semi soft coking coal)
3	Semi or weakly coking coal	non coking coal or thermal coals

BENEFICIATION OF IRON ORE

Beneficiation Methods :

- Milling (crushing, grinding)
- Magnetic Separation

- Flotation
- Gravity Concentration
- Thickening/Filtering
- Agglomeration (pelletizing, sintering, briquetting, or nodulizing)
- If percentage of iron is more than 50 % in ore then it is simply crushed into desired size and washed before sending to b/f . Where as if percentage of iron is less than 50 then it is beneficiated by various methods to increase the percentage of iron before sending to b/f.

Most common methods use is milling and magnetic separation.

- Flotation is primarily used to upgrade concentrates from magnetic separation by reducing the silica content of the concentrate
- Most beneficiation operations will result in the production of three materials:
 - a concentrate
 - a middling or very low-grade concentrate, which is either reprocessed (in modern plants) or stockpiled; and a
 - tailing (waste),

Milling

Milling operations are designed to produce uniform size particles by crushing, grinding, and wet or dry classification. Milling is a multistaged process and may use dry or wet ore feed. Typically, primary crushing and screening take place at the mine site. Primary crushing is accomplished by using gyratory and cone crushers (Weiss 1985). Primary crushing yields chunks of ore ranging in size from 6 to 10 inches. Oversize material is passed through additional crushers and classifiers to achieve the desired particle size. The ore is then crushed and sized at a secondary milling facility (Weiss 1985). Secondary milling (comminution) further reduces particle size and prepares the ore for beneficiation processes that require finely ground ore feed. The product resulting from this additional crushing is usually less

than 1 inch (1/2 to 3/4 inches). Secondary crushing, if necessary and economical, is accomplished by using standard cone crushers followed by short head cone crushers. Gyratory crushers may also be used (Weiss 1985). Subsequent fine grinding further reduces the ore particles to the consistency of fine powder (325 mesh, 0.0017 inches, 0.44 microns). The choice of grinding circuit is based on the density and hardness of the ore to be ground. Although most taconite operations employ rod and/or mill grinding, a few facilities use autogenous or semi-autogenous grinding systems. Autogenous grinding uses coarse pieces of the ore itself as the grinding media in the mill. Semi-autogenous operations use metallic balls and/or rods to supplement the grinding action of the ore pieces. Autogenous grinding is best suited to weakly cemented ores containing some hard material (e.g., labrador specularite). The benefit of autogenous grinding is that it is less labor- and capital-intensive. Semi-autogenous grinding eliminates the need for a secondary crushing circuit. Rod and ball wear, the principal maintenance cost of traditional grinders, is also eliminated with this method (Weiss 1985). Between each grinding unit, operation hydrocyclones are used to classify coarse and fine particles. Coarse particles are returned to the mill for further size reduction. Milled ore in the form of a slurry is pumped to the next beneficiation step. If the ore being milled is destined for flotation activities, chemical reagents used during the process may be added to the slurry at this time. To obtain a uniform product, many operations blend ores of several different grades, compositions, and sizes. The mixing of ore materials is typically accomplished through selective mining and hauling of ore

Magnetic separation

- Magnetic separation is most commonly used to separate natural magnetic iron ore (magnetite) from a variety of less-magnetic or nonmagnetic material.
- Today, magnetic separation techniques are used to beneficiate over 90 percent of all domestic iron ore.

- Magnetic separation may be conducted in either a dry or wet environment, although wet systems are more common.
- Magnetic separation operations can also be categorized as either low (use magnetic fields between 1,000 and 3,000 gauss) or high intensity (20,000 gauss.).
- Low intensity techniques are normally used on magnetite ore as an inexpensive and effective separation method. This method is used to capture only highly magnetic material, such as magnetite. This method is used to separate weakly magnetic iron minerals, such as hematite, from nonmagnetic or less magnetic gangue material.

Magnetic separation involves three stages of separation:

- cobbing,
- cleaning/roughing, and
- finishing.

Each stage may employ several drums in a series to increase separation efficiency. Each

- successive stage works on finer particles as a result of the removal of oversized particles in earlier separations. Cobbers work on larger particles (3/8 inch) and reject about 40 percent of the feed as tails. Cleaners or scavengers work on particles in the range of 48 mesh and remove only 10 to 15 percent of the feed as tails. Finally, finishers work on ore particles less than 100 mesh and remove the remaining 5 percent of gangue (because of the highly concentrated nature of the feed at this point) (Weiss 1985).

FLOTATION

- Flotation is a technique where particles of one mineral or group of minerals are made to adhere preferentially to air bubbles in the presence of a chemical reagent. This is achieved by using chemical reagents that preferentially react with the desired mineral. Several factors are important to the success of flotation activities. These include uniformity of particle size, use of reagents compatible with the mineral, and water conditions

that will not interfere with the attachment of the reagents to the mineral or air bubbles.

CHEMICAL REAGENTS OF THREE MAIN GROUPS MAY BE USED IN FLOTATION

- • Collectors/Amines—Cause adherence between solid particles and air bubbles in a flotation cell.
- • Frothers—Are used to stabilize air bubbles by reducing surface tension, thus allowing collection of valuable material by skimming from the top of the cell.
- • Antifoams—React with particle surfaces in the flotation cell to keep materials from remaining in the froth. Instead, materials fall to the bottom as tailings.

Iron-bearing metallic mineral flotation operations are of two main types: anionic and cationic. The difference between the two methods is related to which material (values or gangue) is floated and which sinks. This is determined by preliminary test results, weight relationships of the values and gangue, and the type of reagents used. In anionic flotation, fine-sized crystalline iron oxides, such as hematite or siderite, are floated away from siliceous gangue material such as quartz or chert. In cationic flotation, the silica material is floated and the value-bearing minerals are removed as

Underflow

GRAVITY CONCENTRATION

- Gravity concentration is used to suspend and transport lighter gangue (nonmetallic or nonvaluable rock) away from the heavier valuable mineral. This separation process is based primarily on differences in the specific gravities of the materials and the size of the particles being separated. Values may be removed along with the gangue material (tailings) despite differences in density if the particle sizes vary. Because of this potential problem, particle sizes must be kept uniform with the use of classifiers (such as screens and hydrocyclones).

- Three gravity separation methods have historically been used for
 - washers,
 - jigs, and
 - heavy-media separators
- Wastes from gravity concentration are tailings made up of gangue in the form of coarse- and finegrained particles and process water. This material is pumped as a slurry to a tailings pond. The solid content of the slurry varies with each operation, ranging between 30 and 60 percent. Following separation of solids in a tailings pond, tailings water can be recycled to the mill or discharged.

Thickening/Filtering

- Thickeners are used to remove most of the liquid from slurried concentrates and waste slurries (tailings).
- Thickening techniques may be employed in two phases of iron ore production: concentrates are thickened to reduce moisture content and reclaim water before agglomeration, and slurried tailings are thickened to reclaim water. Facilities usually employ a number of thickeners concurrently. Typically, iron ore operations use continuous thickeners equipped with a raking mechanism to remove solids. Several variations of rakes are commonly used in thickeners. When concentrates are being thickened, underflow from the thickener (concentrate) is collected and may be further treated in a vacuum filter. The filter removes most of the remaining water from the concentrate
- The liquid component removed during the thickening process may contain flotation reagents, and/or dissolved and suspended mineral products. The liquid is usually recycled to a holding pond to be reused at the mill. When concentrates are thickened, the solid material resulting from these operations is collected as a final concentrate for agglomeration

and processing (Fuerstenau 1970). Thickened tailings are discharged to a tailings impoundment

BLAST FURNACE OPERATION

Blowing in means starting a newly lined furnace.

a-drying

b-filling

c-lightening

d-operation until normal production .

Banking : temporary shut down of b/f due to any break down of b/f or other reasons.

Tapping: periodically removal of the furnace products metal and slag. It depends upon size of furnace, and production rate.

Fanning : reduction in blast input by 25 percent when full production capacity of furnace is not required.

Back draughting :

- in this case the blast is put off and the bustle pipe is put under negative pressure to force the furnace gas to flow in reverse direction into the stove where it is burned. A special backdraught chimney is there .

Blowing out: the process of stopping the furnace operation at the end of its campaign (lining being worn out).

Campaign period- 10 -15YRS now days.

BLOWING IN

DRYING

is done by introducing a lighted gas pipe in the combustion chamber , slowly increasing its intensity in about 10-15days .

- Techniques used in drying : a-apply hot blast from stove b-use of dutch oven as an auxiliary furnace c-use of coke or wood fire.

FILLING

- furnace is cleaned off the filling started- collars are turned on- filling is done-a report is made and every thing is checked – Light wood saturated with oil upto tuyers from heart is filled –on this scaffold of old timber slippers is put – coke is put on this timber scaffold fom top to bosh level. –the mixture of coke and lime stone is charged over this blank coke – mixture of /f slag and and coke is feed upto Mantle level. The early slag volume is deliberately maintained at high level to heat up the hearth and preare its receive iron . one of coke blank are laid light burden charge of ore , lime stone and coke .initially 0.5-0.6 then 0.03-0.05 ratia of iron ore to coke. The furnace is now ready to be lighted or ignited.

LIGHTENING AND OPERATION UNTIL ROUTINE PRACTICE IS ESTABLISHED.

dust catcher valves are closed.Furnace is lighted by a-gas touch b- inserting hot bars through the tuyers or slag notch and iron notch . highly combustible material are kept at tuyers during filling to light the furnace readily. First 24-36 hrs burning is allowed with natural draught. After that alight blast is put on ,when reasonable quantity of top gas is seen the valve is opend. Then slowly normal blowing is done at the end of 4th day $\frac{3}{4}$ volume of blast is supplied. Full blast is supplied at the en of the week. Initially tap hles are open to remove the waste gases , when slag starts forming its is closed. After nearly two days as the ratio of iron ore to increase in the burden .

BANKING

Banking : 4-5 days .

Reasons of banking

- a- labor troubles,
- b- shortage of raw material.
- C-serious breakdown

- furnace cannot be put on or off readily so its temporarily shut down so that it can be resumed with minimum efforts.
- In this case reduction in combustion rate , achieved not by extinguishing the fire but by taking blast of covering the fire with excess coke , smoothing the stock with fine material . fire is still inside the furnace.
- Amount of blank coke charge decides the Length of shut down . the blank coke charge is followed by light offer charge 50-60 of normal burden. Here the metal and slag is tapped of when the blank coke reaches the bosh portion

TAPPING

Tapping : slag density is 3 times lighter than metal so its volume is 3 times greater slag is removed in every two hours and metal is tapped every 4-6 hours.

BLOWING OUT :TWO METHODS

- Charging is stopped and the stock is allowed to descend until minimum of its remains inside . as the stock sinks blast is reduced and the top of the stocks is cooled by water spray inserted through the top .take 24 hrs to cool
- Blank is charge followed by charge of clean silica gravel of +25 mm and -55mm size the stock line is kept at the normal level in the beginning but later on it is slowed to sink . water is sparingly used to control the stock line temperature . the blast volume is not reduced to the extent done in the aforementioned methods . the left over gravel are washed out with water in the end . the time required for blowing out is 6-8 hrs.

MODULE-3

AGGLOMERATION OF ORE

What is agglomeration: agglomeration is a technique by which the fine iron ores are converted into lumps.

Why agglomeration is required :

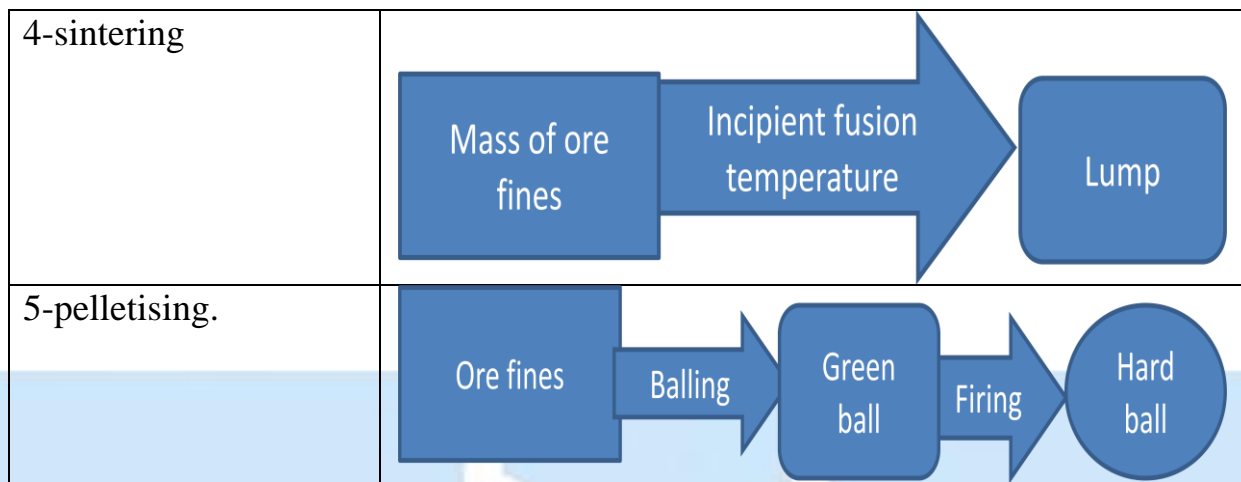
1- use of fine iron ore in iron making , since during commination of iron ore some of the ores are converted into fines. So these fines cannot be feed into furnace directly so it is first converted into lumps .

Why we cannot charge fines into blast furnace :

1- if we charge fines into furnace it get converted into lumps inside the blast furnace and it will reduces permeneabilty for gases and slag and metals .

2- heavy dust loss occurs from the top in the b/f gas.

AGGLOMERATION TECHNIQUES	PROCESS
1-briquetting:	<pre> graph LR A[Fine ores] --> B[Pressing with or without binder] B --> C[Block /briquettes] C --> D[Hardening] </pre>
2-nodulising[rotary kiln sintering]	<pre> graph LR A[Fines with carbonaceous material (tar)] --> B[Rotary kiln heated by oil or gas] B --> C[Nodules] </pre>
3-vacuum extrusion	<pre> graph LR A[Moist fines] --> B[De airing chamber] B --> C[Extruded product] C --> D[Cut into desired size] </pre>

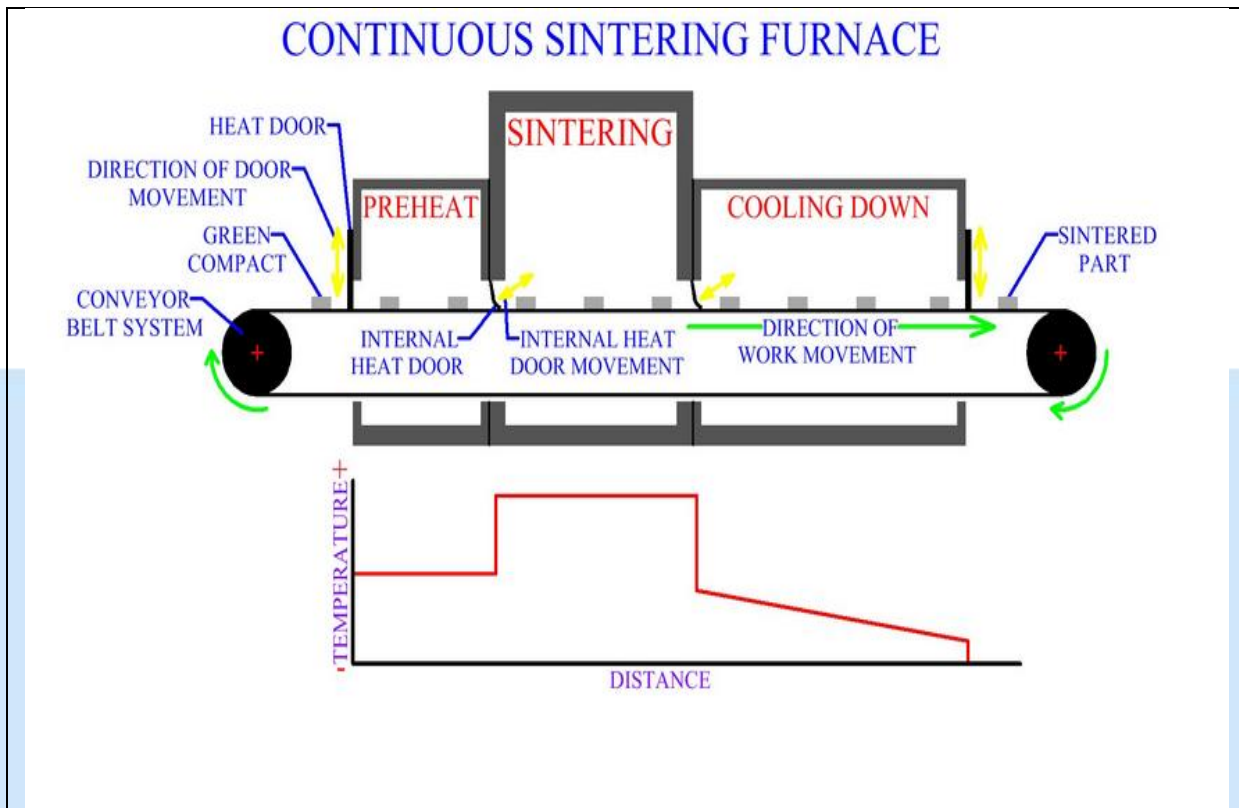


SINTERING TECHNIQUE

- Sintering principle
- Process variable
- Equipment for sintering
- Mechanism of sintering
- Raw materials requirement?
- Sinter types

SINTERING PRINCIPLE: here the iron ore fines or iron bearing fines are mixed with solid fuel(coke) and put on a permeable grate.

Top layer of this sinter bed is heated to the sintering temperature (12-1300) by a gas or oil burner and air is drawn downwards, through the grate , with the help of exhaust blower connected. From underneath to the grate. A narrow combustion zone is formed on the top and this combustion travels downwards layer by layer upto sintering level.



The cold blast drawn through the bed cools the already sintered layer and thereby gets itself heated. The heat contained in the blast is utilized in the drying and preheating the lower layers in the bed that is in advance of combustion of each layer.

In the combustion zone bonding of grains takes place and a strong and porous aggregate is formed. The process is over when the combustion zone has reached the lowest layer of the bed.

The sinter formed is dropped after partial cooling it is then broken, screened, and cooled to produce desired fraction. The undersized is recycled and over is sent to b/f

Up draught sintering {for ferrous ore} here the air is suck downwards through the ore bed, or grate

Down draught sintering [for non ferrous ore] here the air is suck upward through the ore bed, grate.

Process variables in sintering

During sintering time and temperatures plays a important role in deciding the nature and strength of bond develop during sintering of a given mix. And area under the curve above 1000 degree centigrade for iron ore is the effective factor in deciding the extent of sintering , rather than The whole area under the curve from room temperature toi the combustion temperature (1300).

And the nature of the time-temp graph will depend upon the rate of heating and cooling of a give mix.

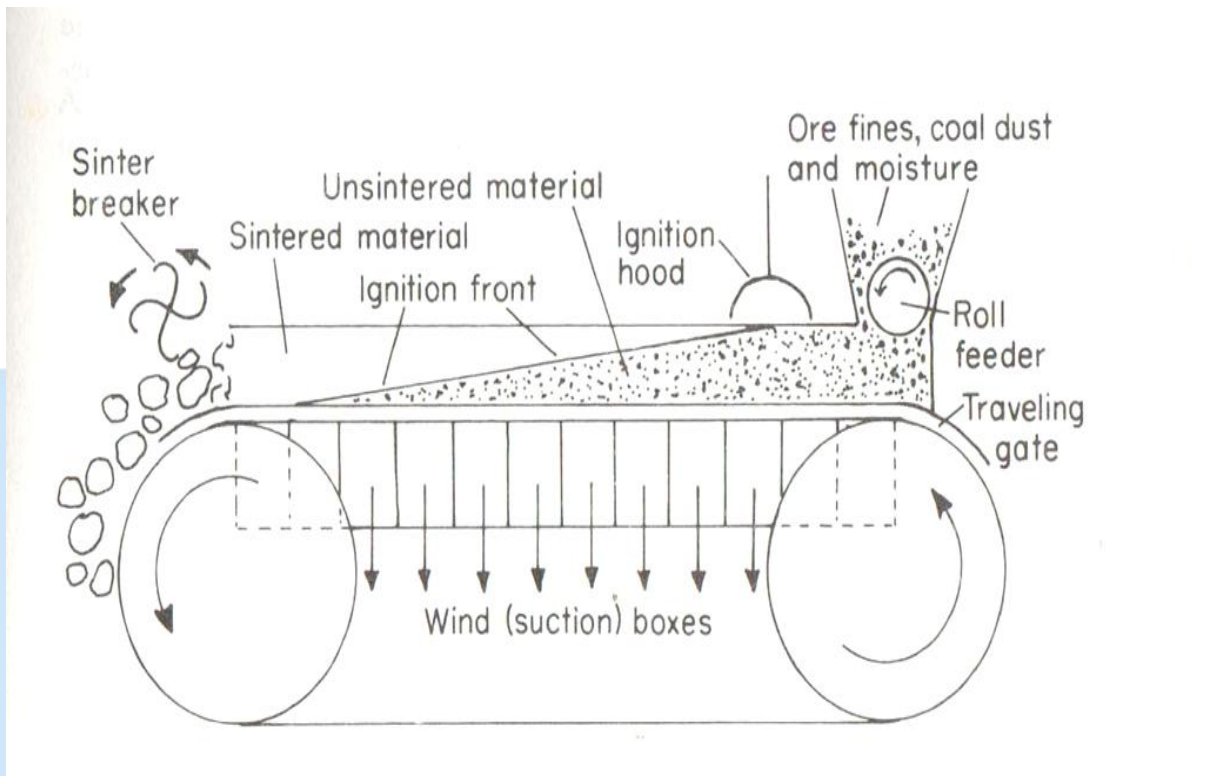
Variables

- 1- bed permeability as decided by the particle size and shapes of the mix.
- 2- thickness of the bed
- 3- total volume of air blast drawn through the bed for its sintering.
- 4-rate of blast drawn through the bed during sintering.
- 5-amount and quality of solid fuel used.
- 6-amount and type of carbonate
- 7-amount of moisture in the charge .
- 8-chemical composition of ore fines
- 9-any non uniformity in the bed composition.

Sintering is a heat exchange process where there is a exchange of heat between solid and gas,

So obtain faster rate of heat exchange , the heat capacity should be maximum , the rate of air drawn should be maximum for that the permeability of the bed should maximum .

EQUIPMENT FOR SINTERING [DWILIGHT LLYOED SINTERING MACHINE]



- 1- the fine concentrate is charged as a layer 15-50 cm thick on to the endless revolving belt or grate or pallets which moves over wind boxes at regular speed .
- 2- burners under the ignition hood is used to start the combustion of the bed surface . This combustion is propagated through the mass or charge by a current of air drawn through the charge into the wind box below which is connected a suction fan sufficient high temperature are develop in the material to cause partial or incipient fusion which produces a porous cinder like material called sinter
- 3- when the sinter reaches the end of the machine it is discharged and cooled .
- 4-The cooled sinter is sized to give a uniform product .

The sinter roasting of sulphide ore does not require

addition of any fuel to the charge because the sulphur in the charge itself act as a fuel .

But for an oxide or fuel is required ex- iron ore

MECHANISM OF SINTERING

layer below the ignited top layer undergoes changes in the order.

Wet ore- drying-calcination-preheat

Two types of bond formed during sintering:

1-solid state bond or recrystallisation bond or diffusion bond :Here a bond is formed due to recrystallization of parent particles at the point of contact in solid state.

2-slag bond or glass bond:bond is formed due to formation of slag or glass at the point of contact of two particle , which depend upon the mineral and flux.

More is the slag bond stronger is the sinter but with less reducibility and more is the diffusion bond more is the reducibility but less is the strength.

EFFICIENCY OF GOOD QUALITY OF SINTER DEPENDS UPON

Size: Strength of the sinter directly depends upon the size distribution of the charge mix.

Because this factor determines the contact area of the particle .size is large contact area is small and vice versa and less contact area less will be the strength.

Best size for sintering are as follows:

Coke breeze of fine anthracite coal -3 mm

Limestone or dolomite -3mm

Ore size 10 mm

FUEL CONTENT

Fuel content is usually in the range of , 6-8%

For better result two layer charging with relatively less fuel in the lower layer has been found to give better result.

Cost of fuel is 50 % of total coast of sinter operation.

Double layer charging , extended hood, gas sintering decreases the solid fuel requirement.

MOISTURE

Presence of moisture in the sinter mix is advantageous :

- 1- It maintains permeability in the bed during sintering
- 2-the rate of rise of temperature at higher temperature levels is more rapid in wet than in dry mix .
- 3- the presence of moisture increases the specific volume of air required for sintering. For better heat transfer during sintering.

CIRCULATING LOAD

For higher output of the sintering strand the circulating load should be low. A low circulating load however reduces the permeability of the bed and consequently the input rate to the strand has to be reduced.

PELLETISATION TECHNIQUE

Here the very fine iron ore or iron bearing materials(100 mesh size) are rolled into balls with addition of binders and additives .

Raw materials may be flue dust collectd from b/g steel making shop, fines produced during upgradation of lean ores. Pyrite residue.

- Process of pelletisation
- How bonding occurs in pelletisation
- Mechanism of ball formation
- Commercial production and quipment used

PROCESS OF PELLETISATION

In this process the fine iron ores are rolled in the presence of additives and binders into green ball and to get the desired strength these green balls are dried preheated and fired at a high temperature of (1250-1350)degree centigrade. So on heating this at high temperature sufficient strength is produced between the particles. And here the sensible heat of out going gas is recovered which is feed back in the indurations period. This process is carried out in oxidizing atmosphere.

STEPS OF PELLETISATION

- 1-preparation of feed
- 2-production of balls and sizing
- 3-green ball indurations which consists of [a-preheating – firing-cooling of hardened pellets.]also called hardening
- 4-cooling of hardened pellets

BONDING THEORY

Moisture is very much essential for pelletisation process and it must be in less quantity.

Excess moisture is also detrimental .

How this moisture helps in binding the particles ?

Surface tension of the moisture present in between the particles help in binding.

Rolling of moist particles lead to formation of high density balls .

Easy with which the particles are rolled into balls depend upon the grain finess that is surface area. More surface more will be tendency of balling.

THREE WATER PARTICLE SYSTEM

1-pendular state:[in this type of water particle system water is present at the point of contact between the particles and the surface tension hold the particles.

2-funicular state:[in this type of system all the pores are fully occupied by water in an aggregate system.

3-capillary state:[in this system all the pores are fully occupied by water but there is no coherent film of water covering the entire surface of particle.

So strength of the ball depends upon the surface tension and mechanical interlocking.

DIAGRAM OF WATER PARTICLE SYSTEM

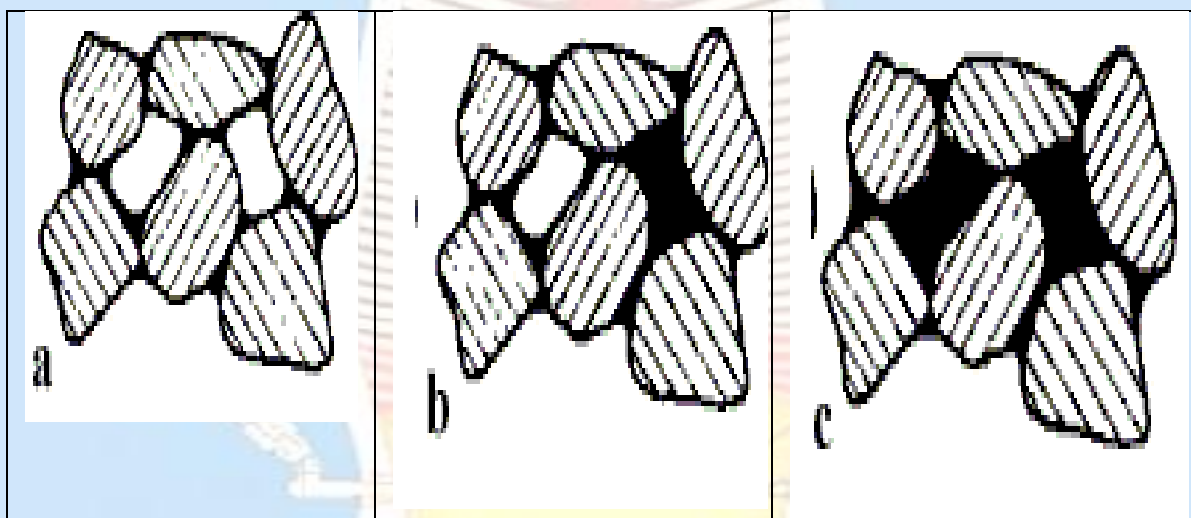


Figure 1: Distribution of liquid in the agglomerates; a-pendular state; b-funicular state; c-capillary state (Schubert, 1977).

Example showing the strength of green ball with critical amount of water:

When we go to sea beach for dry sand to wet sand which is just attached with the sea. We find a region in between these two which contains less water. So if we determine the strength the strength is maximum for the sand from middle region.

MECHANISM OF BALL FORMATION

Mechanism behind this ball formation is the nucleation and growth mechanism.

1-So first stage is nucleation of ball

2-Then growth of this ball

But the entire process depends upon the critical amount of moisture (water) present in the feed.

Suppose the amount of water is less than critical amount then there is non uniform water distribution in the system, the major amount of water will be present in granulate material leaving non granulated material dry. And if the amount is more than critical amount then growth will be more where as strength will be reduced due to increase in plastic behavior.

- Nucleation formation region:-
- A bond is formed immediately between particles when one wet particle comes in contact with another dry or wet particle. In this way other particles are also attached with it and a highly porous loosely held aggregate is formed. And due to rearrangement and partial packing in short duration to form a small spherical stable nuclei.
- Transition period : after nuclei are formed they pass through a transition period. In this period rearrangement of particles occurs which lead to removal of pores and voids. System goes from pendular –funicular- to capillary.
- this wet granulates grows if they are favorably oriented. In this process some granules may even break because of impacts, abrasion etc. growth occurs by two alternative methods.

A- growth by assimilation: is possible when balling proceeds with out the addition of fresh feed material.[during rolling some small particles breaks due to rolling action and these particles attached with bigger one and bigger will grow more big. Here thee is no addition of fresh materials.

B- growth by layering : growth occurs by addition of fresh materials. [here the ball pick up new materials while rolling the amount of materials picked up by the balls is directly proportional to its exposed surface.

EQUIPMENT OR INDUSTRIAL PRACTICE

- Two type of pelletiser are there :
- 1- disc
- 2-drum

Disc pelletiser: it consist of a disc with outward sloping perpheral wall .resemble like flying saucers. Which rotates around its own center , in an inclined position to horizontal .

Dia of disc -3.6-5.6 m .

Inclination is 45 degree to the horizontal.

The material to be pelletized is generally fed directly onto the disc and moisture level is made up with the help of moist material on the disc. It can also control the material flow pattern on the disc. In the reason where water is added seeds are easily formed . With the growth of these seeds their fractional drag against the disc decreases and the centerifugal force acquired by them increases and consequently they move out of nucleation zone. They also tends to rise on the inclined surface of the pelletiser in the direction of rotation and fall down against the toe section of the disc. The height and the width of trajectory of the ball movement increases with the size of the ball until eventually the balls are

deflector downwards by the scraper. During this movements the ball encounter fresh feed and growth takes place more by layering while compaction assimilation plays a relatively minor role.

THE RATE OF PRODUCTION OF BALLS ON A DISC IS A FUNCTION OF THE FOLLOWING VARIABLES

- 1- diameter of the disc
- 2-height of the peripheral wall
- 3- angle of inclination of disc
- 4-place on the disc where mix is fed
- 5-speed of rotation
- 6-place where water is sprayed
- 7-rate of feed
- 8-rate of moisture addition
- 9-rate of withdrawl of the product
- 10-nature of size of feed.
- 11-desired size range of pellets and percentage recycled
- 12- binders and flux.

DRUM PELLETISER

This type of pelletiser is a steel drum which is having both end open with a length to diameter ratio of 2.5-3.5 rotating around its own axis in a slightly inclined position to the horizontal .

Length-6-9 m

Dia-2-3m

Angle of inclination-2-10 degree

Rotate at (Rpm)-10-15 rpm

Here the charge is fed from that side of the drum which is at higher level. water is also sprayed there the material rolls over the surface of the rotating drum and slides downward due to inclination of the drum in a cascading motion. And finally it comes out at other end.

Disc pelletiser	Drum pelletiser
1-acts as classifier	1-Not acts as classifier
2-Growth occurs mainly by layering	2-Growth occurs mainly by assimilation
3-more flexible to operate	3- less flexible
4- close sized products	4- wide range of products size
5-screening is rarely adopted and when if very narrow size range products is required	5-screening is required must
6-specific production rate is more here	6- specific production rate is less

ORGANIC AND INORGANIC BINDERS USED IN PELLETISATION

- Organic binders : starch , dextrine, alginate
- Inorganic binders: ferrous sulphate , alkali chlorides, alkali and alkaline earth carbonates, bentonite (max 1 percentage is added in mix)
- Limestone and dolomite can be used which produces slag bond during this process.

CHARACTERISTIC OF RAW MATERIALS (CHARGE MATERIALS) FOR BLAST FURNACE :

- Room temperature physical properties(cold strength, resistance to impact, abrasion, and porosity of burden,)
- Reducibility
- Physical behavior during reduction at high temperature.

Determine the Room temperature physical properties: such as resistance to abrasion and impact during handling and charging are :

A-Shatter test,(impact test)

b- tumbling test (abrasion test)

C-Porosity test

D-Compression test

Shatter test

It is done to determine the impact strength of the raw materials as raw materials are charge from a big height into the blast furnace and during handling also its suffers .

In this test a standard amount of material is taken and it is dropped for a certain no of drops from a standard height on a standard floor. And then the amount of material retained on or passed through the certain sieve expressed as percentage of the original weight is indicated as the shatter index.

Shatter test in u.k

Developed in U.K and test in U.k : 20 kg sample is taken with size +10mm dropped 4 times from height of 2 m. the material is then screened and shatter index is expressed as the percentage materials greater than 10mm surviving.

Tumbling test and abrasion test

This test is used to determine the strength and abrasion resistance of sample.

Also called micum test .

Here a standard weight of material is tumbled in a standar size drum for fixed number of revolution which is carried out at a standard speed . The percentage material passing through or retained on a certain seive is the index.

According to these test pellets are high quality products then sinter and natural ore.

In case of micum test :sample weight : 50kg

Drum dia x length 1x1 m

Speed(rpm)=25

No of revolution = 100

Compression test

- Compression test: we cannot measure the compression strength of the raw material as there are not in regular size. But pallets we can measure as it is regular in size.
- Standard weight of material is taken (2kg) with standard size 10-15 mm size is dried and placed in a cylinder of 200mm dia and a load of 100 t is applied on it via piston . the + 5mm materials surviving the test is the compression strength index.

Porosity

Porosity : expressed as the volume of pores as a percentage of total volume of the material tested. Two types of porosity are there open and closed . open pores are those pore which is accessible to fluids.

Reducibility test

This test determines the rate of reduction of raw materials under blast furnace condition. Since condition inside the b.f is different in different region from top to bottom. So a special apparatus is designed to carry out this test. Here we use a special apparatus with tempeartur of 900- 1000 degree centigrade and reducing gas of co_2 or $co+N_2$ of constant composition for study. Here the sample of know weight of certain fixed size and is placed in the furnace in the form of static bed of fixed dimension .

PHYSICAL BEHAVIOR OF MATERIAL DURING REDUCTION AT HIGH TEMPERATURE

The disintegration of raw materials inside the blast furnace occurs mainly due to

- 1-decrepitation
- 2-low temperature break down under reducing condition
- 3-failure under over lying load at high temperature
- 4-Swelling at high temperature under reducing condition
- 5-premature softening of materials.

Decrepitating test

it means breakdown of iron ore (sinter , pellets) due to thermal shock when they suddenly comes in contact with exhaust gas while charging.

In this test dropping a known weight of materials in a furnace previously heated to a temperature level of 400-600 deree centi under reducing condition or neutral . after the charge attend the temperature it is removed , colled and sieved to measure the breakdown.

Weight-500gm, size-20-40 mm, time-30 mints

Flow rate of N2 gas – 5000 liter, /hour

It is believe that ores with more than 10 % porosity will not be decrepitate . Similarly a small amount of moisture may also be beneficial.

Low temperature breakdown test(LTBT)

- It has been seen that breakdown of the iron ore(sinter pellets) occurs at lower temperature that is at upper stack in mild reducing and lower temperature condition. It may be due to

A-carbon deposition reaction

B-micro crack present in sinter.

- In this test the charge material subjected to static bed reduction at low temp in a rotating furnace for fixed duration . the percentage fines generated shows the lbtbt index.

RDI (reduction degradation index test)

RDI (reduction degradation index test) here first reduction is done then tumbling of same material is done and then screening is done to find the amount of fines generated.

- Standard weight and size of materials taken and put in an inconel vessel and this vessel is pused into muffle furnace maintained at 500 degree centigrade. Pure N2 gas is passed till the sample is stabilize at 500 degree then mix N2 and Co gas is passed in ratio of 70:30 for 30 mints then sample is cooled to rt by passing N2
- Reducibility test (R.I) on iron ore
- $RI(\text{reducibility index}) = \% \text{ wt. loss divided by } (\text{Fe}(t) - \text{Feo}) \times 48/112 + \text{Feo} \times 16/56 \text{ into } 100.$
- In this test the temperature of the sample is raised to 900 and mixed gas (N2: Co ::70:30)@15lit/min is passed for 3 hours . the colled sample is weighted to find out the % wt loss against 500 gm (initial wt).

Coke reactivity test (CRI) and coke strength after reduction

- 200 gm of dry coke of 19 mm to 21 mm size is placed in the reacting vessel (450mml x 75 dia) made of inconel -600 grade steel . the vessel is pushed in an electric muffle furnace kept at 1100 degrade temp . pure co gas is passed for 2 hours . @ 5 lit/min . subsequently sample temperature is bought down to room temperature by passing N2 Gas @5lit/Min. Cold reacted coke is weighted and the % Wt loss against initial of 200 Gm is reported as CRI. Coke reactivity index.
- Then the reacted coke is rotated in a drum (700 mm l x 130 mm dia) at 20 rpm for 30 mints . Tumbled coke is screened on 10 mm round screen.

The percentage of + 10 mm fraction is reported as CSR .coke strength after reduction.

Development in coke making practices or modification in coke making:

1-Stamp charging:

- cake is made equal to the size of battery by compacting it with hammer the coal blend which increases the bulk density and which lead to the increase in particle contact area leading to the better bonding between the coal particles during carbonization .
- it leads to the
- high strength of coke.,
 - B-csr increase from 35 to 55 value.

Econosing coke charge- since the rate of coke is increasing day by day

- A-Use of oil(0.4-0.6%) and and moisture(8-9%) in the coal mix and cheaper coal also . due use of this increases the flow ability and bulk density and bulk density of the mix . its also helps in good shrinkage of cake volume during carbonization leads to better oven life.
- B-Incorporating 5-10 % of non coking coal in coal blend during coke making .

USE OF WASTE PLASTIC IN COKE MAKING

- plastic is an organic material and it can be used as fuel.
- Initially fine plastic are incorporated into b/f through tuyers , then coarse plastic is done course plastic show better result and these plastic incorporated were free from chlorine as it harms the lining.

- The coarse plastic give higher combustion and gasification efficiency compared to fine plastic and pulverized coal. The CO_2 gas gasification rate of unburnt char derived from plastic was much higher than that of pulverized coal. Hence waste coarse plastic is useful as reducing agent in b/f.
- Now a days certain types of plastic are incorporated with coal in coke oven for better result.
- For feeding plastic into coke oven it must be free from metallics, ceramic, pvc, and other foreign matter.
- Main other advantages of using waste plastic is that : here waste plastic are utilized and it reduces CO_2 emission and save the coal.

ALTERNATIVE FUELS FOR BLAST FURNACE

no other solid fuel can be substituted the coke in b/f

Forms of alternative fuel are –

- 1-pulverised form
- 2-liquid
- 3-gas

Alternative fuels cannot be feed as a burden material but can only be feed through tuyers with hot blast.

Examples of fuels are

- : 1-natural gas
- 2-oil
- Coal tar
- Coal slurry
- Plastic

In some cases charcoal is used as fuel instead of coke

FORMED COKE

- Another fuel is formed coke (molded fuel from non coking coal)
 - Advantages of using formed coke :
- Cheaper non coking coal are used to make formed coke
- Relative lower capital cost and running cost for its manufacturing
- More consistent quality of the product from a given process
- Continuous operation of the plant unlike the coke ovens.

FERRO COKE

- A carbonized lump produced from a mixture of iron bearing fines and non metallurgical coal is known as ferro-coke:
- Here the percentage of iron bearing fines is 15-20 %.
- Ferro coke is made in the same manner as coke making by carbonizing both the mixture of coke and iron fines.
 - Advantages are :
- 1-non metallurgical coal is used in b/f
- As some iron is charged as pre reduced iron into b/g it reduces the fuel consumption
- Coke consumption is reduced
- Productivity is improved.

MODERN TRENDS IN B/F PRACTICES

Main aim of the modern trends in b/f practices is to

Minimize coke consumption

Increase the productivity

1-large capacity

2-better prepared burden and better quality of coke

3-better distribution of charge (

4-high top pressure

5-high blast rate and temperature

6-oxygen enrichment

7-humidification of blast

8-auxiliary fuel injection through tuyers

9-lime dust injection through the tuyers

HIGH TOP PRESSURE

Aim to increase the gaseous reduction .

Here by throttling back discharge gas the static pressure inside the furnace is increased. Throttling device is located after the second stage of cleaning after scrubbers. here a septum valve is provided just after the wet scrubber and part of the semi cleaned gas is by passed to the big bell hopper to obtain zero pressure differential across the big bell. Major problem face in case of high pressure is noise level emitted at the septum valve control area.

Result of high top pressure of 0.7-0.85 kg/cm² gauge top pressure

A-increase the production rate by 11%, and

b-shaving of coke is 35kg/t of pig iron and

c-marked decreases in flue dust loss .

Limit of the effective top pressure is about 3kg/cm² gauge for obtaining increased production rate and decreased coke rate.

Benefits of high top pressure:

1- increased production rate : due to increase in the contact time between ore and reducing gases due to increase in the residence time of the gas in the stack portion , and due to high pressure the rate of reduction of ore increases.

2- reduction in fuel consumption that is coke consumption rate .

3- more uniform operation with lower and more consistent hot metal silicon content . It is due to the flexibility of operation .

4- furnace campaign life increases due to increase in the lining life due to smoother operation.

5- decreases in the dust loss(leads to reduction in load on gas cleaning system) and channeling.

6- boudouard equilibrium moves to left side due to which coke consumption decreases.

BURDEN PREPARATION

1-Iron ore fines agglomerated by sintering and pelletisation.

2-incorporation of flux in the sinter (fluxed and super fluxed sinter)

3-incorporation of mgo in the form of dolomite in the sinter to offset the ill effect of high alumina under Indian condition.

4-Increased in the strength of pellets with lower fuel consumption. By using low sulphur portland cement , slaked lime etc. as binders to develop the strength. The carbonate bonding (C-B) process, the hydrothermal and the (COBO) process are the typical example of this category.

In C-B process slaked lime is used as binder during balling and the pellets are hardened in carbon dioxide atmosphere . The calcium carbonate thus formed developed the strength. In COBO process hardening is carried out at 200 degree centigrade. In an autoclave under 15kg/cm² pressure of co₂ to expedite the process.

BELL LESS TOP WITH ONLY VALVE SEALS

There is no bell here so problem due to bell is eliminated . Here one receiving hopper for receiving the raw materials . Then a valve is there to allow the material to material handling bin then a valve is there to allow the material to rotating distributor chute to distribute the material into the furnace . The chute rotate in a circular or helical fashion and at variable angles. Charge at a point in sequence and in spiral form is possible also.

Here there is sealing function.

HIGH BLAST TEMPERATURE AND DRIVING RATE

Thermal efficiency of the b/f can be increased by increasing the hot blast rate and increasing the temperature of the hot blast.

change in hot blast temperature 600(fiftees)—900(sixtees)—1200—1300(now a days) degree centigrade.

So to increase the hot blast temperature demand in increase in the design of the stoves to store more heat energy at high temperature. This is done by design of the checker shapes and materials ,

Various chances or modification of hot blast stove are :

1-combustion chamber is located out side the stove so that entire stove volume is available to build checker and thereby store more energy.

2-Combustion chamber is located in the dome itself by altering the dome shape to hold the burner. (stove efficiency reaches upto 90 %)

A recuperator system on the stoves has been used to preheat the gas and combustion air to generate higher temp while side by side improving its efficiency . The stove waste gaseous are used to preheat the gas and combustion air to almost 450 degree.

Due to high temp of hot blast it reduces the fuel consumption in the furnace.

A higher hot blast temp is often used in conjunction with humidified blast so that flame temp in the combustion zone of the blast furnace is still within proper limits .

OXYGEN ENRICHMENT OF BLAST

- OXYGEN ENRICHMENT UPTO 25 % IN THE BLAST IS FOUND TO BE ADVANTAGEOUS .
- The presence of 79 % nitrogen by volume in blast restricted the temperature generated in the combustion zone . this temp can be increased by decreasing the nitrogen percentage in hot blast .
- it has been show that only 2 % increase in oxygen reduces the nitrogen burden by about 4 unit per unit weight of coke and higher temperature would be possible.
- For every percentage increases in oxygen content , increases in production rate of about 3-4 % with marginal shaving of coke. Main reason of shaving of coke is due to cracking of moisture giving rise to hydrogen which acts as a reducing gas up in stack.
- Disadvantage of – sticking of stocks and increasing Si content in hot metal
- Generally oxygen enrichment and humidification(endothermic reaction) is done simultaneously .

- Disadvantages : there is a limitation of excess temp in tuyer region but if temp exceed the
 - 1- bridging occurs
 - 2-sticking of stocks
 - 3- higher silicon content in pig iron .

HUMIDIFICATION OF BLAST

By incorporating moisture through tuyers we can generate double the volume of reducing gas per mole of carbon burnt.

For every carbon burnt one mole of CO and an addition mole of hydrogen will be available as product of burning of coke for reduction in bosh and stack.

The more the moisture more will be the additional hydrogen available.

Kinetically H₂ reduction of iron oxide is faster than by CO because of its smaller size.

$\text{Fe}_2\text{O}_3 + \text{H}_2$ ---- exothermic reaction

$\text{H}_2\text{O} + \text{C}$ ----- $\text{CO} + \text{H}_2$

$\text{H}_2\text{O} + \text{C} = \text{CO} + \text{H}_2$

$h^0 (1200 ^\circ\text{C}) = + 2700\text{kcal/kgc}$

$= + 1800 \text{ kcal/kg h}_2\text{O}$

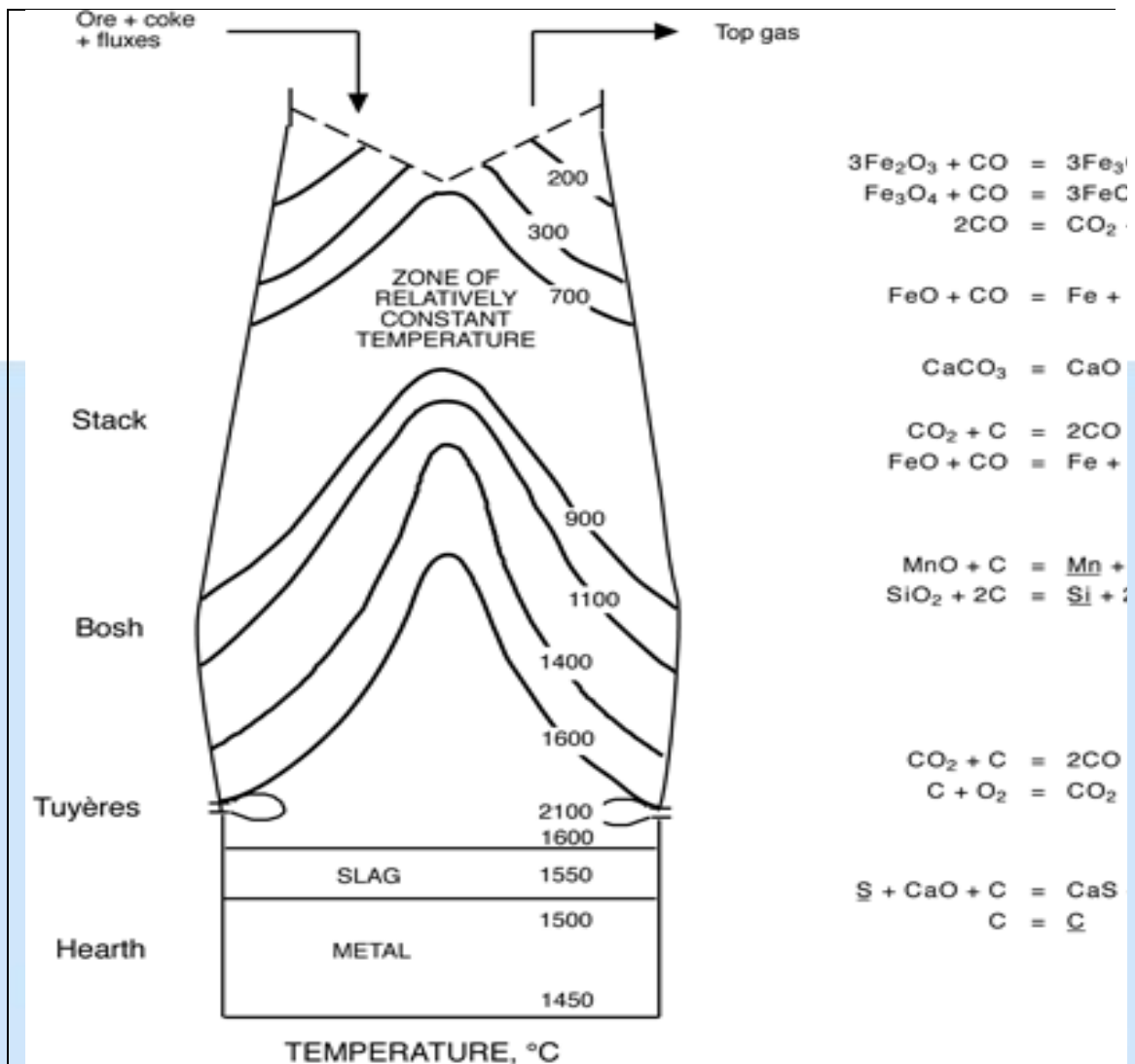
this reaction is exothermic in nature . so furnace temperature decrease so to compensate this temperature the blast temperature is increased or adding oxygen enrichment is done.

moisture is introduced in form of water because if steam is introduced the cost increases as it required fuel to heat the water into steam.

INTERNAL STRUCTURE OF BLAST FURNACE DURING WORKING CONDITION

- Granular zone : entire charge is sold
- Cohesive zone: except coke other crhage is in semi solid . formation of fesio4
- Active coke zone : mainy bosh zone , coke take part in raction , direct reduction of from the trickling slag and its own interation with co2 gas
- tuyere zone: coke burns infron of tuyers by hot blast to form co2 then to co
- Stagnant coke zone: coke is in solid which that support the over lying burden and slag and metals get trickles down and saturated with carbon.
- Hearth zone: stratification of slag and hot metal and their interation and reach an equilibrium.

BLAST FURNACE TEMPERATURE PROFILE



BLAST FURNACE IS MAINLY CLASSIFIED INTO TWO MAIN ZONES

- Upper zone half zone called conditioning zone : preheating and partial reduction occurs by upcoming gases takes place .(indirect reduction)
- Lower half zone called processing zone where complete reduction of iron oxide takes place and fusion of the reduced products occurs to get slag and metal. Direct reduction zone , solution loss , melting zone coke reserve zone .

- On the basis of these processing zones blast furnace is having 2 heat exchange zone which is separated by a isothermal heat zone (larger part).
- This isothermal zone is further divided into thermal reserve zone and chemical reserve zone .
- At upper heat exchange zone : $t_g > t_s$
- But at lower heat exchange zone $t_g < t_s$. (here better heat exchange occurs between the gas and solid .
- At isothermal reserve zone : $t_g = t_s$

GENERAL COMPOSITION OF HOT METAL

- C- 3.5-4.2
- Si-0.2-1.5
- S-0.020- 0.050
- P-0.1-2.0
- Mn-0.2-1.5

SULPHUR IN HOT METAL

Main source of sulphur-coke (90 %)

Iron ore,(sulphide) flux (sulphide, sulphate)

Effect of sulphur :disadvantage of sulphur

- Hot shortness:Sulphur affects both internal and surface quality of steel
- Sulphur contributes to the steel brittleness and when it exists in sulphide phase it acts as a stress raiser in steel products.

- It forms undesirable sulphides which promotes granular weakness and cracks in steel during solidification.
- It has adverse effect on the mechanical properties.
- It lowers the melting point and intergranular strength and cohesion of steel.

Advantage of sulphur :

Free cutting steel

Machanability

DESULPHURIZATION OF HOT METAL

Sulphur reaction :

- $[fes] + (caO) = (Cas) + (Feo)$
- $K = \frac{a(cas) \cdot a(FeO)}{a[fes] \cdot a(cao)}$
 - or assuming henarian behavior we can write
- $K = \frac{\% (cas) \cdot (\% FeO)}{\% [fes] \cdot (\% cao)}$
 - DESULPHURISATION INDEX
- $(\% s)$ directly proportional to $(\% cao) / (\% feo)$
 - $[\% s]$
 - The ratio $(\% s) / [\% s]$ is reffered as the desulphurising index and which varies with basicity and the oxygen potential

CONDITION FOR SULPHURAL REMOVAL

- Temperature- high
- Basicity-high
- Atmosphere-reducing
- Oxidising potential of sla- low
- The presence of Mn int the melt help in removal of the sulphur .
- So generally we are adding Mn ore or Mn bearing slag during iron making.
- To prevent the use of use of Mn in the iron making we are carrying out external desulphurization. Due to this we are getting low Mn hot metal and this situation leads to decrease the operating temperature of the furnace and there by decreases silicon iron which are better for steel making.

DESULPHURIZATION IN BAST FURNACE CAN BE CARRIED OUT BY 4 MEANS

- Adding Mn ore or Mn slag bearing material
- Increasing the hearth temperature
- Increasing the basicity of slag
- increasing the salg volume (higher is the basicity higher is the hearth tempearture

EXTERNAL DESULPHURISATION

Unlike other impurities which are removed from the hot metal by oxidation in the oxygen converter, the most economic method of removing sulphur from the hot metal is by reduction either in the transfer

ladle or in the charging ladle, before it is charged in the converter. A number of technologies have been developed for the external desulphurization of hot metal but all of them have the basic requirement of a reagent and a method of mixing. The difference between the technologies used is the properties of the reagents, the effectiveness of the reagent to remove sulphur and the effectiveness of the mixing method to get the reagent into solution. . Also the effectiveness of hot metal desulphurization is inversely proportional to the desulphurization reagent injection rate. The most popular desulphurizing process today is deep injection of desulphurizing agent in the hot metal.

- Dip lance process is the most economical, effective and reliable method of desulphurization hot metal. It consists of pneumatic injection of fine grained desulphurization reagent into the hot metal with high dosing precision via a dispensing vessel and a refractory lined lance. For each reagent, one separate dispensing vessel is used. All the vessels are identical. Nitrogen gas is normally used as a carrier gas for the desulphurization reagent. The reagent transfer in the injection line is under dense flow conditions. The dense flow conditions maximize reagent delivery as well as reduce abrasion wear of injection lines. The injection of desulphurization reagents through deeply submerged lance causes an intimate mixing of the desulphurization reagent with the hot metal. The process allows the use of several desulphurization reagents, such as lime, calcium carbide and magnesium, which remove the sulphur in the hot metal by chemical reaction and convert it to the slag. Sulphur rich slag generated during the process is removed immediately after completion of the reagent reaction. The most common method is to tilt the ladle and rake the slag off with the help of a slag raking machine.

DESULPHURIZING REAGENTS

The most commonly used desulphurizing reagents are lime (CaO), calcium carbide (CaC₂) or magnesium (Mg).

Lime – Its low cost and easy availability make it an attractive reagent. But it has got some critical disadvantages. During the process of desulphurization, lime particles are continuously being covered by two precipitates namely calcium sulphide (CaS) and calcium silicate (CaSiO₄). These compounds impede the desulphurizing reaction by surrounding the lime and forming

thick barriers at the lime – hot metal interface. In order to reduce this growth, the grain size of the lime is to be restricted to 45 micrometer maximum. The desulphurizing reaction with lime takes place as per equation: $2\text{CaO} + 2\text{S} = 2\text{CaS} + \text{O}_2$.

Calcium carbide – Calcium carbide was once most used desulphurizing reagent but now it is less prevalent. Complicated material handling procedures as well as stringent environment requirements associated with the disposal of slag have negatively influenced its use. Calcium carbide is also subject to layer formation similar to lime, which impedes the desulphurizing reaction. The desulphurizing reaction with calcium carbide takes place as per equation: $\text{CaC}_2 + \text{S} = \text{CaS} + 2\text{C}$.

Magnesium – Magnesium has a high affinity for both oxygen and sulphur. Unlike lime, magnesium is not accompanied by oxygen when it is injected into the hot metal, therefore it can rapidly react with sulphur to form magnesium sulphide. Magnesium in solution that does not react with any oxygen in the hot metal, thus removing excess oxygen. Mono injection process with magnesium reagent is less common because of the violent nature of the reaction and the relatively complicated equipment requirement. Magnesium is the only one of the three common desulphurization reagents that is soluble in hot metal and reacts with sulphur in solution. The desulphurizing reaction with magnesium takes place as per equation: $\text{Mg} + \text{S} = \text{MgS}$. Due to low boiling point (1090 deg C), magnesium vapourizes as it enters the hot metal. This vapour is under high pressure which is directly related to solubility. Once in ladle, the magnesium vapour forms bubbles which rise through the hot metal, dissolve and react with sulphur in solution, forming magnesium sulphide (MgS). This magnesium sulphide then floats on the top of the ladle and settles in the slag layer, which is skimmed off. The lime that is injected with the magnesium assists in dissolution by reducing the diameter of the bubbles as well as providing precipitation sites for the MgS. There are some important issues with respect to the desulphurizing reagents. All desulphurizing reagents are not equal in their ability to remove sulphur. Magnesium although more expensive, has approximately 20 times the capacity of removing sulphur than lime. Calcium carbide has eight times more potential to remove sulphur than lime. However, if injected into hot metal on its own, it must be blended with volatiles in order to increase the agitation of the bath. Pre blending of

different desulphurizing reagents such as magnesium-lime or magnesium-calcium carbide is not useful since blended reagents are prone to segregation during transport and storage besides individual injection rates of desulphurizing reagents gets sacrificed

IRREGULARITIES IN BLAST FURNACE OPERATION AND THEIR REMEDIES.

Main three reasons of irregularity in b/f:

- Due to faulty mechanical devise like any fault in cooler , valves.
- Due to faulty mechanical operation : ;like charging , taping etc
- Abnormal physio chemical changes inside the furnace.
 - Burden takes 6-10 hours to travel through the furnace.

B/F irregularities	Irregularities Cause and remedies
Hanging:	<ul style="list-style-type: none"> • There is an ununiform descent of burden material due to bridging, scaffolding , wedging. • Main reasons are : • Solidification of previously fused slag that is sintering of this into large mass. • Bridging of ore particles in the vicinity of fine coke parricles which instead of sepreating the ore particles flow in the interstitial position of the ore particles. • The deposition of excess carbon due to naumaan reversion reaction in the voids and consequent decrease in the permeability of the burden. • Condensation of alkali vapous in the upper part of stack there by cementing the charge into impervious mass. • Excess blass pressure resulting in counteracting the downward moment of the stock. <p>Classification of hanging :Remedies</p> <ul style="list-style-type: none"> • General hanging and bottom hanging :

	<p>if hanging occurs anywhere above the tuyere due to low voidage in the stack.</p> <ul style="list-style-type: none"> • Top hanging : hanging occurs in stack due to alkali condensation and carbon deposition <p>Cold blast, reduction in blast pressure, addition of excess lime (helps in solution loss reaction),</p>
<p>Scaffolding:</p>	<ul style="list-style-type: none"> • In this case formation of scaffold (which is a larger mass of material stuck to the furnace wall at top portion). <p>Due to scaffolding many problems arise:</p> <ul style="list-style-type: none"> • Reduction in the cross section, uneven moment of stock, rise in blast pressure, increase in dust loss, decrease input put, increase in fuel consumption, decrease in amount of gas produced. • Main reason of scaffold formation is presence of alkali oxides in burden. The alkali vapour condensed on the bricks lining and form low m.p alkali aluminosilicates and to this sticking of ore particles progressively resulting in formation of massive block of charge material stuck to the wall. <p>Main reasons of formation of scaffold :</p> <p>Remedies</p> <ul style="list-style-type: none"> • Poor furnace design, improper fluxing, heavy burden . • Remedies to scaffolding: • Minimises the alkali content of the burden • Decreases the fuel rate • Scaffolding has been successfully removed by jumping the furnace that is the blast is put off suddenly to relieve the pressure under scaffold.

Slip:	<ul style="list-style-type: none"> • Sudden Slippage of burden material generally the scaffold , wedging hanging . • Results of slip is explosion , chilled hearth • Remedy : allow the f/c to slip on its own by adjusting the blast temp and pressure. • Main reason may be bad bosh design,
Chilled hearth: cause :	<ul style="list-style-type: none"> • Hearth get chilled which affect the tapping . main causes are water leakage from tuyers, excessive moisture in the blast, slip
breakout	<ul style="list-style-type: none"> • the slag or metal or both flow out in an uncontrolled manner due to failure of hearth or bosh wall . • it causes explosion when the metal comes in contacts with collers. • when its occurs the tapping is done in an faster way
pillaring :	if the blast is unable to penetrate right upto the center of the furnace it leads to the formation of cold central column of stcok with hot zone around it . it can be found out by inserting a rod
Flooding :	If the velocity of upward moment of gas is more then weight of metal .

PHYSICO CHEMICAL PRINCIPLES

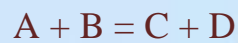
Iron making principle involves heat and mass transfer , but it is difficult to determine it due to presence of various components in the system and other hand also consists of various phases solid

liquid gaseous. And another most important thing is that whether the various phases reaches equilibrium or not. Even after these difficulty we can predicts these by use of thermodynamics and kinetics data.

Equilibrium constant and activity

Equilibrium for a reaction will be reached when velocity of forward reaction of reactant = velocity of reverse reaction of reactant

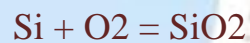
Representation of equilibrium for a general reaction :



$$\text{Equilibrium constant}[k] = a_C \cdot a_D / a_A \cdot a_B$$

Where a- activity of the components

K- is function of temperature



$$K = a_{\text{SiO}_2} / a_{\text{Si}} \cdot a_{\text{O}} = a_{\text{SiO}_2} / a_{\text{Si}} \cdot P_{\text{O}_2}$$

Activity of a gaseous component can be taken as equivalent to its partial pressure.



MODULE-4

USE OF SPONGE IRON

- 1- Since it does not contain any residual elements or tramp elements it is used to produce better quality of steel with desired specification in electric arc furnace.
- 2- To improve the productivity it can be used as burden material in b/f (upto 50% sponge iron)
- 3- Sponge iron used in LD and open heart for making steel.

LIMITATION OF DRI PROCESS AND B/F

- 1- Very low productivity of individual unit as compared to B/f.
- 2- Transportation problem of dri as it is prone to reoxidation
- 3- Electric power is needed for melt and make steel .
- 4-

CHARCOAL BLAST FURNACE (USEFUL VOLUME -100 TO 800 METER CUBE) AND LOW SHAFT FURNACE

In charcoal b/f charcoal acts as a reducing agent and fuel .

WHY THIS METHOD IS NOT USED NOW A DAYS
THERE ARE VARIOUS FACTORS

1-main reason is deforestation.

MAIN LIMITATION OF CHARCOAL B/F

a-that the height and size could not be increased to a large extent .

b-Second is that since its bulk density is very low it results in its occupying substantial useful volume of the furnace. Due to this factor c b/f has low productivity.

ADVANTAGES OF CHARCOAL B/F

Volume of slag produced is very low due to the low ash content of charcoal.

Offgas contains more amount of CO gas (c.v of 4.0-4.2 Mj/Nm cube) whereas coke b/f off gas c.v is 3.1 M/J Nm cube

TALL SHAFT B/F VS LOW SHART FURNACE

Advantage of tall shaft b/f is that it has extremely high thermal efficiency this is because processing (depends upon reducing power and temp of gaseous generating at tuyeres) , preheating and reduction takes place before it descends into the melting zone.

And one of the reasons for using tall b/f is that the gas produced at tuyeres is 60% N₂ and nitrogen is inert which helps only in heat transfer.

How to increase the thermal efficiency and reduction in low shaft furnace ?

If the heating and smelting zones in the furnace are compressed by accelerating the heat exchange and chemical reaction that means more sharper thermal efficiency and reducing potential gradient are obtained.

For this we are using oxygen enriched blast which produces higher temperature and furnace gas containing lower nitrogen content and higher reducing potential . consequently the necessary heat transfer and reduction would be achieved over a shorter shaft.

LOW SHAFT FURNACE :

ADVANTAGES OF LOW SHAFT FURNACE

- 1- Use of fines , low grade friable type of ores in the charge
- 2- Use Low grade fuels like lignite or that in non metallurgical coal.
- 3- Top gas is rich in fuel which can be used anywhere in plant
- 4- Costly high capacity turbo blowers are not necessary for blowing of hot blast as blast pressure required here is low .
- 5- Costly stoves are not necessary since preheating of blast is done in recuperators.
- 6- Si content is low
- 7- Production rate is around 2.5 t/m³ of usefull volume of the furnace which is more than that of b./g
- 8- Control of smelting operation is easy

Disadvantage :

Briquetting of charge mix may be necessary for efficient production whih adds to the cost of raw materials

The daily production of individual unit is low of 100-200tpd and hence battery of furnace are required to be obtained even a sizeable production rate.

LOW SHAFT FURNACE

It can run on two types of charge , one is consists of lumps of individual charge materials. Other consists of briquettes made from suitable mixture of fines or ore, stone and lignite with tar as binder . advantages of using briquette is that it assures uniform distribution of charge but guarentees sufficient permeability for efficient heating and reduction.

In this furnace little reduction occurs in the upper part but rapid reduction occurs a short distance above the tuyers. The reduction of ore takes place predominantly directly by carbon rather tthan by gas because of short shaft . the off gas contain large amount of heat (high temperature) and concentariuon of co is high also that is ($co/co_2 = 6$)

CONSTRUCTION OF LOW SHAFT FURNACE:

- Heaight more that 5 m
- Circular and rectangular cross section furnace are used
- Hearth is 8- 10 m² in area
- Avg consumption of lignite is 2000 kg/t of iron

- No coke oven plant and sintering plant is necessary which save capital

FERRO ALLOY

Ferro vanadium, ferro cr, silicon, titanium, manganese, tungsten , molybdenum,

Main function of ferroalloy is facilitate the addition of alloying elements to molten steel.

Ferroalloys ensure that the loss of the alloying elements due to oxidation is kept low because they have fusion points lower than those of alloying elements due to oxidation is kept low because they have fusion point lower those of the alloying elements and can, there fore dissolve rapidly in steel or iron.

Other function is deoxidation of steel :

It is used to help in eliminating oxygen and other dissolved gases.

. these alloying elements form stable oxide which do not dissolve in steel and ferroalloy of titanium and zirconium forms stable nitrides and eliminates nitrogen from steel.

Ferro alloys of silicon and nickel control the graphite morphology in cast irons, which improves the mechanical

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