LECTURE NOTES

On

Ferrous Metallurgy I

ORISSA SCHOOL OF MINING ENGINEERING
Government of Odisha
ଓଡ଼ିଶା ଖଣି ଯାନ୍ତ୍ରିକ ବିଦ୍ୟାଳୟ, କେନ୍ଦୁଝର

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Metallurgical Engineering Department

Orissa School of Mining Engineering Keonjhar

Course code: Th4 Semester: 3rd

Vision and Mission of the Department

VISION: To offer quality technical education In the field of Metallurgical Engineering with orientation towards industry, entrepreneurship, higher education and to strive for developing professionally competent technicians meeting the needs of the global economy.

MISSION:

M1 : To develop students in the field of Metallurgical Engineering as highly motivated, skillful and qualified manpower for employment and higher learning

M2 : To promote a conducive environment for all round development of students.

M3 : To promote linkages with external agencies to meet changing needs of industry and society.

M4 : To Improve Laboratories

Program Education Objectives (PEOs)

PEO 1: Diploma professionals will be able to make a successful career in metallurgical industries or higher studies to meet the needs of future requirements.

PEO 2: Diploma metallurgists will have technical and behavioral competencies through adequate exposure to industry.

PEO 3: To impart technological knowledge and skills for solving real-time engineering problems.

PEO 4: To develop human resources with capabilities of effective communication, moral values and social responsibilities.

Lecture-1

What is Metallurgy?

It is a branch of science/engineering that deals with extraction of pure metals from their ores &modifies them for use.

Minerals: - All the naturally occurring minerals present on earth's crust are called minerals.

Ores: - Minerals from which metals can be extracted economically are called ores. So, all ores are minerals but not all minerals are ore.

1.0   Raw Materials for Iron Making
1.2 Deposits of iron ores flux and coal in india with particulars reference to Odisha
Minerals found in ODISHA: -

Minerals	Location
Iron ore	Keonjhar, Sundargarh, Mayurbhanj, Jajpur
Chromite	Jajpur
Bauxite	Koraput, Raygada, Kalahandi, Keonjhar
Coal	Anugul, Sambalpur, Jharsuguda, Dhenkanal
Dolomite	Sundargarh, Bargarh
Limestone	Sundargarh, Koraput, Bargarh

Introduction: -

All the engineering materials can be categorised into 2 types- Metals, Non-metals

Metals can be broadly categorised into 2 types based on their chemical composition.
1. Ferrous metals   2. Non-ferrous metals.

Ferrous metals are those metals which basically consist of iron (Fe). E.g. Mild steel, Stainless Steel, High carbon steel etc. & non-ferrous metals are those metals which doesn't contains iron. E.g. Aluminium (Al), Copper (Cu), Zinc (Zn) etc.

About iron: -

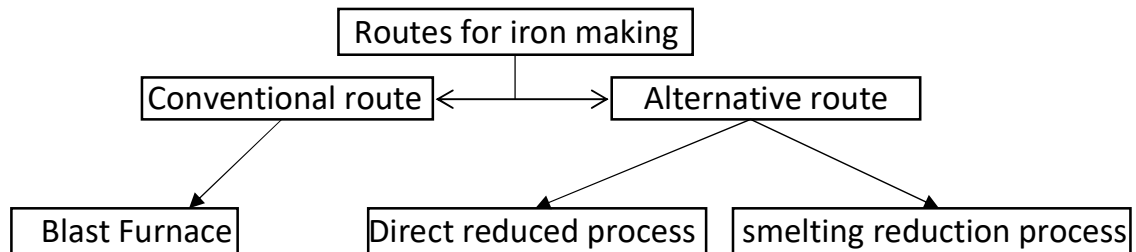Symbol - Fe   Atomic number - 26
Atomic weight - 56   Melting point - 1539°C
Density – 7.8 gm/cm^{3}

Lecture-2

Iron Making

It is the metallurgical process of extraction of iron from its ore.

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                    Routes for iron making
                    /                    \
    Conventional route  <----------->  Alternative route
            |                          /              \
      Blast Furnace      Direct reduced process   smelting reduction process
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Blast Furnace Iron Making: -

    1.1   Different Raw Materials and their functions
    2.0   Quality requirements of raw materials

Raw materials required for blast furnace iron making: -

- Iron bearing material (Iron ore, sinter, pellet etc.)
- Coke
- Flux (Limestone, dolomite, quartzite)
- Air (Hot blast at temperature around 1100°C)
- Coal dust (PCI)
- Oxygen

Gangue: - Impurities present in the metal ore are called Gangue. These impurities are very difficult to remove physically. e.g. Al_2O_3, SiO_2, MnO, TiO2 etc.

Flux: - Chemical substance/material used to convert impurities which are not easily removable (gangue) into slag. Fluxes used in iron making are: Limestone, Dolomite, and Quartzite.

Slag: - This is the product formed when flux and gangue combine together which are easily removable.

Lecture-3

2.1 Different types of iron ores

2.2 Composition and characteristics of raw materials.

Iron ore: - Iron ore are the minerals from which pure iron can be extracted economically. Iron ores vary in colour from black, dark grey, bright yellow, deep purple to rusty red.

Iron ore type	Example	Fe content	Colour
Oxide	Haematite Fe_2O_3	70%	Red
	Magnetite Fe_3O_4	72%	Black
Hydroxide	Goethite FeO(OH)	63%	Brown
	Limonite FeO(OH).nH_2O	55%	Brown
Carbonate	Siderite $FeCO_3$	48%	Brown/Grey
Sulphide	Pyrite FeS	47%	Pale yellow

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Q. If an iron ore contains 80% Haematite. Then what will be the amount of iron ore required to produce 1 tonne of hot metal/pig iron having 95% Fe content in it.

Ans-95% of 1tonne is 950Kg.

$\Rightarrow$ Given that the ore contains 80% haematite. I.e. in 100Kg ore 80 Kg Haematite is present.

$\Rightarrow$ Again, in Haematite 70% Fe is present. Then in 80Kg, $80 \times \frac{70}{100} = 56Kg$

$\Rightarrow$ That means 56kg Fe is present in 100Kg of ore.

$\Rightarrow$ Then 950Kg iron will be present in $\frac{100 \times 950}{56} = 1696.42Kg$ = 1.696 Tonne

$\therefore$1.696 Tonne iron ore is required to produce 1 tonne hot metal having 95% Fe content.

2.3 Evaluation of iron ores.

Evaluation of iron ore: -

Iron ore can be evaluated on the basis of several factors like-

1. **Richness: -**
   - → It means the percentage of metallic iron present in the ore.
   - → Higher the richness of ore, lesser will be the amount of ore required to produce high unit weight of pig iron.
   - → For richer ore, the flux consumption will be lesser as it contains less gangue material.
2. **Location: -**
   - → Both geological and geographical locations are taken into consideration for evaluation of ore.
   - → Geological location is related to whether the ore deposit is on the surface or underground.
   - → Geographical location is related to mode of transportation required to bring the mined ore to industry location.
3. **Composition of gangue: -**
   - → The composition of gangue associated with iron ore may decrease the value of rich ore or may increase the value of lean ore.
   - → The effect of associated gangue is related to its nature, whether it entirely stays in slag, partially in slag or entirely in metal.
   - → If the ore contains gangue that stays in metal phase, it decreases the valuation of ore.
4. **Treatment and preparation needed: -**
   - → The treatment and preparation required for an ore to be made suitable for blast furnace use decides the cost of that ore.
   - → Dense ore may need crushing or breaking to make them porous.
   - → Fine ore particles need to be agglomerated & Carbonate ore will have to be calcined to become suitable for use in blast furnace.
   - → All these add to the overall cost of ore & therefore decrease the value of ore.
5. **End use: -**
   - → End use of iron ore also decides its value.
   - → There mostly 2 routes available for using iron ore to extract iron. So, whether an ore is used for conventional process or alternative iron making process acts as a factor to evaluate iron ore.

Finally, the value of iron ore is decided not only by the Fe content alone but also by various other mineral associated with it & other factors.

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2.4 Metallurgical coal

Coal: -

- Coal is a naturally occurring organic mineral which forms by the accumulation & preservation of plant materials.
- Coal mostly contains carbon with variable amounts of other elements; chiefly hydrocarbon, sulphur, oxygen & nitrogen.
- Natural coal is too dense & fragile to be used in the blast furnace.
- So, naturally occurring coals are not used directly in b/f instead we use coke in b/f.

Coke: -

- Coke is product of bituminous coal.
- Coke is produced by carbonisation of coking/metallurgical coal. (Carbonisation is a process of heating coal in absence of air.)
- Coke has high fixed carbon content & low volatile matter content. It is porous & stronger than coal.

2.6 Required properties of coke for making iron

- The coke that to be used in blast furnace should have high fixed carbon (>85%), low volatile matter content (<2%) & low ash (<10%) also should have low sulphur & phosphorus.

2.5 Difference between coal and coke

Difference between Coal & Coke: -

Coal	Coke
I. It is a naturally occurring mineral.	I. It is formed by carbonisation of metallurgical coal.
II. It is dense and fragile.	II. It is porous & strong.
III. It has low calorific value than coke.	III. It has high calorific value than coal.
IV. Its fixed carbon is low with high volatile matter, ash & moisture content.	IV. Its fixed carbon is high with low volatile matter, ash & moisture content.
V. Produce more smoke during burning.	V. Produce very less smoke during burning.

- In India, the coking coal reserves are mostly in Jharia region of Jharkhand. However, the coking coal reserve is only 15% of the total coal.
- Also, the qualities of coking coals available in India are poor as compare to the worldwide available coking coal quality.
- So, for blast furnace iron making in India, coking coals are imported from Australia and Canada.

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2.7 Flux and its types

Flux: -

Flux is the material/substance that is added to remove the gangue material present in ore as slag. There are 2 types of flux- Acidic flux & Basic flux.

- ➤ Acidic flux: - The flux/oxide which is acidic in nature is known as acidic flux. These fluxes are used to remove basic oxide impurities. E.g. Quartzite (SiO_2).
- ➤ Basic flux: - The flux or Oxide that are basic in nature is known as basic flux. These fluxes are used to remove acidic oxide impurities. E.g. Lime stone ($CaCO_3$).

2.8 Evaluation of Flux (available base & basicity)

Basicity (B): -

The flux/oxides which are basic in nature are known as basic flux. These fluxes are used to remove acidic oxides or impurities.

$$Basicity\ (B) = \frac{\%\ of\ basic\ oxide}{\%\ of\ acidic\ oxide} = \frac{\%\ of\ (CaO+M\quad)}{\%\ of\ SiO_2}$$

- → In general, the basicity of blast furnace is 1-1.3 .
- → In blast furnace, we usually use lime stone and dolomite as flux. And sometimes we may use quartzite (SiO_2) as flux.
- → Flux which is used in blast furnace also sometimes associated with some gangue materials like Al_2O_3, Phosphorus & Sulphur. SO, the flux should be so chosen that it contains minimum amount of gangue associated with it.
- → Lower the content of gangue in flux mineral, higher will be the value of flux.
- → Lime stone & dolomite mines are available in Odisha at Biramitrapur of Sundargarh district.

<div align="center">Lecture-8</div>

3.0 Burden Preparation

Raw materials required to produce1 tonne of hot metal in Blast furnace: -

1. Iron bearing materials (Iron ore, sinter, pellet) – 2-2.5 T
2. Coke – 0.5-0.7 T

3. Flux (lime stone & dolomite) – 0.4-0.5 T
4. PCI, O_2, Steam – 0.1-0.2 T
5. Air / Hot blast – 4 T

Composition of Hot metal	Composition of Slag
Fe – 93-95%	CaO – 30-32%
C – 3.5-4.5%	SiO_2 – 32-35%
Si – 0.5-1.5%	Al_2O_3 – 12-20%
Mn – 0.2-0.7%	MgO – 10-15%
S – 0.02-0.06%	FeO – 0.5-1%
P – 0.03-0.1%	

Composition Of Blast Furnace Gas

C0	(22-25)%
H2	(4-5)%
CO2	(16-20)%
N2	(51-55)%
O2	(0.2-0.5)%
Little amount of NH3, H2S	Almost Nill

BURDEN PREPARATION: -

⇒ The development in the field of iron making has always been decided to increasing the productivity at minimum fuel consumption.

⇒ Pig iron with low silica & sulphur content makes the process of conversion of hot metal to steel economically.

⇒ Maximum productivity can be achieved by using better quality of charged raw material.

⇒ The quality of naturally occurring raw material may not be up to the mark to be use in blast furnace directly.

⇒ Burden preparation is done to make the raw material suitable to be used in blast furnace, which includes treatment of ore, coke & flux.

⇒ However, the treatment process mainly focuses on ore & agglomeration process. For an ore to be used in the blast furnace, it should be uniform size, adequate length & good reducibility.

⇒ In broad sense, the ore must meet some specific physical & chemical property.

3.1 Quality of burden (physical & chemical properties)

Physical properties: -

1. Close size range
   Size of the lump ore should be homogeneous, size of lump ore to be used in blast furnace is 10-30mm.
2. Strength
   It should possess high strength so that fine generation during handling & the generation inside the furnace will be minimum.
3. Reducibility
   It's the ability to get reduced for an ore to be used in the blast furnace should have good reducibility so that coke consumption will be minimum.
4. Swelling
   The ore should swell much inside the furnace, otherwise affects permeability & smooth movement of burden
5. Softening characteristics
   The softening temperature should be high & to differentiate between softening & melting temperature should be low.

Chemical properties: -

1. The composition ore should be homogeneous.
2. It should contain higher percentage of iron ore & low percentage of gangue.

Various processes used for burden preparation: -

   I.   *Crushing, grinding & sizing: -*
   -   Crushing & grinding refers to breaking the ore to small size. Sizing refers to choose the right size of iron ore for Blast furnace operation.
   -   Ore size below 5mm size will lead to decrease in permeability of burden. So, must furnace operation avoid material in that size range.
   -   Proper size range of material is done by using screen. The reduction of the ore inside the furnace largely takes place by gas which has to diffuse in to ore particles.
   -   Too large size ore would result in unreduced material coming down the stack into tuyere & increase the coke rate.
   -   The crushing & sizing operation carried out mostly in mines. Maximum amount of ore is in the size range 25-37mm.
   -   Fraction of ore below 10mm size needs to be agglomerated for making it useful as blast furnace feed.
   II. *Beneficiation: -*

- Physically separate the gangue material from ore.
III. *Drying: -*
- Remove the moisture present in the ore.
IV. *Calcination/Roasting: -*
- Remove volatile oxides, hydroxides, carbonate sulphur present in the ore.
V. *Blending: -*
- Mixing of 2 or more type of raw material to homogenised variation in physical chemical qualities.

<p align="center">Lecture-10</p>

3.2 Different types of agglomeration required for burden preparation for blast furnace

Agglomeration of iron ore: -

It is process of accumulating small fine mass & producing lump mass. Iron making agglomeration process is used to convert ore fines into lump so that they can be used in blast furnace.

Various agglomeration processes are: -

a. **Briquetting: -**
   → In this process fine iron ore pressed to a particular shape with addition of some water or other binding material. The pressed material is hardened by heating to a suitable temperature.
   → Binder like tar, pitch, lime stone, bentonite etc. are generally used in briquetting as per requirement.

b. **Nebulising: -**
   → In this method of agglomeration ore fines along with some carbonaceous binder like tar are passed through a rotary kiln heated by gas or oil.
   → The temperature inside the kiln is sufficient enough to soften the fines. So that they get fused with each other.
   → The nodules formed are varied considerably in composition & too dense (not porous). So, this process is obsolete.

ore fines + binder →   → dense nodules
                       ← hot gas
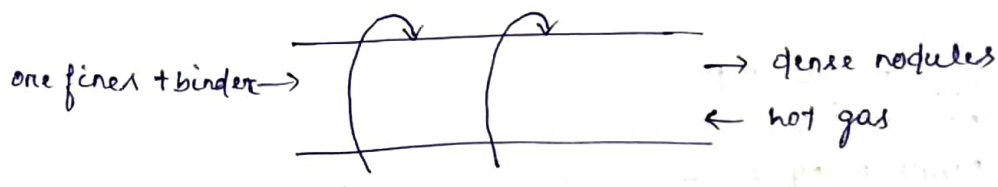
c. **Vacuum extrusion: -**
   → Moist ore with or without binder is fed in to a chamber. They are extruded to get cylindrical shape & then they are cut down up to desired length.
   → The product is dried to remove the moisture content before we ignite it in blast furnace.
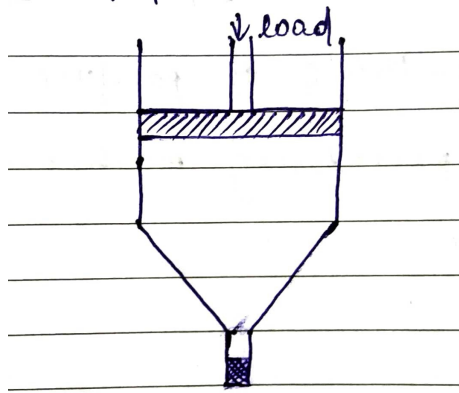
d. **Pelletizing: -**
  → During mining & ore dressing operation large amount of iron ore fines are generated (<0.005mm sized) which can't be used for sintering process because of very low permeability of bed.
  → So, in order to use them for iron making, they are agglomerated by rolling them up with presence of moisture & suitable adhesives. This process is known as green ball formation.
  → Pelletisation is a process that involves mixing of very finely ground particles of iron ore size (<0.05mm) with flux such as lime stone dolomite etc. & binding material like water & bentonite.
  → This mixture is mixed thoroughly & moisture percentage is generally adjustable around 10%. The mixture is then converted into green ball, if size 8-2mm in pelletiser machine.
  → These green balls are then dried, preheated & fired at temperature at 1250-1350°C to produce pellets. There are 2 types of pelletising machine-
    ▪ Disk pelletiser
    ▪ Drum pelletiser.

e. **Sintering: -**
  → About 65-75 % of iron ore gets converted into fines (-5mm) during various operations from mining to conversion of blast furnace feed.
  → Sintering is the most widely used method for agglomeration of these fines to make them useful for blast furnace are sintering & palletisation.
  → Sintering is essentially a process of heating a mass of fine particles to the stage of incipient fusion for the purpose of agglomeration them into lumps.
  → Sinter is typically a limp mass of size 5-40 mm made from ore fines below 10 mm in size (ideal size of iron ore for sintering is 0.07-10mm).

**Objective of sintering: -**

- ➢ To increase the size of ore fines to a level acceptable for use in blast furnace.
- ➢ To form a porous & strong agglomerate.
- ➢ To remove volatiles like CO_2 from carbonates, S from sulphides.
- ➢ To incorporate flux into the sinter.
- ➢ To increase the blast furnace output & decrease the coke rate.

Principle of sintering: -

A. Iron ore sintering is carried out by putting a mixture of iron bearing fines mixed with solid fuels on a permeable bed. The top layer of sinter bed is heated upto the temperature of 1200-1300°C by a gas or oil burner (external source).

B. The combustion zone initially develops at the top layer & travel through the bed rising the temperature layer by layer to the sintering level. The cold blast drawn trough the bed cools the already sintered layer & get itself heated.

C. In the combustion zone, bonding takes place between the grains & a strong & porous aggregate is formed. The process is over when the combustion reaches the lower layer of the bed. Then get screened and under sized sinter is recycled &oversized is sent to blast furnace.

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Situation of sintering box after few minutes of imagination: -
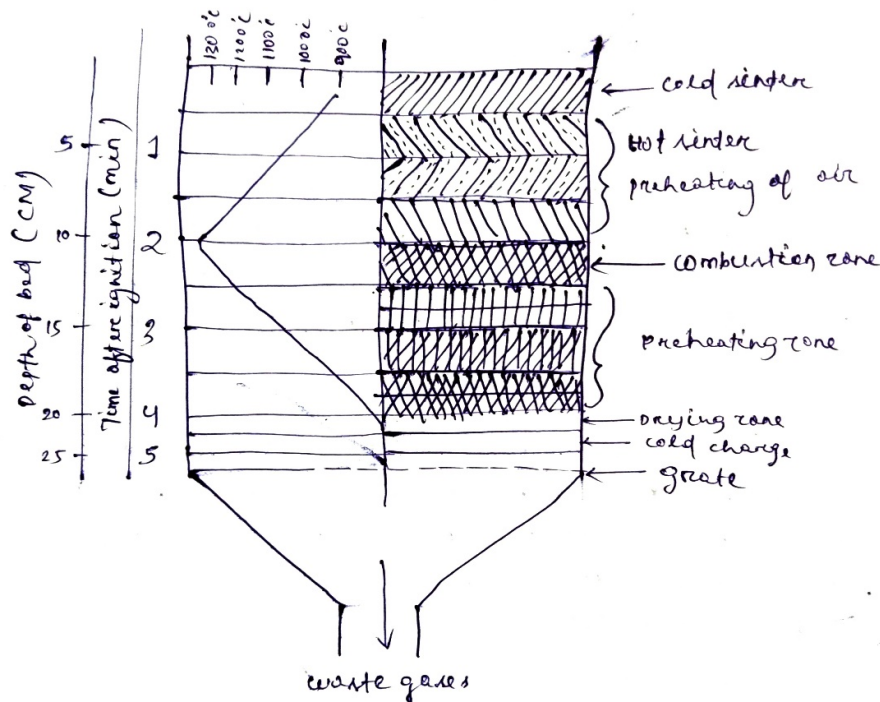
Mechanism of sintering: -

2 types of bonds are formed during sintering.

1. *Diffusion / Re-crystalline / solid state bond*   2. *Slag / Glass bond*
1. *Diffusion / Re-crystalline / solid state bond*: -
   It is formed as a result of re-crystallisation of the parent phase at the point of two particles in solid state & hence the name.
2. *Slag / Glass bond*: -
   It is formed as a result of formation of low melting slag or glass at the point of contact of 2 particles depend upon the material constitution, flux addition etc.

Variable in sintering process: -

a) An increase in particle size increase bed permeability & the volume of the air drawn.
b) Strength of sinter gets reduced with an increase in particle size of the ore due to reduction in contact area.
c) For effective sintering, the use of larger ore lump is undesirable. Iron ore >10mm is rarely preferred.
d) Higher portion of -100# size fines adversely affects the bed permeability.

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4.0 Blast Furnace Fuel :

4.1 Function of coke

COKE

Coke is the universal fuel used in blast furnace. It acts both as a reducer as well as a supplier of heat. It also comprises the major portion of iron production coal.

The function of coke in blast furnace is fivefold. Namely-

$\Rightarrow$ It acts as a fuel by providing for the thermal requirements in the furnace, the reaction being- $2C + O_2 \rightarrow 2CO$; ΔH = -2700 Kcal/Kg

$\Rightarrow$ It provides CO for the reduction of iron oxide.

$\Rightarrow$ It reduces the oxides of Mn, Si, P & other if present.

$\Rightarrow$ It carburises the iron & lowers it melting point.

$\Rightarrow$ It provides permeability (in the dry as well as wet zone) & also mechanical support to the large charge column permitting the gases to ascend through the voids.

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4.2 Quality requirement of coke

Quality requirement of coke: -

Efficiency of blast furnace directly depends on the permeability of the charge in the furnace & which in terms depends on the quality of coke. The properties which a blast furnace coke should have are –

1. Coke size: -
   - The coke size is important as it provides permeability in the dry as well as in the wet burden.
   - The optimum size range for coke is 40-80mm.
   - Since the coke size becomes smaller as it descends through the blast furnace due to mechanical breakdowns, gasification etc. the factor of prime importance is the strength of coke.

2. Coke strength & abrasion resistance: -
   - It is the quality that prevents the coke from collapsing & tends to avoid the formation of small particles.
   - On the basis of breakage by impact, compression or abrasion the coke strength should be ascend both at ambient as well as high temperature.
   - It should withstand high compressive force at high temperature in all important lower furnace.

3. Chemical composition: -
   - The fore most component of coke as its fixed carbon content because carbon acts as a fuel reducing agent in blast furnace.
   - Apart from fixed carbon other components of coke are VM, Ash & Moisture.
   - The coke ash mostly constitutes of SiO_2, Al_2O_3, CaO, P, S etc. most of the sulphur directly goes in to hot metal where as the refractory oxides directly goes in to blast furnace slag. Some amount of P & Si gets dissolved in hot metal.
   - An increase in ash content increase the coke consumption & decrease productivity.

4. Coke reactivity: -
   - It is the rate at which carbon atoms of coke reacts with oxidising gases like O_2, H_2O, CO_2 etc.
   - A high reactive coke may react with ascending gas in the upper part of blast furnace & lose its strength & a low reactive coke may take longer time to get burnt in front of tuyeres.
   - There are 2 properties which measures the reactivity of coke –
     - ➢ CRI (coke reactivity index)
     - ➢ CSR (coke strength after reaction).
   - Reactivity of coke mainly depends upon area exposed, temperature of blast (hot air), affinity of carbon towards oxidising gases.

5. Thermal stability: -

- This property of coke refers to resistance due to thermal stress. Larger the size of coke more the chance of degradation due to thermal process.

4.3 Preparation of B.F. fuel in India

Preparation of blast furnace fuel: -

➢ Coke is produced by heating coking coal at a temperature of 1100°C in absence of air (carbonisation).

➢ When coking coal is heated in absence of air the coal mass fuses, particles joint together & produce a compact mass.

➢ This whole process is carried out in coke oven. Coke oven plant is consisting of coke oven batteries containing numbers of oven (around 65 ovens in each battery).

➢ The coal is charged through charging holes & then carburized for 18-20 hrs during which VM of coal is removed and coke oven gas is sent to the recovery section for recovery section for recovery of valuable chemicals.

Parameters	Coal value in %	Coke value in %
Moisture	6-7 %	3-5 %
Ash	15-16 %	12-15 %
Volatile matter	22-25 %	<1 %
Sulphur	0.65 %	0.65 %
Fixed carbon	58-60 %	80-85 %

Process Layout of coke oven: -
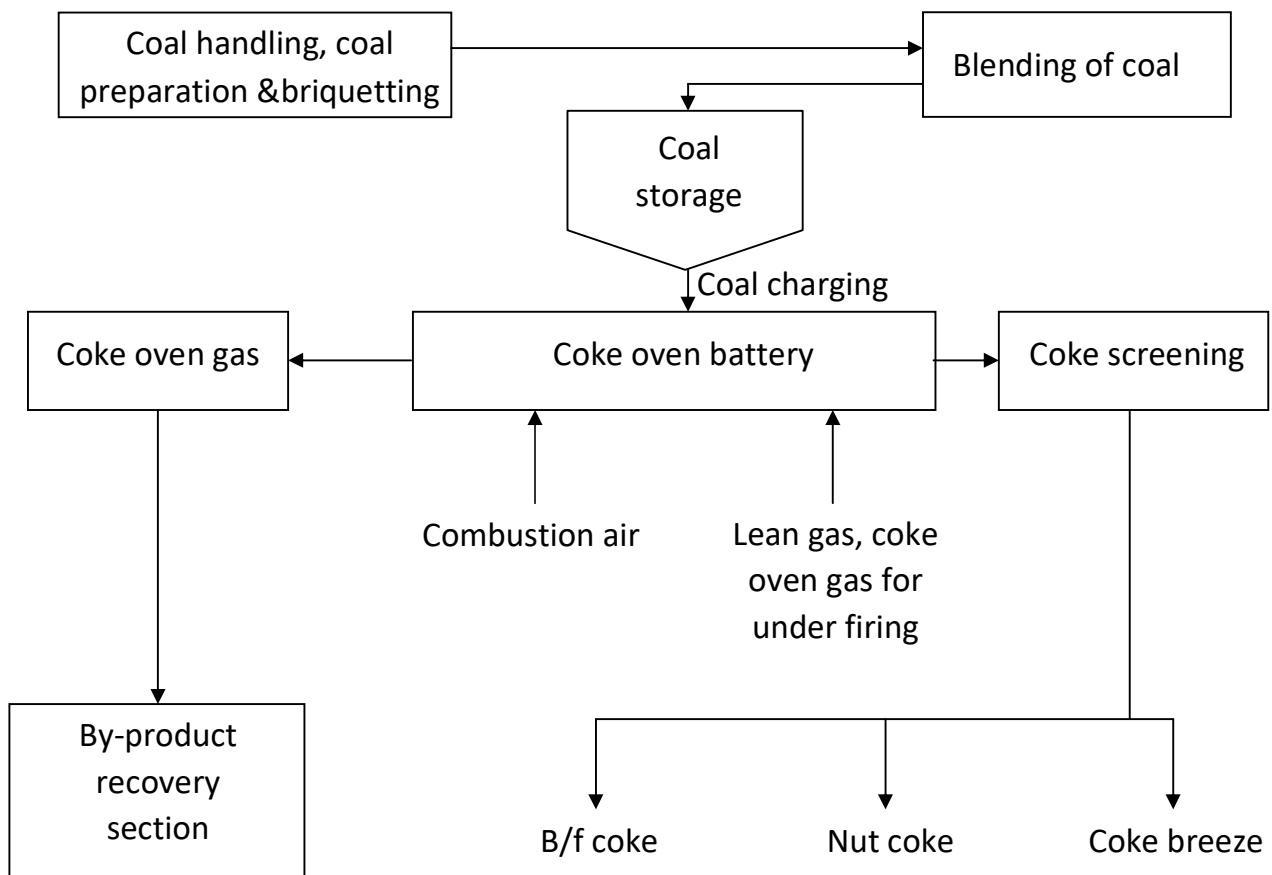
There are three type of oven-

1. Beehive coke oven
2. Recovery coke oven: - the recovery coke oven collects the valuable by products like tar, sulphur, coke oven gas, crude benzol, ammonium etc.
3. Non-recovery coke oven: - volatile matters evolved during coal carbonisation are not recovered as by product but are combusted in the oven itself in the presence of controlled quantity of air.

4.4 Auxiliary fuels

4.5 Fuel Injection

4.6 Factors affecting fuel consumption in blast furnace

6.0 Blast furnace Accessories :

Blast Furnace Plant & process: -

Modern blast furnace consists of the following sections in order to work properly.

⊙ Blast furnace
⊙ Hot blast supplying unit (stoves)
⊙ Gas cleaning plant (GCP)
⊙ Raw material handling plant
⊙ Liquid product disposal
⊙ Process control unit

A modern blast furnace producing 3000 T/day usually has a height approx. 30m (100ft).

Hearth diameter – 8-9m   Hearth height – 3-3.5m
Bose diameter – 9-10m   Bose height – 3-4m
Stack height –18-20m   Stack angle – 85⁰-87⁰
Throat diameter – 5.5-6.5m   Working height – 21-24m
Useful height – 30-32m

Furnace details: -
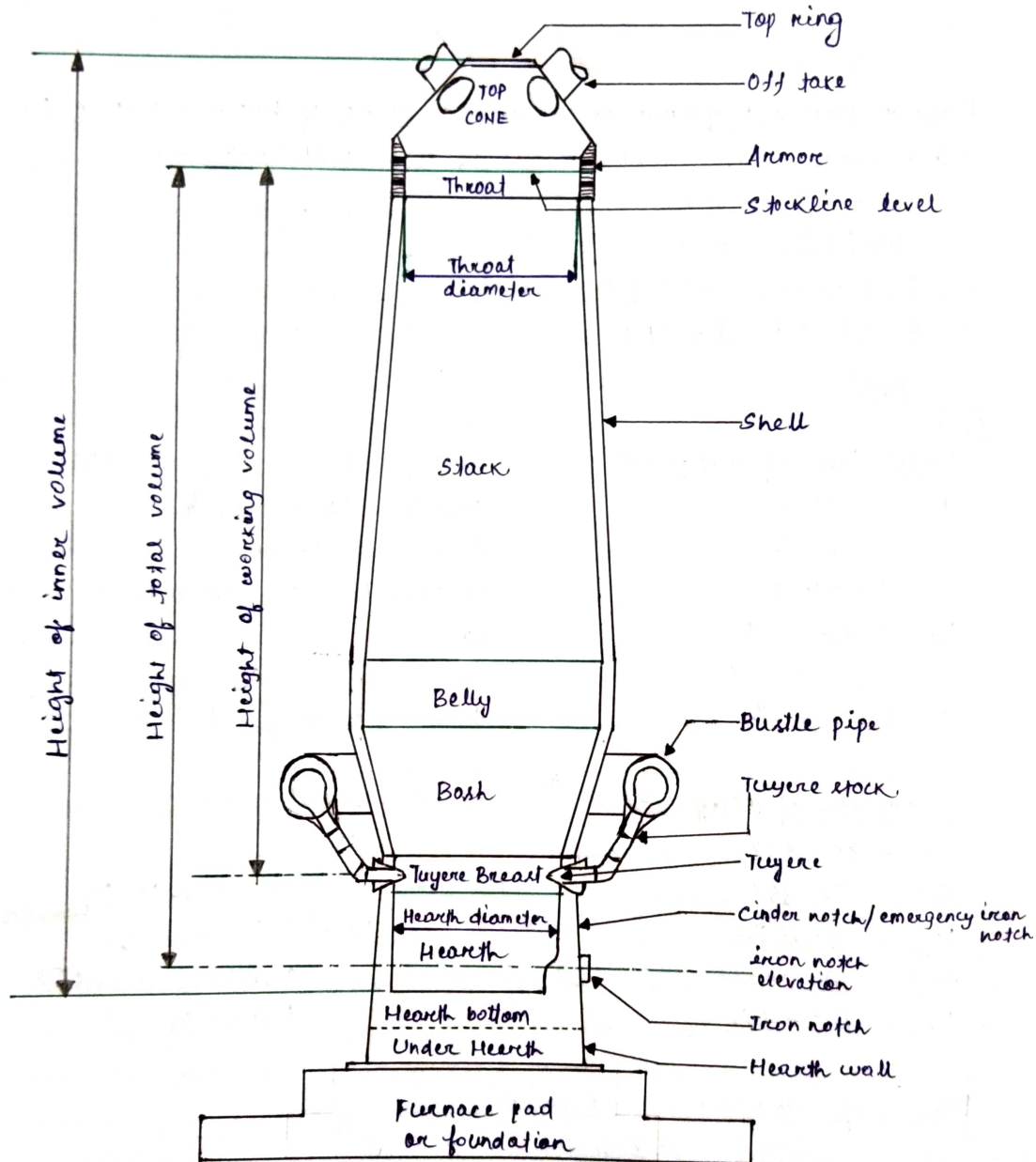
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- **Foundation: -**
  - ➤ It is a massive steel reinforced concrete structure partially embayed below the ground. It should be sufficiently strong enough to with stand the loaded furnace weight, which may be as much as 10000T for a 2000TPD furnace.
- **Hearth: -**
  - ➤ It is the reservoir/storage in blast furnace where entire charge is in liquid state. In this section of the blast furnace, slag & metal separated into 2 different layers.
  - ➤ The walls of hearth are parallel & it has smallest cross-sectional area in blast furnace. In hearth wall, a tap hole is there of 12-15cm diameter & about 0.3-

0.6m above the hearth bottom level is there for discharge/tapping of hot metal.

  ➢ And a slag notch at 1.2-1.6m above the iron notch & at a right angle from iron notch.

- **Bosh: -**
  ➢ In this region of blast furnace, melting of burden takes place except coke. The gangue & flux combine to form slag. The furnace wall in this region are parallel and then tapered.

- **Tuyere: -**
  ➢ Immediately above the hearth, tuyere is present through which hot blast is blown for combustion of fuel (coke).
  ➢ The number of tuyeres varies with the size of furnace and usually there are always even nos. of tuyeres are present.
  ➢ Tuyeres are present uniformly all over the periphery. By the time, the charge runs down to tuyere except coke all are in liquid state.
  ➢ The oxygen from hot blast burns the coke in front of tuyere. Maximum temperature in blast furnace is produced at the tuyere known as RAFT (raceway adiabaticflame temperature).
  ➢ Air from hot blast stove is supplied to a huge circular pipe circulating the furnace at bosh level. This pipe is called bustle pipe which equalise the pressure of blast in each tuyere.

- **Stack: -**
  ➢ This extends from stock line to the bosh parallel. The charge gets heated from 200°C at stock line level to nearly 1100-1200°C at bottom of stock.
  ➢ In order to ensure freefall of the charge material, since it expands with increase from top to bottom mush of the iron oxide reduction occurs in stack.

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Working of Blast furnace: -

In the blast furnace solid material like iron bearing material, coke & flux charged from the top of the furnace & hot air blast is blown through tuyeres from bottom of furnace.

The oxygen of hot blast combines with carbon of coke & generates heat &CO gas. The gas phase containing mostly CO, N_2 ascends upward through the charge which reduce & extract heat from gas.Finally, the charge melts, results in metal & slag.

Therefore, Blast furnace is a counter current reactor.

BLAST FURNACE ACCESSORIES

6.1 Blast furnace refractories

Blast furnace refractory: -

Between the outer shell wall & inner working volume of the furnace, there is a thick lining of refractory is present. This lining protects the outer shell & also reduce the heat loss by the thermal conduction.

Refractory: - It is a type of mineral having high melting point & poor thermal conductivity.

For a longer campaign life (time period between re-lining) good & appropriate refractory should be used. In blast furnace, different regions are lined with different types of refractories depending upon the requirement & working condition.

6.2 Stack lining :-

6.4 Hearth walls :-

6.5 Bosh lining:-

- **For Stack**
  In stack region the refractory lining has to withstand abrasion by moving charge as well as attack by CO gas.
  In upper stack region ordinary fire clay bricks containing 40-45% Al_2O_3 are used where as in lower stack region high duty fire clay containing 60% Al_2O_3 is used.
- **For Bosh**
  In bosh region, the lining has to deal with high temperature, attack of alkali, liquid slag & also erosion by ascending gases.
  Refractory bricks used in bosh region are high duty or super duty fire clay containing 60% Al_2O_3 is used.
- **For Hearth**
  Hearth has to deal with the molten metal & slag. The brick that to be used in hearth should have better thermal conductivity than fire clay.
  Carbon bricks are used as lining in hearth region. These bricks have better thermal conductivity & they provide a clean surface to the molten metal. But these carbon bricks are costly than fire clay.

<div align="center">Lecture-20</div>

6.13 Charge hosting appliances
6.14 Top charging system

Charging system in blast furnace: -

There are two types of charging systems are available for charging of raw material in to the blast furnace. Those are-

A. Double bell charging system: -
   The furnace charging in 2 bell charging system is done in 4 steps;
   i. Step-1: - The charge material is taken to the furnace top by a skip car or by a conveyer belt & is delivered to the receiving hopper. Small bell & large bell both are in closed condition. The charge materials from skip or conveyer are dumped in to the hopper above the small bell. Gas flowing from top of the furnace through uptake located in the dome (top cone).
   ii. Step-2: - With closed large bell, the small bell lowered & the charge material is dropped on the large bell.
   iii. Step-3: - The small bell is closed to prevent escape of gas to atmosphere. The large bell is lowered & the charge material is discharged into the blast furnace.
   iv. Step-4: - Both the bells are closed & the system is ready for repeat charging.

B. Bell less top charging system: -
   This is a unique design in which large bell is replaced by a distributer chute with 2 hoppers. A rotating chute is provided inside the furnace top cone.
   ADVANTAGES: -
   - Greater charge distribution flexibility.
   - More operational safety & easy control over varying charging particles.
   - Less wearing parts; easy maintenance.

Lecture-21

6.16 Gas cleaning plant

Gas cleaning plant (GCP): -

- Composition of blast furnace gas is CO (20-30%), CO_2 (10-20%), N_2 (55-60%).
- Its calorific value is about 900 Kcal/NM^3.
- The outgoing gas from the furnace can't be directly used as a fuel since a substantial quantity of dust from the burden is also discharged along with it.
- The gas is therefore cleaned before its use.
- The uptakes & the down-comer are steel pipes & are lined from inside with refractory bricks. The sizes of the off takes & down-comer and the angle of their joints are such that the gas flows out of the furnace smoothly without any hinderance.
- A bleeder valve is a safety device, which opens automatically or opened to release extra pressure developed inside the furnace & there by eliminate the danger of explosion.
- The average dust content may vary in the range of 7-30 gm/m^3. In general, cleaning is carried out in 3 stages i.e. coarse, semi fine & fine cleaning.

- The coarse cleaning is done in dust catchers & cyclone separators in dry conditions. The dust content of the coarse cleaned gas is nearly about 3-5 gm/m^3.
- The semi fine cleaning is carried out in scrubber, ventury washers, cyclone separators, centrifugal dis-integrators, feld washer or even in electro static precipitators. The dust content is there by reduced to 0.5-1.5 gm/m^3.
- The fine cleaning is carried out mainly by electrostatic precipitators. The dust content is there by reduced down to 0.01 gm/m^3.
- The semi fine & fine cleaning is carried out either in wet or dry condition. Wet methods are generally preferred more than dry methods for their better efficiency & smooth working.

<div align="center">Lecture-22</div>

6.17 Blast furnace stoves

Hot blast stove: -

- It essentially consists of a tall cylindrical structure comprising of a combustion chamber and heat regenerator unit of checker bricks.
- The clean blast furnace gas is burnt in the combustion chamber & the hot products of combustion later heat up the checker bricks. In this case the stove is said to be *"on gas"* & is maintained *on gas* un-till the checker bricks are heated to a certain temperature.
- Firing is stopped & cold air is passed through checkers which impart the heat sorted in them & there by produce preheated blast. The stove is said to be *"on blast"*.
- It can continue heating the blast till a certain minimum temperature of blast is obtained. The stove is again put in *on gas* & the cycle is repeated.
- In practice, the stove may be *on gas* for 2-4 hrs & *on blast* for 1-2 hrs for an un-interrupted steady supply of blast at a specified temperature.
- Therefore, a battery of at least 3 stoves is necessary. A 2-stove system is quite un-satisfactory & hence, 3 or 4 stove system is preferred.
- The checker bricks have to absorb maximum heat at faster rate while heating & should desorb heat equally & rapidly to the incoming cold air.
- The larger the weight of the bricks, the more will be its heat storing capacity. The larger is the surface area exposed as flues the faster is the heat exchange with the gas.

<div align="center">Lecture-23</div>

6.6 Blast furnace cooling arrangement
6.7 Shaft coolers
6.8 Hearth & bosh coolers

6.9 Tap holes and top hole drilling machine
6.10 Cast house

6.11 Tuyeres assembly

6.12 Raw materials section/Stock House

5.0 Blast furnace Operation

BLAST FURNACE OPERATIONS

5.1Charging methods and process

There are two types of charging systems are available for charging of raw material in to the blast furnace. Those are-

C. Double bell charging system: -
   The furnace charging in 2 bell charging system is done in 4 steps;
   v.   Step-1: - The charge material is taken to the furnace top by a skip car or by a conveyer belt & is delivered to the receiving hopper. Small bell & large bell both are in closed condition. The charge materials from skip or conveyer are dumped in to the hopper above the small bell. Gas flowing from top of the furnace through uptake located in the dome (top cone).
   vi.   Step-2: - With closed large bell, the small bell lowered & the charge material is dropped on the large bell.
   vii. Step-3: - The small bell is closed to prevent escape of gas to atmosphere. The large bell is lowered & the charge material is discharged into the blast furnace.
   viii. Step-4: - Both the bells are closed & the system is ready for repeat charging.

D. Bell less top charging system: -
   This is a unique design in which large bell is replaced by a distributer chute with 2 hoppers. A rotating chute is provided inside the furnace top cone.
   ADVANTAGES: -
   -   Greater charge distribution flexibility.
   -   More operational safety & easy control over varying charging particles.
   -   Less wearing parts; easy maintenance.
       -
       -
       -
       -

i. **5.2 Blowing in: -**
   The process of starting a newly constructed blast furnace is called blowing in. it mostly consists of 3 steps –

   - **5.3 Drying: -**
   Newly constructed blast furnace or newly lined blast furnace contains significant amount of moisture. This moisture should be removed completely before the temperature of furnace is raised. This process is known as drying. It is done by supplying pre heated air (hot blast) in to the furnace from the stove.

   - **5.4 Filling: -**
   After drying the furnace completely, the furnace is filled with various materials. The hearth is filled with wood, then above its coke is filled along with some flux up to the bosh region or higher. This whole process is called filling.

   - Lightening: -
   In this process a hot rod is inserted into the furnace through the tap hole & start ignition.

ii. **5.5 & 5.7 Blowing out / Blowing down: -**
   The process of stopping a blast furnace operation when the furnace refractory lining become wared out is known as blowing out.
   This process is started by stopping the raw material charging into the furnace & then completely emptying the furnace.

iii. **5.8 Tapping: -**
   The hot metal & slag are removed from the furnace periodically through tap hole when the furnace is in running condition. The time interval of tapping depends upon the furnace production rate.

iv. **5.9 Fanning: -**
   It is the process in which the hot blast volume is reduced up to 25% of the normal value. It is done to reduce the production rate of the blast furnace.

v. **5.6 Banking: -**
   Shutting down the blast furnace for few days. The blast is taken off, the blow pipe are removed & tuyeres are plugged with clay to prevent air to enter into the furnace. Thus, hearth heat is pressured & the furnace can be returned to normal operation with minimum effect.

vi. **5.10 Back draughting: -**

Taking off the blast from the furnace for few hours (short period) to perform various maintenance of breakdowns.

vii. **5.11 & 5.12   Slag granulation & utilisation: -**
The molten slag coming out from the blast furnace is quenched by high pressure water jet to get fine granules of slag particles. This process is called slag granulation. Granulated slag is used in cement factory as a raw material.

7.0 Blast Furnace irregularities and Remedies :

BLAST FURNACE IRREGULARITIES & REMEDIES

1. **7.1   Hanging: -**
When uniform descend of burden is interrupted by any means, it is known as hanging. It can be due to –
   → Solidification of previously fused slag.
   → Formation of bridging inside the furnace.
   → Lack of permeability.
   → Excessive blast pressure.
   → Insufficient batter in stack wall.

   REMEDIES: -

   ⇒ Adding lime stone into the furnace.
   ⇒ Reducing the blast pressure.
   ⇒ Adding extra coke or blank coke.

2. 7.2 **Scaf-folding: -**
   → A scaf-folding is a large mass of material that gets stuck to the furnace wall as a single block.
   → It occurs at the top portion of the bosh.
   → It results in decreasing the furnace cross-sectional area & interrupt in smooth movement of the burden.
   → It is formed due to condensation of alkali vapours onto the refractory bricks through which ore particle stick & forms a large mass.

   REMEDIES: -

   ⇒ Decrease alkali content in the raw material.
   ⇒ Decrease refractoriness (melting temperature) of slag. (previously formed during sintering).
   ⇒ Shut off blast for some time.

⇒ Addition of extra coke to produce more heat & melt down the solid mass.

⇒ Increasing addition of quartzite in flux which makes the slag more siliceous.

3. 7.3 **Slip: -**
→ It is defined as sudden sinking of burden in the furnace.
→ It could be due to collapse of hanging or scaf-folding.
→ It can result in chilling hearth.

REMEDY: -

⇒ Allowing the furnace to slip on its own by adjusting blast temperature & pressure.

4. 7.4 **Chilled hearth: -**
→ It is defined as the sudden decrease in temperature in the hearth region.
→ It could be due to low coke rate, slip or increase in moisture content in hot blast.
→ It adversely affects the tapping of metal.

REMEDY: -

⇒ Increase the fuel rate & hot blast temperature.

5. 7.5 **Pillaring: -**
→ If the blast is unable to penetrate to the centre of the furnace, it will lead to formation of a cold column at charge material. It is called pillaring.

REMEDY: -

⇒ Pillaring can be eliminated by increase the hot blast pressure which will penetrate more & heat up the pillar.

6. 7.6 **Breakout: -**
→ Flow out of liquid slag & metal in an uncontrolled manner from the furnace wall is known as breakout.
→ It is basically due to the failure of refractory lining in bosh or hearth region.

REMEDY: -

⇒ Minimize the joint area between refractory bricks & use of carbon bricks in hearth region.

7. 7.7 **Choking of gas uptakes: -**
→ Accumulation of dust particles in gas uptakes & down-comer results in chocking as the path of blast furnace gas is blocked.

→ It may be due to faulty design or high quantity of fines in raw material.

8. 7.8 **Channelling: -**
   → Preferential flow of gases through certain areas of the burden is termed as channelling.
   → This occur due to better permeability in some part of the burden.
   → This arises because of improper distribution & wide size range of the charge in the furnace.

   REMEDIES: -

   ⇒ Decrease productivity by decrease in gas-solid interaction.
   ⇒ Use of uniformly sized burden & proper distribution of burden can minimize this.

9. 7.9 **Leaking tuyere, tap hole, coolers: -**
   → Leakage in any cooling system will result in higher coke rate & will decrease the refractory life.

   REMEDY: -

   ⇒ Leakage part should be rectified or replaced instantly.

10. 7.10 **Flooding & coke ejection through tap hole: -**
    → In bosh, liquid slag & metal trickle through the permeable coke bed against the ascending gas.
    → Liquid metals & slag gets accumulated in the gap present in between coke when the weight increases such that it can overcome the pressure of hot gases, it descends suddenly into hearth. This is called flooding.
    → Due to this sudden fall of liquid substance into the hearth, some coke pieces are also get felled into the hearth & which are comes out from the furnace with the hot metal during tapping. This is called coke ejection through tap hole.

    REMEDY: -

    ⇒ Choosing better mean size of coke.
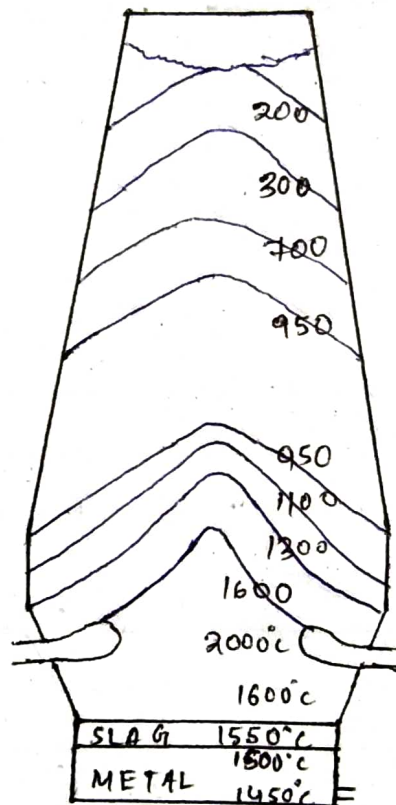
8.0 Chemistry of Blast Furnace operation :

CHEMISTRY OF BLAST FURNACE

8.1 Blast furnace profile

8.2 Thermal, physical and chemical profile

Thermal profile of the blast furnace: -

- ➲ Reduction of iron oxide is a high temperature process & the thermal requirement of the process are met by burning of coke, hot blast & fuel injection (if any).
- ➲ Maximum temperature of around 2000°C is generated in front of tuyeres where hot blast burns coke.
- ➲ The temperature generated decreases either side of tuyere. The exhaust blast furnace gas temperature is around 200°C & hearth around 1350-1500°C.

8.3 Physical chemistry of blast furnace process

Reduction of iron oxide: -

$Fe_2O_3 \rightarrow Fe_3O_4 \rightarrow FeO \rightarrow Fe$
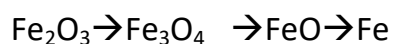
(Haematite) (Magnetite) (Wustite) (Pure Iron)

8.9 Direct & indirect reduction

Reduction of iron oxide can occur in two ways;

1. **Direct reduction: -**
   - ✎ The reduction of iron oxide by solid carbon is known as direct reduction.
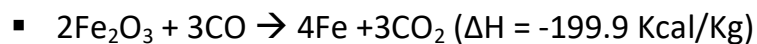   - $Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$ ($\Delta H = 73$ Kcal/Kg)
   - ✎ This reduction reaction is endothermic in nature. So, it will absorb / require heat to occur.
   - ✎ 0.23 Kg of C is required to produce 1 Kg of Fe from Fe_2O_3 & 656 Kcal of heat is absorbed.
2. **Indirect reduction: -**
   - ✎ The reduction of iron oxide by CO & H_2 is known as indirect reduction.
     - $2Fe_2O_3 + 3CO \rightarrow 4Fe + 3CO_2$ ($\Delta H = -199.9$ Kcal/Kg)
   - ✎ This reduction is exothermic in nature. So, it releases heat as it occurs.
   - ✎ 0.81 Kg of C is required to produce 1 Kg of Fe from Fe_2O_3 & about 1790 Kcal of heat is released.
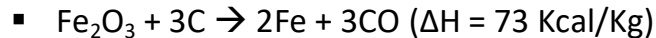
Direct reduction	Indirect reduction
1) Reducing agent is carbon.	Reducing agent is CO & H_2.
1) Carbon is in solid state.	Agent is in gaseous form.
2) Reduction is slow due to solid agent.	Reduction is faster due to gaseous agent.
3) Reaction is endothermic (656 Kcal).	Reaction is exothermic (-1790 Kcal).
4) Coke consumption is less (0.23Kg/T of pig iron).	Coke consumption is more (0.81Kg/T of pig iron).
5) Iron oxide + carbon → iron + CO	Iron oxide + CO/H_2 → Iron + CO_2/H_2O
6) Product is Fe & CO.	Product is Fe & CO_2 / H_2O.

<div align="center">Lecture-38</div>

Carbon-Oxygen reaction: -

Combustion of coke in tuyere zone: -

- ◇ Coke is the only material of the blast furnace charge which descend to the tuyere level in solid state.
- ◇ Coke is the main source of carbon in the blast furnace. Carbon from coke burn with oxygen from the hot blast at tuyere level at a temperature of approximately 1900-2000°C.
- ◇ The reaction of carbon with oxygen includes –
- ◇ Combustion of carbon to CO_2 releases much more heat than conversion to CO.

C-CO$_2$-CO reaction: -

$CO_{2(g)} + C_{(s)} \rightleftharpoons 2CO_{(g)}$ (Boudouard equilibrium reaction).

◇ At high temperature (>700°C) CO is more stable then CO_2. So, CO_2 reacts with the carbon (C) from coke & produce CO. this reaction is highly endothermic reaction & it is called solution loss reaction.

▪ $CO_{2(g)} + C_{(s)} \rightarrow 2CO_{(g)}$
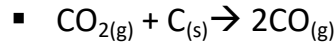
◇ The above reaction occurs at low temperature region of blast furnace.

▪ $2CO_{(g)} \rightarrow CO_{2(g)} + C_{(s)}$
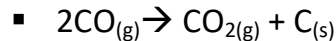
◇ The above reaction is called Naumann reversion / carbon deposition reaction.

◇ The reaction occurs at lower temperature region of blast furnace (upper stack).

◇ The whole equilibrium reaction is called Boudouard equilibrium reaction.

◇ Boudouard's reaction provides reducing agent CO for faster reduction of iron oxide but consumes a lot of heat.

<p align="center">Lecture-39</p>

Physical structure of blast furnace: -

Depending upon the physical structure of raw material in blast furnace, it is divided into 6 zones.

- Granular zone
- Active coke zone
- Stagnant coke zone

- Cohesive zone
- Tuyere zone
- Hearth zone
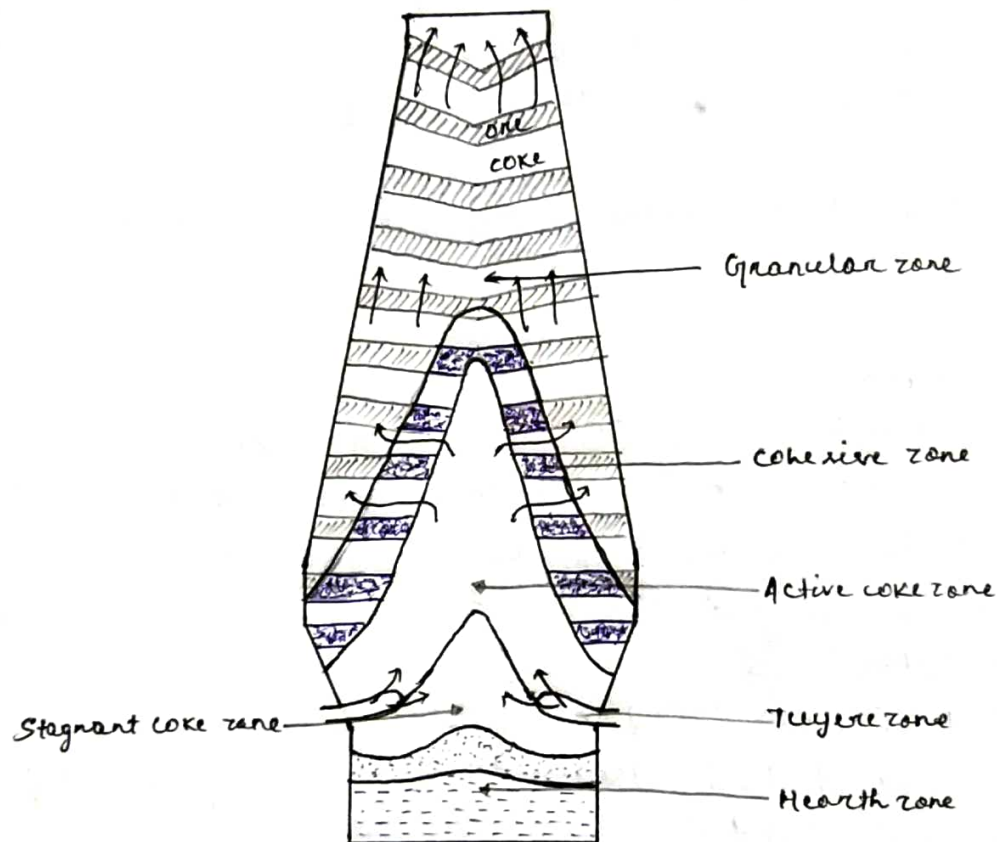
⇒ <u>Granular zone: -</u>
- It is the region in the blast furnace where all the raw materials are in solid state. That is this region represents stack region in the furnace.
- In this zone, preheating (removal of moisture) of raw material & indirect reduction of iron oxide takes place.

⇒ <u>Cohesive zone: -</u>
- In this zone except coke, the rest charge materials are in semi solid / soften state.
- It is the region which separate out the solid state & liquid state of iron bearing material.
- It should be narrow for proper flow of hot gas & it should be present as lower as possible in blast furnace to promote indirect reduction.

⇒ <u>Active coke zone: -</u>
- It is the region where coke activity take part in the reaction involving direct reduction of iron oxide from the primary slag & solution loss reaction.
- This is mainly in bosh region.

⇒ <u>Tuyere zone: -</u>
- It is the zone where coke burns by combining with oxygen from hot blast.

⇒ <u>Stagnant coke zone: -</u>
- It is mostly represents the un-burnt coke that supports overlying burden & through which metal trickles down & pick up carbon.

$\Rightarrow$ <u>Hearth zone: -</u>
   - It is the zone where slag & metal separate out to 2 layers.

Reactions in Blast Furnace: -

Reaction of iron oxide: -

- $\triangleright$ Reduction of iron ore (oxide) with CO (indirect reduction) predominates rather than with solid carbon present in coke until temperature is about 1100^oC.
    - $Fe_2O_{3(g)} + CO_{(g)} \rightarrow 2Fe_3O_{4(s)} + CO_{2(g)}$ [$400\text{-}600^oC$]
    - $Fe_3O_{4(s)} + CO_{(g)} \rightarrow 3FeO_{(s)} + CO_{2(g)}$ [$600\text{-}800^oC$]
    - $FeO_{(s)} + CO_{(g)} \rightarrow Fe_{(s)} + CO_{2(g)}$ [$800\text{-}1100^oC$]
    - $FeO_{(l)} + C_{(s)} \rightarrow Fe_{(l)} + CO_{(g)}$ [$1200\text{-}1800^oC$]
- $\triangleright$ The reason behind predominate indirect reduction is the easy diffusion of gaseous phase CO into the iron ore matrix rather than in solid C atom.
- $\triangleright$ So, the rate of reduction is much higher in case of indirect reduction.
- $\triangleright$ But, for efficient operation of blast furnace we need both direct & indirect reduction reactions to occur. Because indirect reduction produces heat & in case of direct reduction coke consumption is less.

Slag in blast furnace: -

- $\triangleright$ The primary slag in the blast furnace is of relatively low melting point slag which forms at lower part of the stack or in upper part of the bosh.
- $\triangleright$ It mostly consists of FeO, silicate & alumina with some amount of CaO. So, the primary slag is $FeO.SiO_2.Al_2O_3$.
- $\triangleright$ But as the slag descends (comes downward) the iron oxide (FeO) gets reduced by CO & C. Also, with constant dissolution of CaO from lime stone ($CaCO_3$).
    - $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$ [occur at $\approx 900^oC$]
    - $FeO_{(s)} + CO_{(g)} \rightarrow Fe_{(s)} + CO_{2(g)}$
    - $FeO_{(l)} + C_{(g)} \rightarrow Fe_{(l)} + CO_{(g)}$
- $\triangleright$ The slag composition from $FeO.SiO_2.Al_2O_3$ changes to $CaO.SiO_2.Al_2O_3$ along with other minor impurities.
- $\triangleright$ This composition of slag is formed at the bosh parallel region. So, the primary slag is $FeO.SiO_2.Al_2O_3$ but bosh slag is $CaO.SiO_2.Al_2O_3$.
- $\triangleright$ When the slag moves further down towards hearth, more & more CaO from limestone get dissolved into the slag which was not dissolved in bosh region. Also, absorption of coke ash into the slag which is released during combustion takes place.
- $\triangleright$ The basicity of final slag is in between 1.5-2.

8.4 Reactions in tuyere zone

8.5 Reaction in stack

8.6 Reaction in bosh

8.7 Reaction in hearth

Physical chemistry of blast furnace process: -

Two main phenomena that occurs in blast furnace are: -

◇ Reduction of iron oxide by reducing agent (CO or C).
◇ Extraction of sensible heat from the up moving gas thus preheating & eventually melting it.

Reaction in stack: -

⇒ In stack region of blast furnace, preheating of charged raw material occurs followed by predominant reduction of iron oxide by CO gas (indirect reduction) till 1100°C.

⇒ Calcination of lime stone at 900°C & carbon deposition reaction also occurs in stack region.

- $Fe_2O_{3(g)} + CO_{(g)} \rightarrow 2Fe_3O_{4(s)} + CO_{2(g)}$ [400-600°C]
- $Fe_3O_{4(s)} + CO_{(g)} \rightarrow 3FeO_{(s)} + CO_{2(g)}$ [600-800°C]
- $FeO_{(s)} + CO_{(g)} \rightarrow Fe_{(s)} + CO_{2(g)}$ [800-1100°C]
- $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$ [occur at ≈ 900°C]
- $2CO_{(g)} \rightarrow CO_{2(g)} + C_{(s)}$ (carbon deposition reaction).
  On set of slag formation occurs at about 1100°C.

⇒ In order to utilize the full extent of CO gas, the residing time of gas should be higher, however, in practical the gas stays around 1-2 sec inside the furnace. That is why the blast furnace gas coming out from the furnace contains around 20-30% CO.

Reaction in bosh: -

⇒ In bosh region, direct reduction of iron oxide by solid carbon present in coke occurs.

⇒ As the primary slag ($FeO.SiO_2.Al_2O_3$) trickles through the coke bed in bosh region. FeO present in slag comes in intimate contact with coke & get reduced.

- $FeO_{(l)} + C_{(s)} \rightarrow Fe_{(l)} + CO_{(g)}$ [1200-1800°C]

⇒ Besides that, oxides like P_2O_5, Cr_2O_3, SiO_2 & MnO forming part of the slag reduced to some extent.

- $P_2O_5 + 5C \rightarrow 2P + 5CO$
- $Cr_2O_3 + 3C \rightarrow 2Cr + 3CO$
- $SiO_2 + 2C \rightarrow Si + 2CO$
- $MnO + C \rightarrow Mn + CO$

- $CaO + S + C \rightarrow CaS + CO$

Reaction in tuyere: -

$\Rightarrow$ Combustion of carbon in coke by the oxygen from hot blast takes place in front of tuyere.

$\Rightarrow$ The preheated air first reacts with coke in tuyere zone to produce CO_2 which then reacts with more coke outside the tuyere zine to produce CO.

- $C + O_2 \rightarrow CO_2$
- $CO_2 + C \rightarrow 2CO$

Reaction in hearth: -

$\Rightarrow$ In the hearth region slag & metal get separated into 2 layers & various slag metal reaction takes place at the interface between slag & metal.

$\Rightarrow$ Various impurities like C, S, P, Si are get picked up into the hot metal in hearth region.

8.8 Efficiency of B. F. Process

8.10 Silicon & sulphur reaction

8.11 Burden calculation for B/F operation

9.0 Modern Development of Blast furnace operation

MODERN DEVELOPMENT OF BLAST FURNACE

❖ **9.1 Bell less top charging system: -**

This is a unique design in which large bell is replaced by a distributer chute with 2 hoppers. A rotating chute is provided inside the furnace top cone.
ADVANTAGES: -

- Greater charge distribution flexibility.
- More operational safety & easy control over varying charging particles.
- Less wearing parts; easy maintenance.

❖ 9.2 **High top pressure operation: -**

↳ Increase in the furnace top gas pressure is known as high top pressure operation.

↳ It is done by throttling back of the discharge gas by decreasing the outlet opening of scrubber present in scrubber.

↳ Due to high top pressure, an additional cone is connected to lower belt to equalize the pressure between furnace & bell. So that the bell can be opened up easily.

ADVANTAGES: -

- ➤ Increase the productivity as it increases the time of contact between gas & solid.
- ➤ Reduce the coke rate by better utilization of CO gas.
- ➤ Reduce channelling & therefore reduce dust losses.
- ➤ Reduce extent of Boudouard reaction.

Lecture-44

❖ 9.3 **Humidification of blast: -**
  - ↳ Addition of moisture to hot blast deliberately is known as humidification of blast.
  - ↳ It provides additional reducing agent for reduction of iron oxide.
      - • $H_2O + C \rightleftharpoons CO + H_2$ (endothermic)
  - ↳ It decreases RAFT & control it.
  - ↳ For humidification steam is introduced into the cold blast before it is preheated in the stove.

Lecture-45

❖ 9.3 **Oxygen enrichment: -**
  - ↳ Increasing O_2% in hot blast is known as oxygen enrichment.
  - ↳ Due to increase in O_2 percentage, N_2 percentage in hot blast decreases so temperature requirement to preheat gas decreases. Coke rate decreases.
  - ↳ O_2 enrichment increases RAFT.
  - ↳ It increases the production rate by increasing rate of reduction.
  - ↳ But there is a limit up to which O_2 enrichment can be done up to certain extent because heat transfer is also necessary.

Lecture-46

❖ 9.4 **External desiliconisation: -**
  - ↳ External treatment for elimination of silicon from hot metal is known as external desiliconisation.
  - ↳ Reduction silicon content in hot metal by desiliconisation reduces steel making time.
  - ↳ Desiliconisation is generally done in metal runner or in ladle by adding iron oxide.
      - • $Si + 2Fe_xO \rightarrow SiO_2 + 2XFe$

Lecture-47

❖ 9.5 **External desulphurisation: -**
- External removal of sulphur from hot metal before charging in steel making shop is known as external desulphurisation.
- It is done by addition of CaC_2 & Mg into hot metal.
  - $CaC_2 + S + FeO \rightarrow CaS + CO + Fe$
  - $CaO + FeS \rightarrow CaS + FeO$
  - $Mg + S \rightarrow MgS$

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