IRON MAKING

MT410502

Reference Books:

Modern Iron Making by R.H.Tupkary (Khanna Publication)

Iron Making and Steel Making: Theory and Practice, A. Ghosh and A. Chatterjee,

(Prentice Hall)

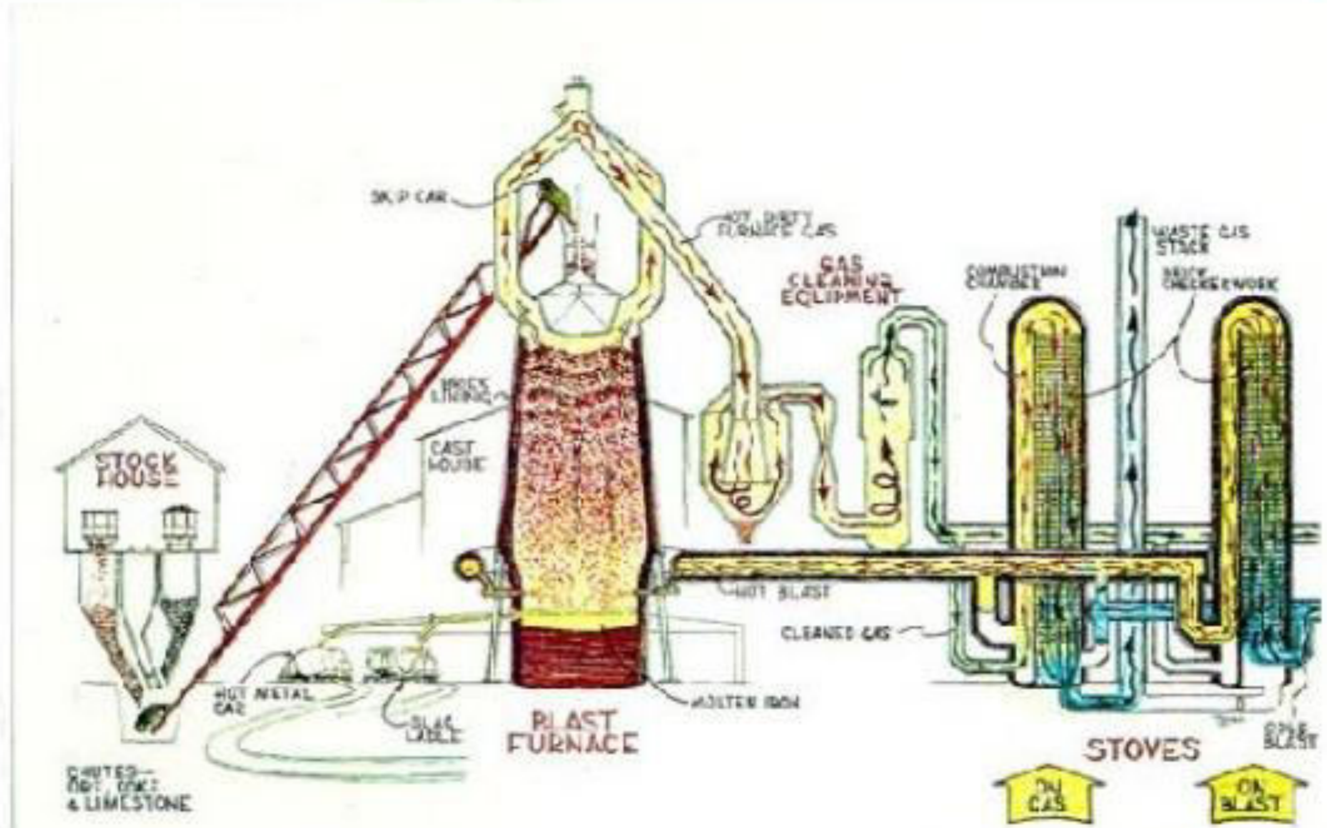
Syllabus:

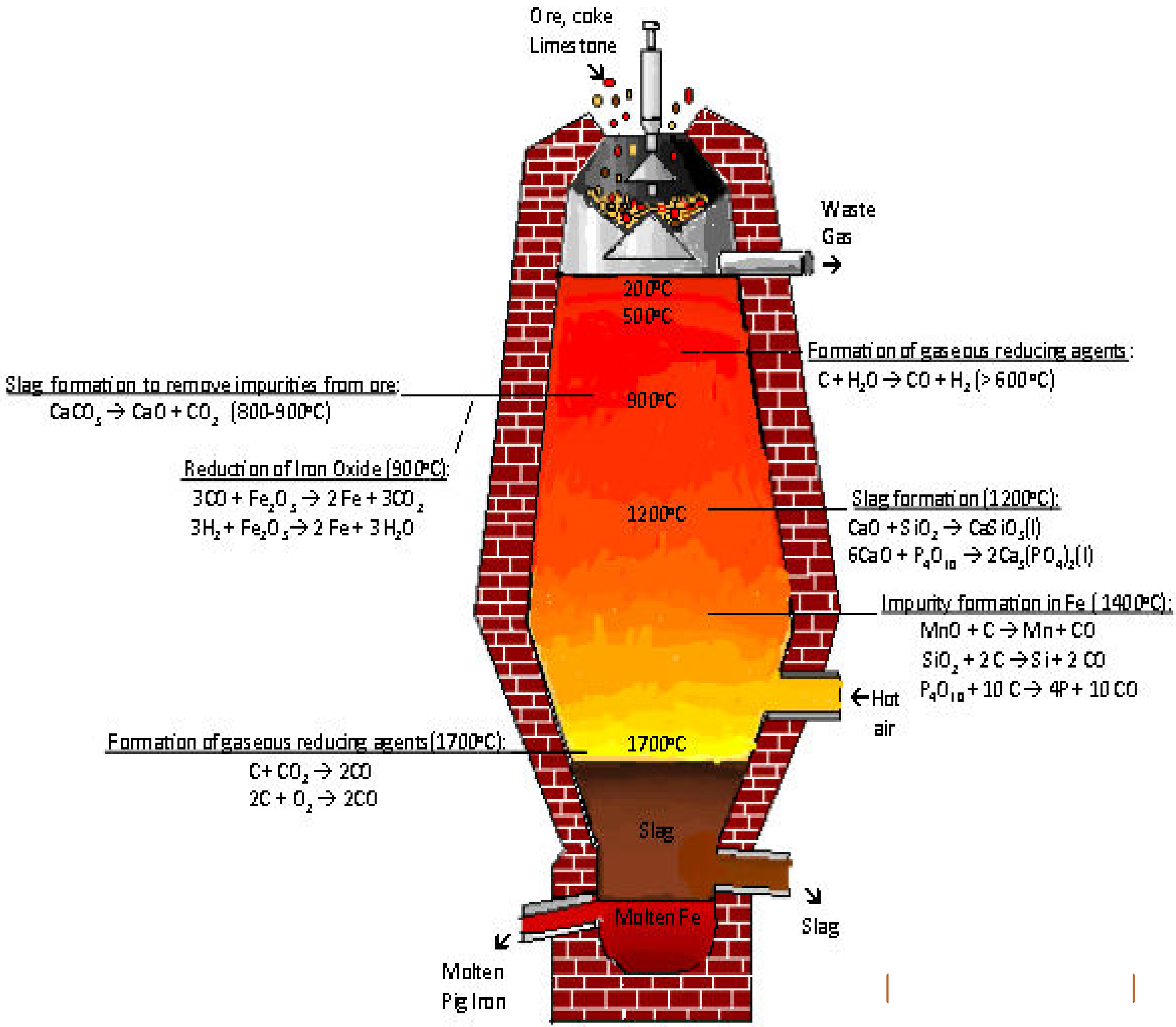
- **Unit – II**
- Blast Furnace (B. F.) Constructional features: Profile, Refractories, Accessories, Charging mechanism, Bell and bell-less charging systems.
- B.F. – Reactions: Physico-chemical principles of blast furnace. Blast furnace reactions. Reaction in stack, tuyere zone, bosh and hearth.
- Thermodynamics equilibria, Direct and indirect reduction. Kinetics of iron-oxide reduction, Slag-metal reactions, Desiliconization, Desulphurization.

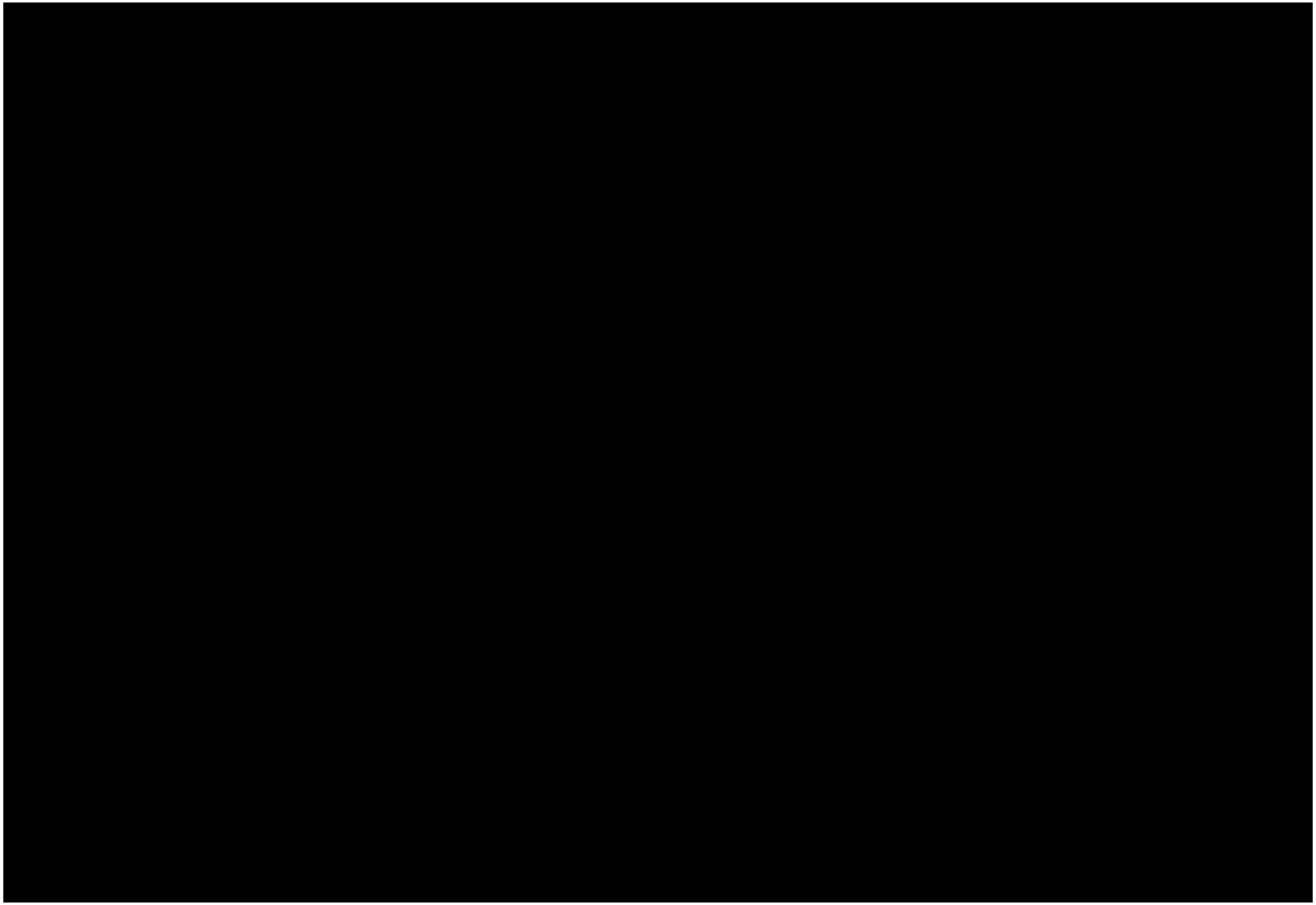
- Modern blast furnace consists of following important sections:
  1) Blast furnace proper
  2) Hot blast supply equipment
  3) Gas cleaning system and gas storage
  4) Raw material storage and handling
  5) Liquid products disposal
  6) Process control equipments

- The modern blast furnace is 30m tall with welded plate construction and varying circular cross section at different levels.
- A furnace producing 2000t of pig iron per day with an effective inner volume in the range of around $2000 m^3$

Schematic Diagram of the Blast Furnace



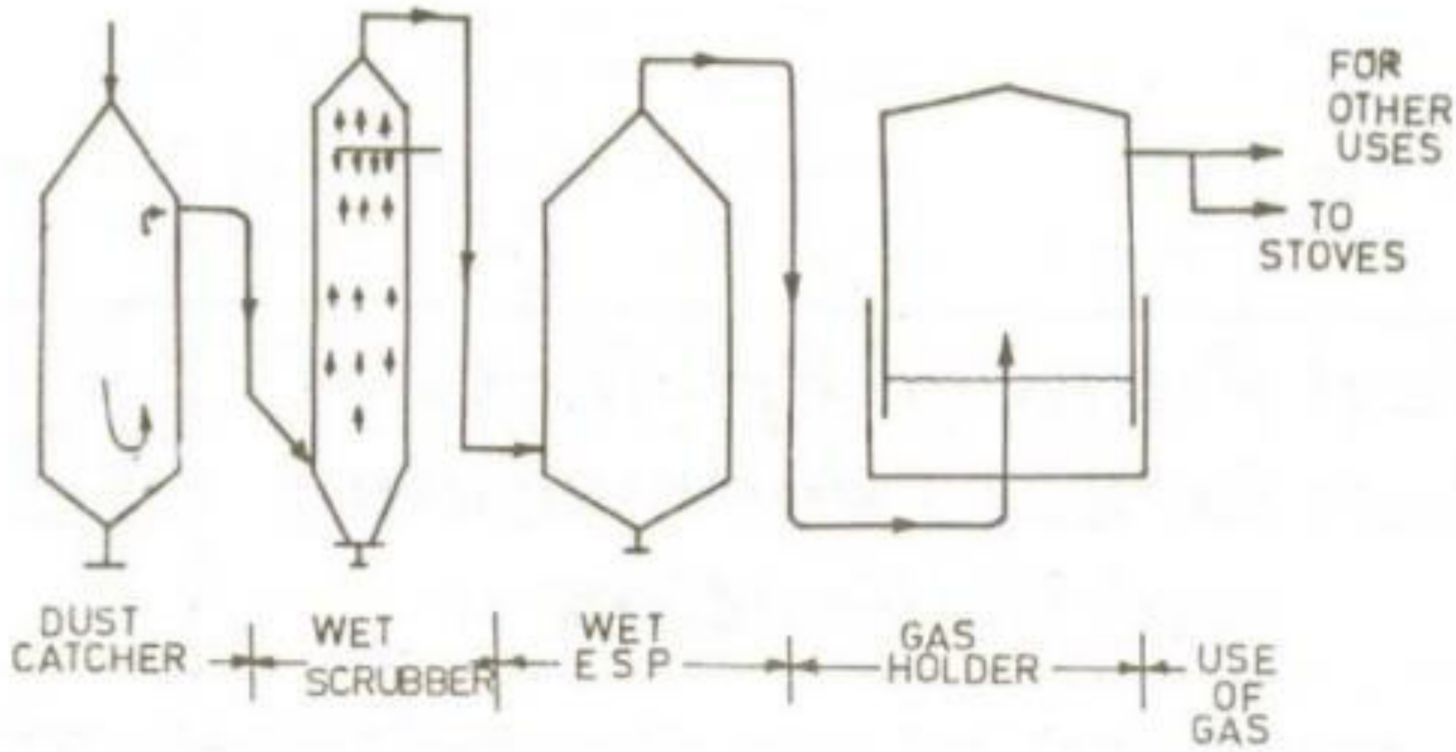

Ore, coke
Limestone
Waste
Gas
200°C
500°C
Formation of gaseous reducing agents:
$C + H_2O \rightarrow CO + H_2$ (> 600°C)
Slag formation to remove impurities from ore:
$CaCO_3 \rightarrow CaO + CO_2$ (800-900°C)
900°C
Reduction of Iron Oxide (900°C):
$3CO + Fe_2O_3 \rightarrow 2Fe + 3CO_2$
$3H_2 + Fe_2O_3 \rightarrow 2Fe + 3H_2O$
1200°C
Slag formation (1200°C):
$CaO + SiO_2 \rightarrow CaSiO_3(l)$
$6CaO + P_4O_{10} \rightarrow 2Ca_3(PO_4)_2(l)$
Impurity formation in Fe (1400°C):
$MnO + C \rightarrow Mn + CO$
$SiO_2 + 2C \rightarrow Si + 2CO$
$P_4O_{10} + 10C \rightarrow 4P + 10CO$
Hot
air
Formation of gaseous reducing agents (1700°C):
$C + CO_2 \rightarrow 2CO$
$2C + O_2 \rightarrow 2CO$
1700°C
Slag
Molten Fe
Slag
Molten
Pig Iron



- Hearth- to collect liquid slag and metal. Lined with carbon blocks.
- Bosh- has max.dia and it is a zone of intense heat.
- Mantle-Furnace structure above the bosh level. Heavily supported by unifromly spaced upright heavy columns, which are firmly anchored in the concrete foundation.
- Stack- Frustum of huge cone mounted on the mantle extending till the top of the stack.

- Tuyeres- Located just above the hearth through which hot air is blown for fuel combustion.
- Bell and Hopper – Also known as cup and cone arrangement. Used for charging the solid charge. For new BF bell-less charging system is preferred. Double bell arrangement ensures charging without leakage of exhaust gases. High top pressure requires several complex seals in the charging arrangement.
- Off takes- Exhaust pipes connected at the top evenly at 4 points.

Scheme of Blast Furnace Gas cleaning system



Why Blast furnace gas cleaning?

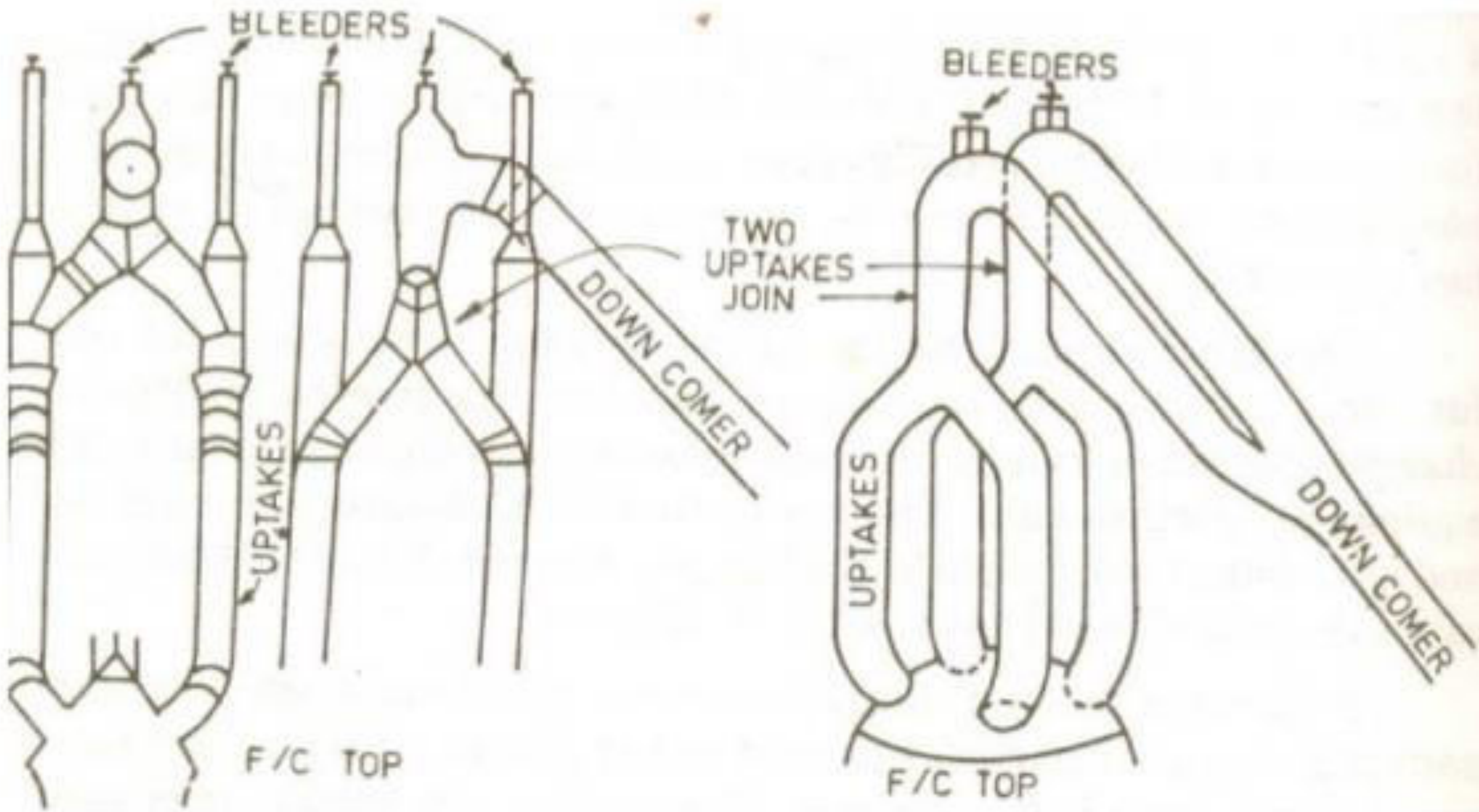
As has been made clear that even the most efficient of the modern blast furnace would produce an effluent gas containing a significant proportion of CO which could not be used for iron oxide reduction. The actual CO content may vary around 20-30% by volume. This has a calorific value of nearly 900 kcal/m^3. The quantity of gas produced depends upon the amount of fuel burnt. For one tonne of coke burnt nearly 4000 m^3 of effluent gas may be produced. Hence a blast furnace requiring 1000 t of coke per day would generate nearly 4×10^6 m^3 of gas with a total energy content of 3600×10^6 kcal which is nearly equivalent to 500 t of coke.

Blast furnace gas cleaning

The effluent gas from the furnace cannot directly be used as a fuel since a substantial quantity of dust from the burden is also discharged along with. It may lead to accumulation of dust and wear in the equipment using the gas. The gas is, therefore, cleaned before its use and in so doing the sensible heat of the gas is invariably lost. The chemi-cal heat of the cleaned gas is what is utilised.

Blast furnace gas cleaning

The average dust content may vary in the range of **7-30 g/m^3**. In general cleaning is carried out in three stages *viz.* **coarse, semi-fine** and **fine cleaning**. The **coarse cleaning** is done in **dust catchers** and **cyclones** in dry condition. The dust content of the coarse cleaned gas is nearly **5-10 g/m^3**. The **semi-fine cleaning** is carried out in **scrubbers**, **ventury washers**, **cyclone separators, centrifugal disintegrators, feld washers** or even in electrostatic precipitators. The dust content is thereby reduced to **0·5-1·5 g/m^3**. **Fine cleaning** is carried out mainly by **electrostatic precipitators** or at times by **high speed rotary disintegrators**, The dust content is thereby reduced down to **0.01 g/m^3** The semi-fine and fine cleaning is carried out either in wet or dry condition. Wet methods are generally preferred to dry methods for their better efficiency and smooth working.

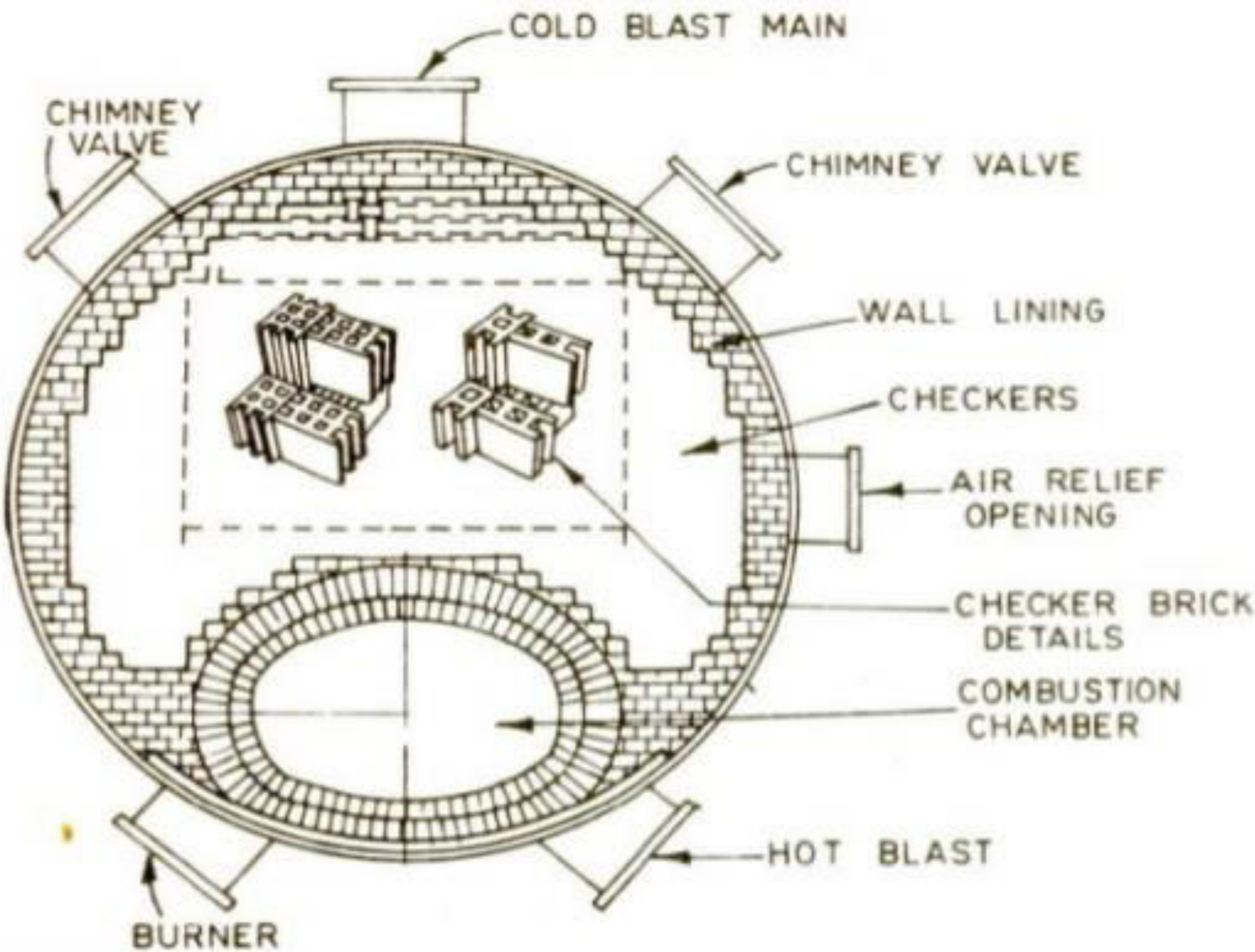

BLEEDERS
UPTAKES
DOWN COMER
F/C TOP
BLEEDERS
TWO
UPTAKES
JOIN
UPTAKES
DOWN COMER
F/C TOP

Uptake, Downcomer and Bleeder

- Two adjacent uptakes are joined together to form one single duct and the two such ducts, thus formed, are connected to form only one duct which carries the gas downwards into the dust catcher. The downcoming pipe or duct is called downcomer.
- A bleeder valve is a safety device, which opens automatically or is opened, to release extra pressure developed inside the furnace and thereby eliminate the danger of explosion.
- The uptakes and the downcomers are steel pipes and are lined from inside with firebricks. The sizes of the uptakes and downcomers and the angle of their joints are such that gas flows out of the furnace smoothly without any hindrance.

Cont…

- The uptakes should be located on the furnace-top periphery at those points which are not directly vertically above the iron-notch, slag notch, blast main entrance to the bustle pipe, etc. These are active points of the furnace and if the uptakes are located right above these points it may cause uneven distribution of the gas through the burden. The entire design should also ensure that minimum of dust is carried form the furnace with the gases.


COLD BLAST MAIN
CHIMNEY VALVE
CHIMNEY VALVE
WALL LINING
CHECKERS
AIR RELIEF OPENING
CHECKER BRICK DETAILS
COMBUSTION CHAMBER
HOT BLAST
BURNER

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 and the hot products of combustion later heat up the checker bricks. In this case the stove is said to be on ***'on-gas'*** and is maintained on gas until the checker bricks are heated to a certain temperature.

Hot Blast Stove

Firing is stopped and cold blast is passed through checkers which impart the heat stored in them and 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 the blast is obtainable. The stove is again put **on gas** and the cycle is repeated.

Hot Blast Stove

The stove design and the number of stoves, employed should ensure a steady supply of preheated blast to the furnace. This duty demands that the amount of heat generated by way of combustion of gas per unit time should be adequate to heat up the required amount of blast to the required temperature per unit time, taking into account the usual efficiency of heat transfer via checker system and the usual heat losses from the system.

Hot Blast Stove

The thermal efficiency of the stove varies between 75-90%. The checker work cools more rapidly whereas it takes longer time to heat it up. In practice a stove may be on gas for 2-4 hours and on blast for 1-2 hours. For an uninterrupted steady supply of blast at specified temperature therefore a battery of at least three stoves is necessary. A two stove system is quite unsatisfactory and hence three or four stove system is preferred.

The checkerwork has to absorb maximum heat at faster rate while heating and should desorb heat equally rapidly to the incoming cold blast. The larger the weight of 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 gas. The bricks should have maximum weight with maximum surface area of flues *i.e.* maximum openings to allow free passage of gases. **It has been found that a ratio of weight of bricks in kilogram to heating surface in square metres of about 5-6 in minimum.** Below this struc-tural difficulties may arise.

The checker bricks are supported on steel grids which in turn are supported by cast iron or steel columns. Since the maximum temperature during combustion is generated near the dome and since the top portion of checker bricks have to stand higher temperatures, with progressively decreasing value downwards, the quality of checker bricks used also very accordingly. Heavy duty fire-bricks are essential for dome construction. The top 3-6 m height of the checkers is made up of higher alumina bricks or semi-silica bricks while the remainder as of good quality firebricks.

Useful Volume

It is the volume of Blast Furnace occupied by the charge materials and the products , i.e. the volume of furnace from the stock line to the tap hole.

Useful volume = the furnace capacity × C.U.U.V.

C.U.U.V = coefficient of utilization of useful volume.

The value of C.U.U.V. varies in a wide range from 0.48-1.50 m^3/ton of pig iron

Useful volume

$V = k\,D^2 H$

V=Useful volume

H=Total height

D=Diameter at the bottom of the shaft

K=A coefficient usually lies with in the range of 0.47 to 0.53. High value is for slim profile.

Height of the furnace

- Total height = useful height +distance between stock line and the charging platform (it is governed by the construction of gas off-take and charging platform, this dimensions varies from 3 to 4m.)
- Useful height= height from the tapping hole to the stock line.

The height of the blast furnace is mainly governed by the strength of the raw materials, particularly that of coke.

The strength of the coke charged to the furnace should be sufficient to withstand the load of raw materials without getting crushed. Coke provides permeability(in the dry as well as wet zones)and also mechanical support to the large charge column, permitting the gases to ascend through the voids.

Total height (H)= $5.55V^{0.24}$

Useful height (H_0) $=0.88\times H$

Bosh Parallel

Diameter:

The belly /bosh parallel is the cylinder that connects the tapers of the shaft and the bosh. Its diameter, d_{bll}, and the ratio of this diameter to the useful or inner height of the furnace as well as to the diameter of the hearth play an important role in the operation of the furnace. The correct descent of the stock, ascent of the gas and efficient utilization of the chemical and thermal energies of the gas depend greatly upon these ratios.

The importance of an adequate belly diameter lies in the fact that softening and melting of the gangue and formation of the slag occurs in this region.

An increase in the diameter facilitates gas passage through the sticky mass and also slows down stock movement, thus increasing the residence time for indirect reduction.

However, the belly diameter cannot be increased arbitrarily as it is directly related to bosh angle, bosh height, hearth and throat diameters and useful height.

The belly height depends upon the softenability of the ferrous burden and also on the shaft angle desired.

If the slag fusion occurs at higher temperatures and in a narrow temperature range as in the case of pre-fluxed burden, the hydraulic resistance decreases in the vertical cross-section and the belly height can be correspondingly reduced.

$$d_{belly} = 0.59 \times (V)^{0.38}$$

$$H_{belly} = 0.07 \times H$$

The Hearth

The hearth is designed such that its volume between the iron notch and tuyeres is sufficient to hold the molten metal and the slag.

The dia of hearth depends upon:

- The intensity of coke consumption.
- The quality of burden.
- The type of iron being produced.

$$D_{hearth} = 0.32 \times V^{0.45}$$

A very approximate relationship between the coke burning rate and hearth diameter is given by the following equation:

$D = c\,Q^{0.5}$

D = hearth diameter, m

Q = coke throughput, tonnes/24h

c = throughput coefficient which varies between 0.2-0.3 depending upon burden preparation.

Calculate for c=0.2 and 0.3
Furnace production 10000 THM/day
and coke rate of 500kg/ton

For highly prepared burden, the value of c = 0.2 has been achieved in modern large furnaces .

There-fore, for a furnace planned to produce 10,000 THM per day with a coke rate of 500 kg/THM, i.e., a coke throughput of 5,000 tonnes per day, the hearth diameter should be about 14.1 m.

The value will be 21.2 m if the value of c=0.3.

With increasing diameter of the hearth, the gas penetration must be ensured by providing adequate bed permeability with the use of mechanically strong, rich, pre-fluxed burden of uniform size and low slag bulk as well as strong lumpy coke.

The Hearth height should be **10%** of the total height of the furnace

Stack/Shaft

The shaft height must be sufficient to allow the heating, preparation and reduction of ore before the burden reaches the bosh. In the upper regions of the shaft , volume changes due to increase in temperature and carbon deposition. These demand an outward batter for smooth flow of materials. In the lower region of the shaft , the material starts fusing and tends to stick to the furnace wall. So to counteract the wall drag an outward butter is necessary.

Stack height $H_{stack} = 0.63\ H - 3.2\ m$

Stack angle

The stack angle usually ranges from 85^0 to 87^0

(i) 85^0 for weak and powdery ores;

(ii) 86^0 for mixture of strong and weak, lumpy or fine ores;

(iii) 87^0 for strong, lumpy ore and coke.

- The variations in the angles are necessary for obtaining an adequate peripheral flow which is an essential pre-requisite for forcing of the blast furnace.
- Since the ore hump is located in the intermediate zone and it moves almost vertically downwards pushing the lighter coke towards the wall and the axis.
- A smaller shaft angle in the case of weak and powdery ore helps to loosen the periphery.

Stack Angle and Bosh Angle

Stack angle can be calculated from the formula

Stack angle (α)= $Cot^{-1}(D-d_1/2xStack\ Height)$

Where, D= Bosh parallel Diameter

d_1= Throat Diameter

Bosh angle can be calculated from the formula

Bosh angle (β)= $Cot^{-1}(D-d/2xBosh\ Height)$

Where, D= Bosh parallel Diameter

d= Hearth Diameter

Throat Diameter

- When the raw materials are charged into the blast furnace, little volume change takes place for a few meters of their descent and hence the walls of the throat are generally parallel
- Throat diameter can not be too small as it has to allow the enormous volume of the gas to pass through at a reasonably low velocity to maintain adequate solid gas contact and to decrease the dust emission, throat hanging and channeling.

Throat Diameter

- Throat diameter can not be too wide as it may compact the charge. A certain velocity and lifting power of gas is necessary for losening the charge at top.

Throat Diameter $d_{throat} = 0.59\ V^{0.35}$

Where, V= useful volume

Inter-tuyere Space

A considerable amount of slag and iron descends to the hearth through the inter-tuyere zones. If they do so without having been adequately heated, the thermal state of the hearth may be disturbed with attendant high sulphur in iron, sluggish slag movement, erratic metal analysis, frequent tuyere burning, etc.

- The distance between the adjacent tuyeres around the hearth circumference should be such as to obtain, as far as possible, a merging of the individual combustion zones of each tuyere into a continuous ring.

A schematic plan view of the combustion zone at the tuyere level of a blast furnace

Number of Tuyeres

The number of tuyeres mainly depend upon the diameter of the hearth. The diameter of the tuyeres depend upon the blast volume.

The following formulae can be used to determine the number of tuyeres

Pavlov: $n = 2d + 1$

Rice: $n = 2.6d - 0.3$

Tikhomirov et al : $n = 3d - 8$

Where n= Number of tuyeres,
d=hearth diameter

Capacity → (THM/Day) Parameter↓	2000	3000	5000
Useful Volume (m^3)	1700	2550	4250
Total Height (m)	33.08	36.46	41.22
Useful Height (m)	29.11	32.08	36.27
Bosh Parallel Dia (m)	9.96	11.62	14.11
Bosh Parallel Height (m)	2.32	2.55	2.89
Bosh Height (m)	4.37	4.81	5.44
Hearth Dia (m)	9.1	10.92	13.74
Hearth Area (m^2)	65.04	93.66	148.27
Hearth Height (m)	3.308	3.646	4.122
Stack/Shaft Height (m)	17.64	19.77	22.77
Throat Dia (m)	6.87	7.85	9.29
Bosh Angle (°)	84.32	85.84	88.05
Stack Angle (°)	85	84.55	83.96
Nos. of Tuyeres	20	25	34

BLAST FURNACE REFRACTORIES

- High duty Fire bricks used predominantly. The lining life should be few years. Thickness can be approximately 1 mtr.
- The life of lining should not be less than a few years. The thickness lining may be around one metre or so in most modern furnaces.

- The chief causes of Failure of lining are:
    1. Carbon Monoxide (CO) attack.
    2. Action of alkali vapours.
    3. Action of limy and alkaline slags.
    4. Action of other volatile matter.
    5. Abrasion by solids, liquids and gases.
    6. Temperature.
    7. Action of molten metals.
    8. Conditions of operation and design.
    9. Blowing- in procedure.

- One or at best a few factors, but not all these factors may be dominant at any one area in the furnace.
- E.g.:
  - Stack region- Abrasion and CO(carbon monoxide) attack.
  - Bosh region- High temperature, Erosion by gas, attack of molten lime and alkali slags.
  - Hearth- Action of molten slag and metals.

Stack Lining:

- A Good dense refractory is suitable for resistance to Carbon Monoxide and solid abrasion.
- Armour plates are used at the throat region.
  - 35-40% Al_2O_3 Bricks
  - 60% Al_2O_3 Bricks are recommended for the lower part of the stack.
- These bricks are made by machine molding under high pressures and are de-aired to improve their density.
- Use of standard type of bricks or larger types of blocks is currently in vogue.

Hearth Lining:

- It should prevent breakouts.
- High alumina/silica ratio bricks with low permeability with well laid joints will prevent breakouts.
- Carbon block lined hearth is used due to high refractoriness, high thermal conductivity, abrasion resistance , low porosity & inertness to carbon saturated iron & slag etc. makes an ideal material for hearth construction.

Hearth Walls:

- Either Carbon lining or carbon blocks facing with high duty fire bricks backing is employed for the walls right upto the central line of the tuyeres or upto the top of the tuyeres in modern furnaces.

Bosh Lining:

- Good refractoriness, refractoriness under load required. Low thermal expansion and resistance to attack by limy and alkali slags.
- High duty or super duty fire bricks with 45-65% Al_2O_3 are used with copper cooling plates.
- In Japan development of graphite – silicon carbide bricks has given excellent performance for bosh as well as hearth region.
- This type of lining may find wider use in near future.

- With carbon lined bosh and hearth, conventional cooling plates are generally replaced by external cooling of the shell.
- The successful use of carbon lined hearth has led to adoption of carbon lining up to bosh level.
- Carbon hearth must be protected from oxidation during blowing-in period with fire clay.
- *Check slide notes*

ADVANTAGES OF CARBON LINING ARE AS UNDER

- Increase in overall campaign life of furnace.
- Minimum break outs and reduced scaffolding.
- Stack cooling may become unnecessary.
- More uniform wear of the lining.
- Clean surface in contact with slag and metal both.
- Thinner lining may be adequate so more volume of blast furnace.

Blast furnace Accessories: structure

- In early design the entire structure of furnace including charging arrangement was supported by solid iron pillars from mantle ring.
- Modern trend is to have box girder jacket surrounding the furnace to support it.
- In this way the furnace shell is relieved of loads imposed on it by the super structure. It allows more clear space for working around furnace bottom.
- Relining of bosh and hearth region can be more easily carried out.

Blast furnace cooling arrangement

- Cooling of blast furnace lining is necessary for longer life and normal functioning of blast furnace.
- This is specially critical for hearth and bosh regions.
- Cooling will keep the shell temp. under control.
- Interruption of cooling even for a short duration can have serious consequences.
- Cooling can help reduce lining thickness and hence useful volume will increase

- Cooling arrangements-
  1. Box coolers (cantilever type , L type cooler, plate type cooler),
  2. Spray cooler for external cooling of shell,
  3. Water jacketed shell ,
  4. Air / Water cooling of furnace bottom,
  5. Evaporation cooling of furnace shell with water.

- **Shell:** Recent trend is to use external water sprays to cool the shell ½ bottom portion.
- Upper half is cooled with cantilever type cooler.
- **Hearth and Bosh:** - Plate type flat copper coolers are used.
- In addition to inserted coolers, external water cooling of almost the entire shell is being adopted.
- On the face (sides) backing layers of graphite with carbon are particularly recommended for effective cooling of the hearth

- External spray cooling is difficult due to oblique walls.
- **Evaporation cooling** – The heat is extracted in cooler by converting water at 100 ^{o}C to steam. Water extracts heat equivalent to amount of steam formed during cooling at the boiling point of water.
- Hearth bottom cooling - C. I. Plates with steel pipes inserted is used.
- Water cooling on big furnaces is also started.

- **Cast house** – The area around the blast furnace in the form of raised platform in which channels are provided for flow of molten metal and Slag to flow to the respective ladles.
- The channels are provided with gates to control rate of flow and direction to any one or two of the spout above the ladle.

- **Tuyere assembly** – The hot blast from the furnace is introduced through a bustle pipe and a tuyere assembly. The bustle is lined with insulation from inside and tuyere nozzle is water cooled.
- Goose neck between bustle pipe and tuyere is eliminated in modern design. This method reduces heat losses.

- **Raw material section** – It runs parallel to blast furnace section and consists of ore yard, bins, scale car and ore transfer cars etc.
- Rail tracks are also provided for lime stone, dolomite, sinter etc.
- It is beneficial to screen ore, sinter and coke just before charging to remove fines.

- **Charge hoisting appliances** - The solid charge is hoisted to the furnace top by bucket or hoist or conveyor belt.
- **Top charging system** - Furnace top is a complicated design which includes charging arrangement and gas outlets along with necessary safety devices.
- Now modern design of blast furnace which adopt high top pressure operation are in use.
- Blowers, pumps, boilers - Blowers are regulated to supply constant volume of air to the furnace via stove.
- Pumps are used to cool the furnace & its accessories.

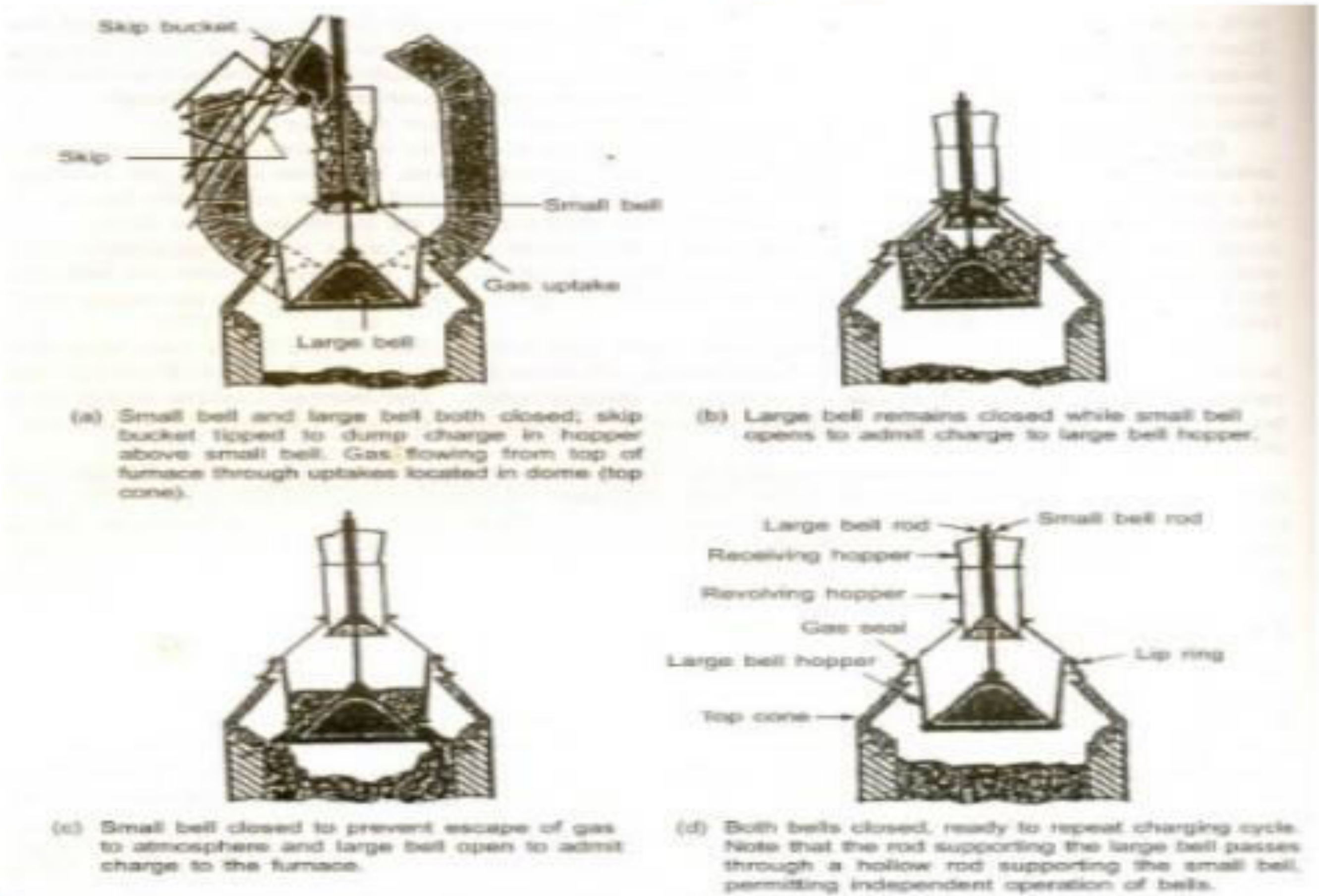
- **Instrumentation and control** –
- Operations of the furnace are controlled with several measuring and recording and controlling devices.
- Every attempt is made to operate the furnace under optimum operating conditions.
- Instruments are provided to measure and adjust the variables affecting the operations.

THE INSTRUMENTS WHICH ARE PROVIDED ARE:

1) Blast temp. and pressure.
2) Blast volume.
3) Stock line recorders and indicators.
4) Hot Blast Temp. recorder.
5) Top gas pressure indicators and recorders.
6) Stove dome temp. recorder.
7) Automatic combustion control device for stoves.
8) Sequence recorders for charging.
9) Alarms for low blast pressure, high stack temp. etc.
10) Furnace wall temp. indicators.

Charging Mechanism

Two bell charging cycle



(a) Small bell and large bell both closed; skip bucket tipped to dump charge in hopper above small bell. Gas flowing from top of furnace through uptakes located in dome (top cone).

(b) Large bell remains closed while small bell opens to admit charge to large bell hopper.

(c) Small bell closed to prevent escape of gas to atmosphere and large bell open to admit charge to the furnace.

(d) Both bells closed, ready to repeat charging cycle. Note that the rod supporting the large bell passes through a hollow rod supporting the small bell, permitting independent operation of bells.

Bell Less Top

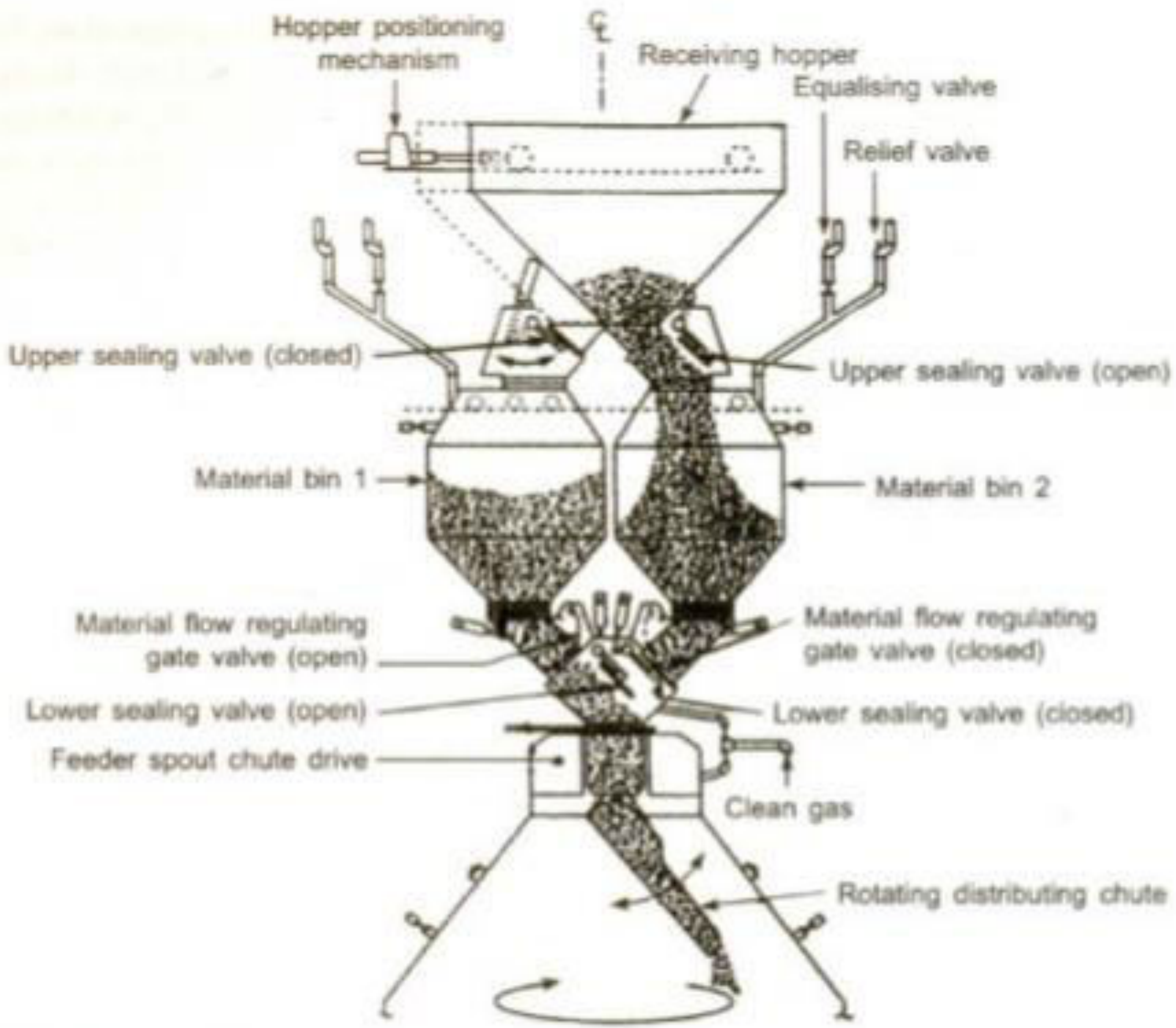
✓ This is a unique design in which large bell is replaced by a distributor chute with 2 hoppers

✓ A rotating chute is provided inside the furnace top cone

Advantages:

- ✓ Greater charge distribution flexibility
- ✓ more operational safety and easy control over varying charging particles
- ✓ Less wearing parts: easy maintenance

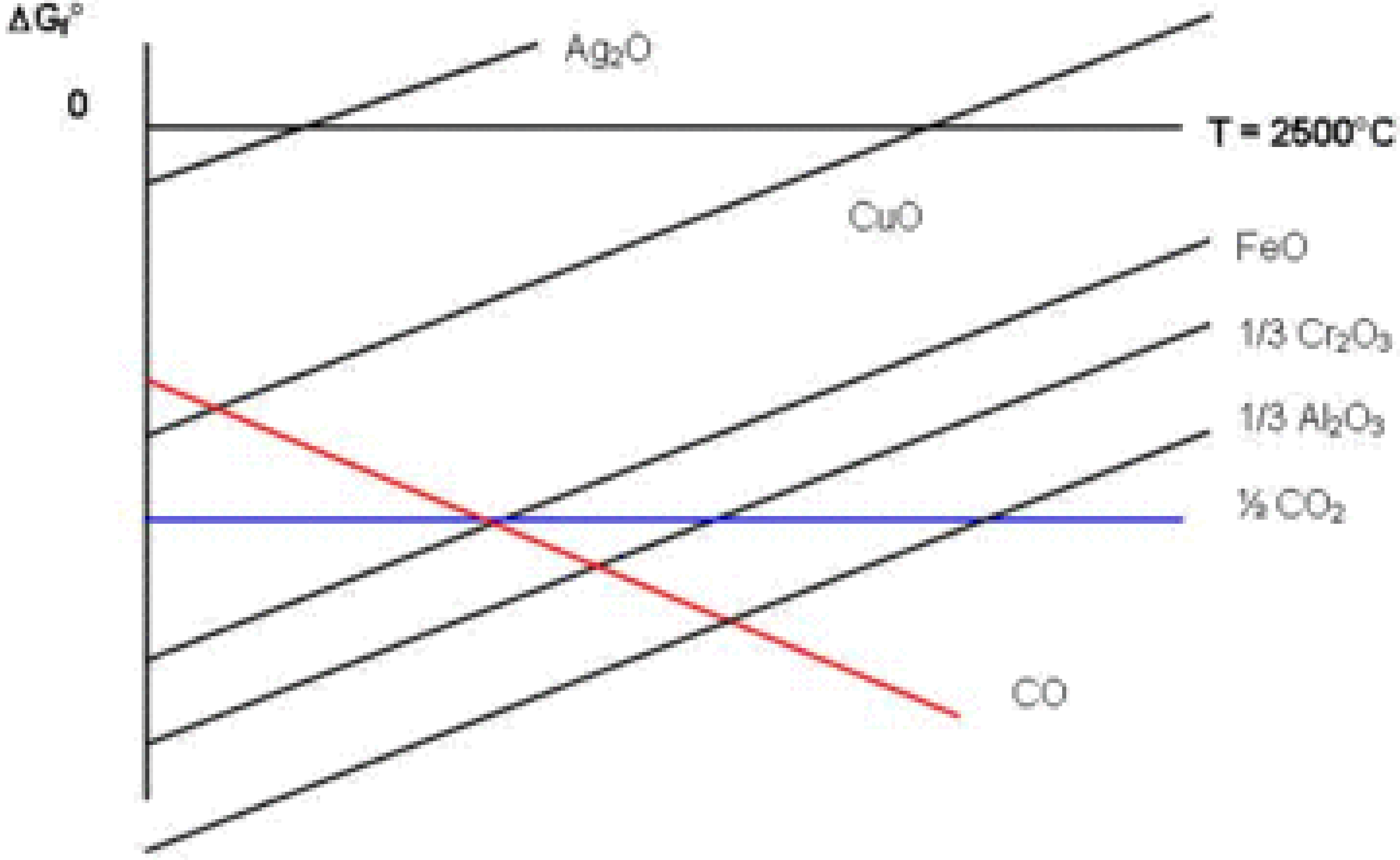
Bell-less top



The advantages accruing from improved distribution control can be summarised as follows:

- Increased productivity, decreased coke rate, improved furnace life .
- Reduced refractory erosion
- Improved wind acceptance and reduced hanging as well as slips
- Improved efficiency of gas utilisation and its indirect reduction
- Lower silicon content in hot metal and consistency in the hot metal quality
- Reduced tuyere losses and minimisation of scaffold formation
- Lower dust emission owing to uniform distribution of fines.

BASICS OF ELLINGHAM DIAGRAM



SALIENT FEATURES

- Curves in the Ellingham diagrams for the formation of metallic oxides are basically straight lines with a positive slope. The slope is proportional to ΔS, which is fairly constant with temperature.
- The lower the position of a metal's line in the Ellingham diagram, the greater is the stability of its oxide. For example, the line for Al (oxidation of aluminum) is found to be below that for Fe (formation of Fe_2O_3)
- Stability of metallic oxides decreases with increase in temperature. Highly unstable oxides like Ag_2O and HgO easily undergo thermal decomposition.

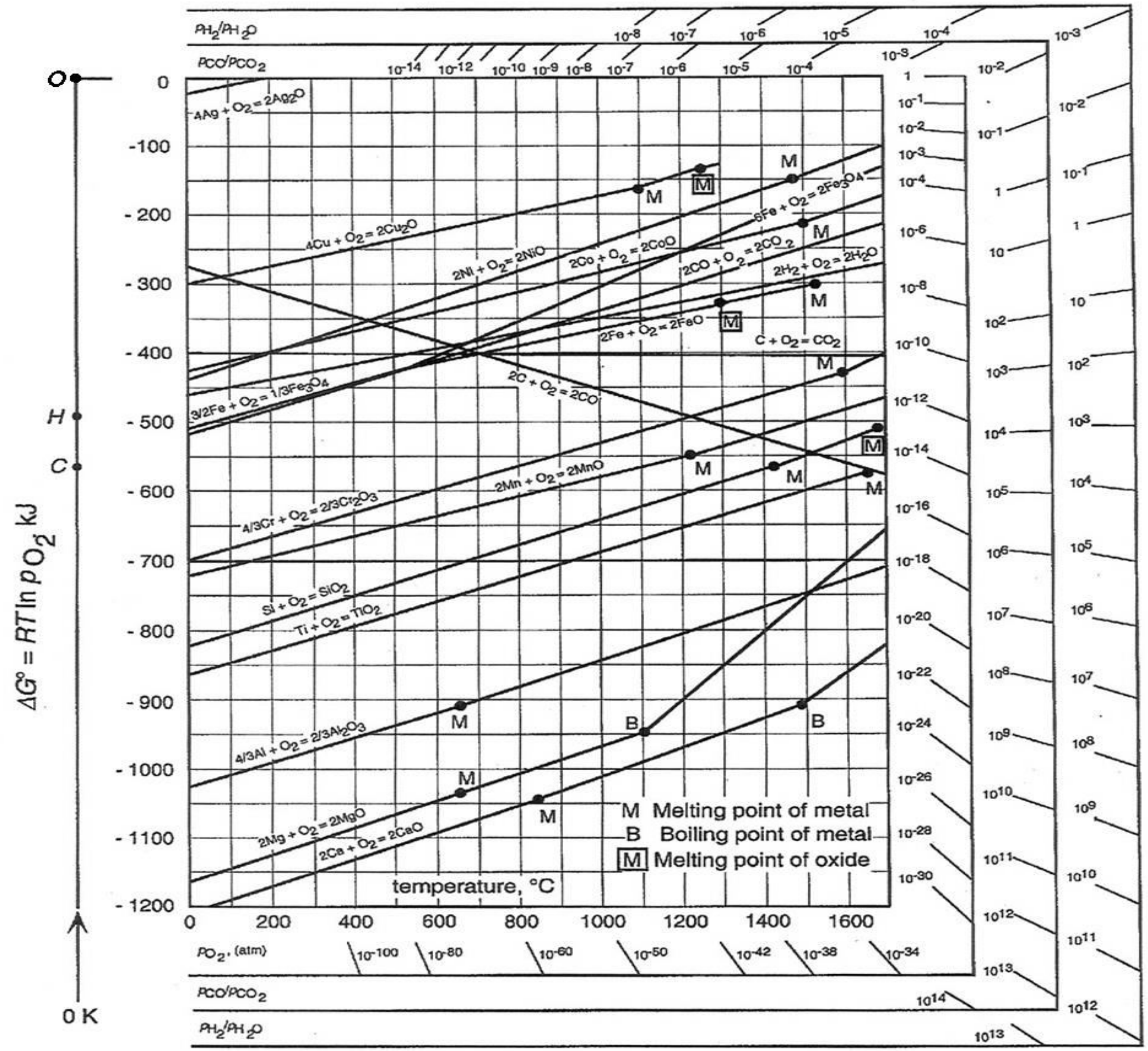


Figure 12.13 The Ellingham diagram for selected oxides.

- The formation free energy of carbon dioxide (CO_2) is almost independent of temperature, while that of carbon monoxide (CO) has negative slope and crosses the CO_2 line near 700 °C. According to the Boudouard reaction, carbon monoxide is the dominant oxide of carbon at higher temperatures (above about 700 °C), and the higher the temperature (above 700 °C) the more effective a reductant (reducing agent) carbon is.

- A reduced substance (such as a metal), whose Gibbs free energy of formation is lower on the diagram at a given temperature, will reduce an oxide whose free energy of formation is higher on the diagram. For example, metallic aluminium can reduce iron oxide to metallic iron, the aluminium itself being oxidized to aluminium oxide.

- The greater the gap between any two lines, the greater the effectiveness of the reducing agent corresponding to the lower line.

- The intersection of two lines implies an oxidation-reduction equilibrium. Reduction using a given reductant is possible at temperatures above the intersection point where the ΔG line of that reductant is lower on the diagram than that of the metallic oxide to be reduced. At the point of intersection the free energy change for the reaction is zero, below this temperature it is positive and the metallic oxide is stable in the presence of the reductant, while above the point of intersection the Gibbs energy is negative and the oxide can be reduced.