FERROUS METALLURGY II

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Steel

Steel making has played a crucible role in the development of modern technical societies.

Steel has been called the world's most useful & inexpensive ferrous alloy. Steel isn't any specific product it is basically a malleable alloy of iron & carbon. The carbon percentage in steel is about 0.02% to 2.1%.

In principle, steel making is a melting, purifying and alloying process carried out at approximately 1600°C in molten conditions.

Steel is specifically differ by their chemical composition.

There are four types of steel as follows-

(i) Plain carbon steel
(ii) Alloy steel
(iii) Stainless steel
(iv) Tool steel
(v) High speed steel.

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steel making processes

Blister steel making :-

In this process bars of wrought iron were layered with powdered charcoal in stone boxes and heated. After about a week, the iron would absorb the carbon present in the charcoal. Repeated heating would distribute carbon more evenly, and the result after cooling was blister steel.

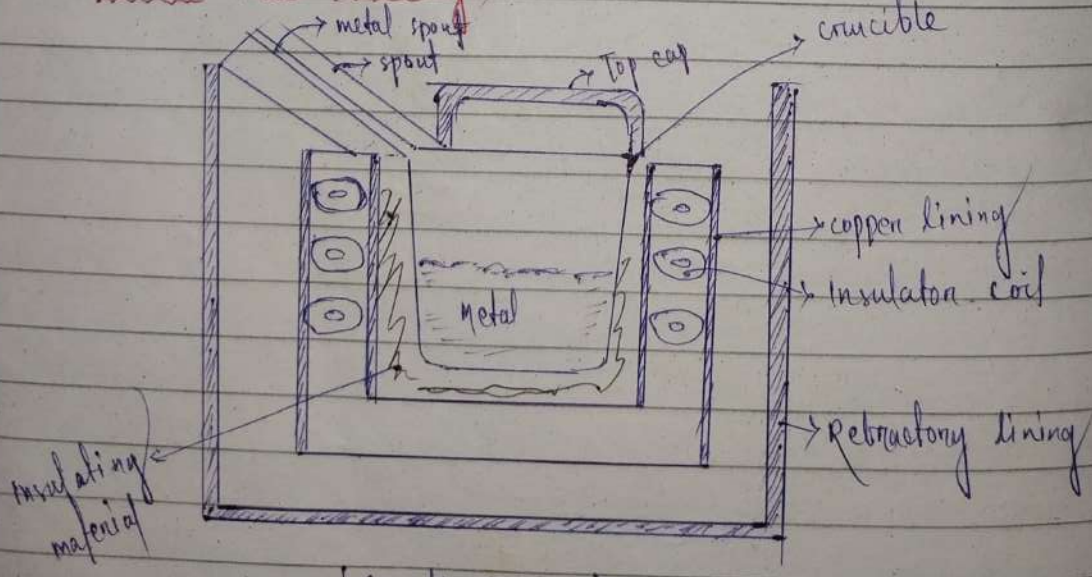
Shear steel making :-

Shear steel is a steel suitable for shears, scythes and other cutting instruments, prepared from blistered steel by repeated heating, rolling, to increase its malleability and fineness of texture.

Shearing is performed by slicing through a piece of sheet metal with a blade that's often affixed to a tool machine.

Hard metals like tungsten can't be sheared.

Crucible steel making :-



(Crucible furnace)

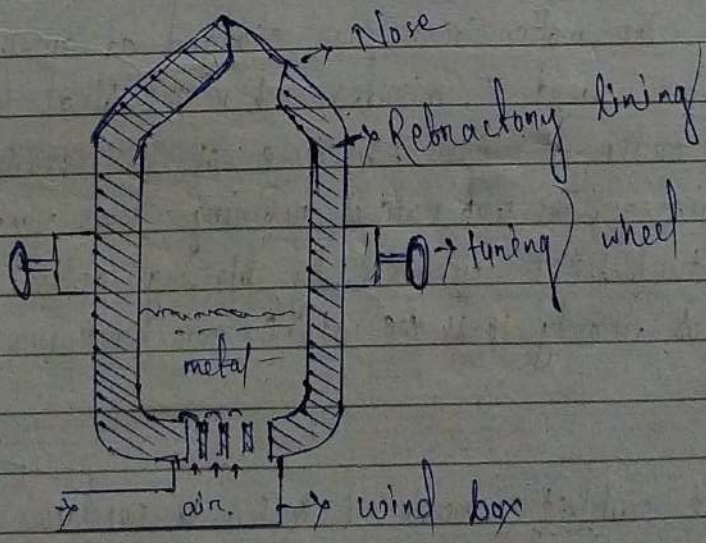
Crucible furnace technique is used for producing fine or tool steel. The earliest known use of the technique occured in India and central asia in the early 1st millenium CE. The steel was produced by heating wrought iron with materials rich in carbon such as charcoal in closed vessels.

Crucible steel is a steel made by melting pig iron, iron & sometime steel often along with the sand, glass, ashes and other fluxes in a crucible.

Hard cast steel made in pots that are lifted from the furnace before the metal is poured into molds.

In crucible process low melting point steel was produced because at that time coal fine & charcoal were not in use to produce high temp.

Bessemer steel making →



* Manufacture by Henry Bessemer in 1856.

It is a very easy process bore producing steel. In this process molten pig iron is held in a vessel with perforated bottom called a converter. This is a autogeneous process i.e. no external heat is needed. The exothermic chemical reactions during rebining provide the necessary heat in order to maintain the metal well above its melting point.

There are two types of Bessemer process

(i) Acid bessemer process →

The 1st ~~bessemer~~ bessemer made by Henry bessemer was a acid bessemer. In this process cold air was blown through molten iron held in a bottom-perforated vessel called converter that which converts iron into steel. The vessel was lined with silica bricks. It could remove only Si, Mn and carbon impurities from iron. It produced viscous, silica saturated slag which readily separated from molten metal to produce reasonably clean steel.

The molten iron was charged at around 1300°C and blown for about 15 minutes when the final temperature was of the order of 1600°C, because of the exothermic reactions of rebining. The ~~rate~~ rate of rebining was very fast because of the turbulence created by blowing action. Decarburisation rate of nearly 10-15 ~~wt%~~ wt%.C per hour was readily obtainable.

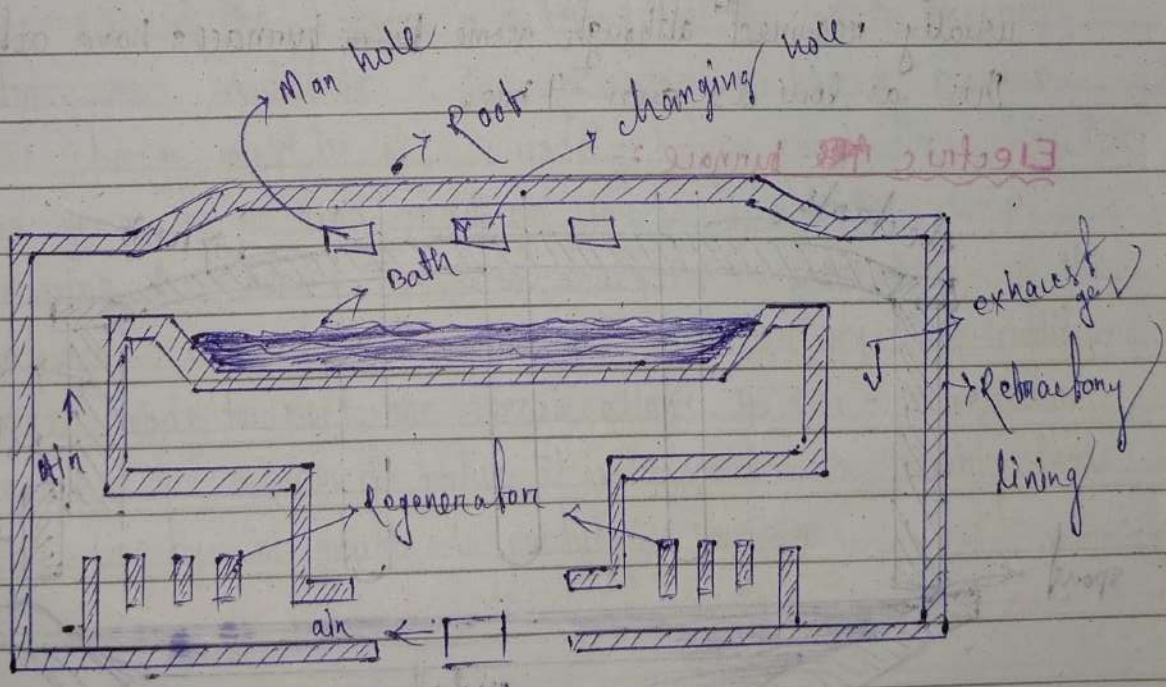
It couldn't remove P & S. It produces low quality steel.

(ii) Basic bessemer / Thomas process →

The early Bessemer process was modified by Thomas to enable to accept the continental irons containing around 2% phosphorous. The lining was changed to basic made from dolomite and limestone was incorporated in the charge to make good basic slag capable of interaction with metal to remove not only silicon & manganese but phosphorous as well. The silicon had to be kept below 1% to contain slag volume. The phosphorous is the chief heat producer to make this a autogeneous process.

The iron composition needed is Si - less than 1.0%, Mn - 0.7% - 1.%, P - minium 1.5%, S - max 0.05%.

Open hearth steel making →



(Open hearth furnace)

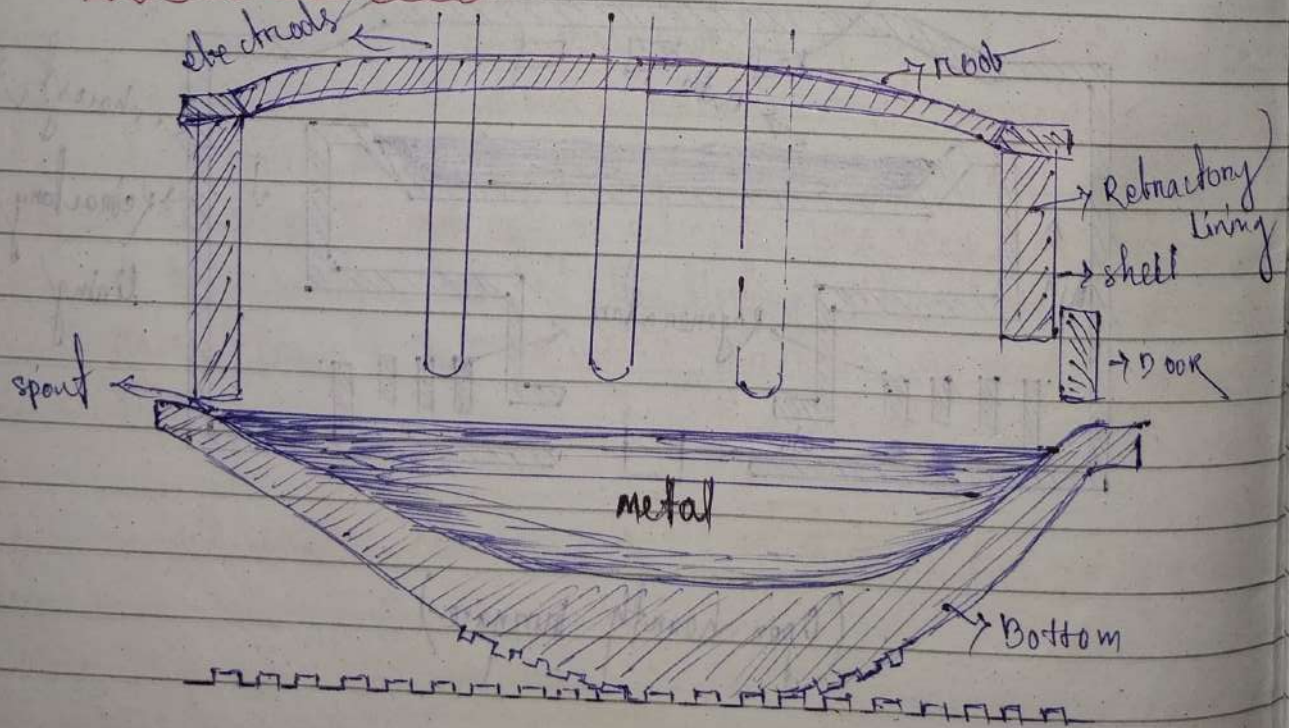
Open hearth furnace is also known as siemens's martin process.

The furnace in this process is mainly shallow basic lined vessel. It is heated by either liquid or gaseous fuels using the heat regeneration principle so as to attain steel making temperatures of about 1600 - 1700°C.

In the modern practice the charge is a mixture of scrap and molten pig iron. The scrap is initially heated to near its softening point and the molten pig iron from the blast furnace is poured onto it. The charge may contain iron ore and limestone.

The basic slag is prepared by adding lime & iron ore. The atmosphere in the furnace is therefore always oxidising. A tap-to-tap time of about 6-10 hrs is usually required although some ~~furnace~~ furnaces have achieved this as low as even 4 hrs.

Electric ~~Arc~~ furnace :-



(Electric Arc furnace)

Electric heating →

Electric furnaces are of three types :-

(i) The resistance furnace

{ Electric resistance heating is not useful for steel-making for a variety of reasons. }

(ii) Induction furnace

(iii) The Arc furnace

(ii) Induction furnace practice —

A furnace of this type consists of an annulare channel surrounding a core of laminated iron sheets. It used a low frequency AC power source. The charge consists of graded steel scrap.

The operation is quite simple. Light scrap is charged at the bottom and heavy at the top to prevent atmospheric oxidation of the scrap, as far as possible. The charge must be of accurately known composition since there is generally no time provision for analysis of the sample during the heat. The bath analysis is controlled by the charge composition. After melting, necessary alloy additions are made to meet the specifications. As the temperature reaches the required value it is tapped in a teeming ladle or directly in moulds to produce castings.

(ii) Electric ARC furnace –

The furnace proper looks more like a saucepan covered from top with an inverted saucer. The electrodes are inserted through the cover from top.

Arc furnaces are of two different designs –

(i) The roof along with the electrodes swing clearly off the body to facilitate charging from top.

(ii) The roof is lifted a little and the furnace body moves to one side clearly off the roof to ~~facilitate~~ facilitate charging.

Generally a three electrode arc furnace is used as electric arc furnace. The steelmaking temperature is maintained by an electric arc struck between the electrodes and the metallic charge.

This process is very similar to open hearth in charging and refining and several hours are needed for one heat. This is the only process, where in either oxidising or reducing conditions can be maintained at will as well during refining since the furnace doesn't possess its own ambient oxidising temperature.

The high cost of electrical energy in general makes this process costly. It is well suited for making alloy steels. It usually ~~run~~ runs on cold charge and the furnace is of small capacity.

The furnace unit consists of following parts:

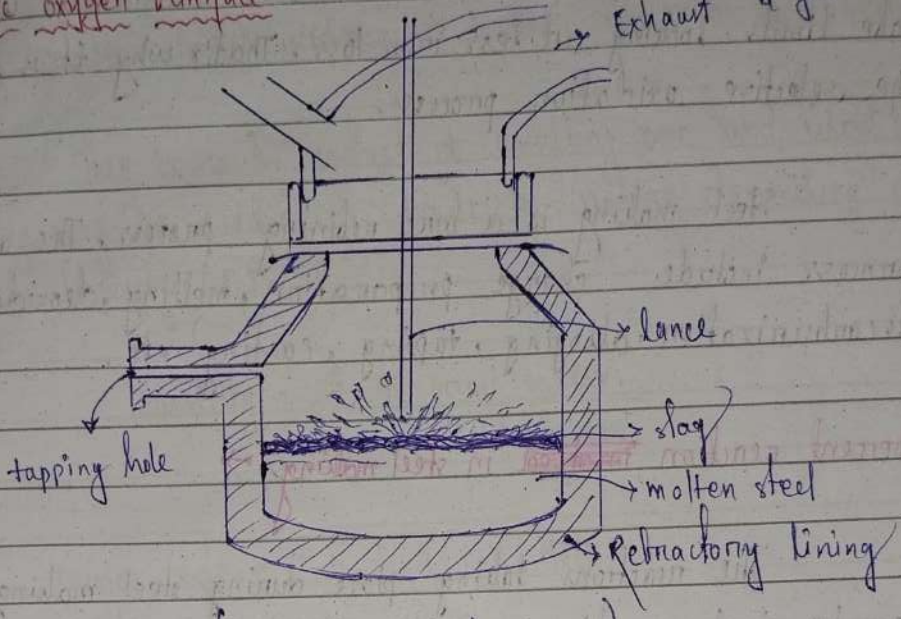
(i) Furnace body – i.e. the shell, the hearth, the walls, the spout, the doors etc.

(ii) Gears for furnace body movements.

(iii) Roof & roof lift arrangements.

(iv) Electrodes, their holders and supports.
(v) Electrical equipments - i.e, the transformers, the cables, the electrode control mechanism etc.

Basic oxygen furnace →



(Basic oxygen furnace)

A basic oxygen furnace (BOF) is a vessel used to convert hot metal into steel.

Basic oxygen process (BOP), a steelmaking method in which pure oxygen is blown into a bath of molten blast-furnace iron and scrap. The oxygen is blown through the lance. The oxygen initiates a series of intensively exothermic reactions, including the oxidation of such impurities as carbon, silicon, phosphorous and manganese.

Principles of steel making

What is steel making →

Steel making is a selective oxidation process in which impurities are removed selectively from pig iron. Impurities are oxidized to their respective oxides and remain within safe limits looking at less iron loss. That's why it is called the selective oxidation process.

Steel making is a fine refining process. The overall process include charge preparation, melting, deoxidation, recarburization, alloying, tapping, casting etc.

Different reaction ~~involved~~ in steel making →

The reactions taking place during steel making can be simply written as follows -

$$[Fe] + [O] = (FeO)$$
$$[C] + [O] = \{CO\}$$
$$[Si] + 2[O] = (SiO_2)$$
$$[Mn] + [O] = (MnO)$$
$$2[P] + 5[O] = (P_2O_5)$$
$$[S] + (CaO) = (CaS) + [O]$$

→ The products in the above reactions are only those which are stable at steelmaking temperature.

→ Except the sulphur reaction all the rest are oxidation processes and are favoured under the oxidizing condition of steelmaking.

→ The oxidation reactions are dealt with in general and the sulphur reaction is described separately.

→ In the case of oxidation of carbon the product being a gas, passed off into the atmosphere but the rest of the oxide products shall remain in contact with the iron melt in the form of a slag phase.

Differenciate between acid process & basic process of steel making →

Slag is a by-product of smelting ore and used metals. Slag may be acidic or basic in nature depending upon its basicity (B).

$$\text{Basicity} = \frac{\Sigma \text{ All basic oxides}}{\Sigma \text{ All Acid oxides}}$$

Basic oxide → CaO, MgO, FeO, MnO
Acid oxide → SiO_2, P_2O_5

Based on the slag type steel making can be of two types
(i) Acid steel making
(ii) Basic steel making

Acid steel making process	Basic steel making process
(i) It is self fluxing (No additional flux required)	(i) Flux is added to increase the basicity of slag.
(ii) Slag type : FeO - MnO - SiO_2.	(ii) Slag type : CaO - FeO - P_2O_5.
(iii) Slag is acidic.	(iii) Slag is basic.
(iv) Lining of refractory is acidic.	(iv) Lining of refractory is basic.

Acid S.M process	Basic S.M process
(v) Chief impurity is "Si".	(v) Chief impurity is 'P' along with Si, Mn can be removed.
(vi) This process is limited to boundries.	(vi) It has vast use.

Reaction involved in steel making →

→ In the refining process of steel making there are several reaction are involved :

$Fe + O \rightarrow FeO$ (Iron oxidation)

$C + O \rightarrow CO$ (Decarburization)

$Si + 2O \rightarrow SiO_2$ (Desiliconigation)

$Mn + O \rightarrow MnO$

$2P + 5O \rightarrow P_2O_5$ (Dephosphorisation)

$S + CaO \rightarrow CaS + O$

(i) All the reactions are exothermic in nature.
(ii) C is removed as CO gas
(iii) Except C, all the impurities are removed as oxides and all these oxides float on the surface of the molten metal as slag phase during refining of hot metal to steel.
(iv) Iron oxidation is unavoidable. Oxidation of Fe is loss in productivity; hence, its oxidation must be controlled.
(v) Oxygen must be dissolved to remove.
(vi) The minimum super heating temperature for the formation of CO is about 30-40°C above the ~~liqu~~ temp. of liquid metal.

Removal of phosphorous (P) →

The boiling temp. of phosphorous is very low i.e. about 280.5°c still then it is dissolved in iron and remain in the liquid form at high temp. because it has high interaction with the iron. It is very difficult to oxidised the P from Fe because the Phosphorous oxide line and iron oxide line are very close to each other in Ellingham diagram.

It is very harmful impurity for the steel because its presence create cold shortness in the steel.

Reactions of Phosphorous (P) →

The different reaction of phosphorous oxidation is

$$2P + 5O \rightarrow P_2O_5$$

Phosphorous oxidation by dissolve oxygen.

$$2P + 5FeO \rightarrow 5Fe + P_2O_5$$

Phosphorous oxidation by iron oxide in slag

$$\frac{2}{5}P + O_2 \rightarrow \frac{2}{5}(P_2O_5)$$

Dephosphorisation can be calculated by dephosphorisation index i.e $\frac{(CaO).P_2O_5}{P^2}$

The equilibrium constant is $K = \frac{a(P_2O_5)}{a[P].a[O]}$

Conditions for dephosphorisation →

i) The Furnace atmosphere should be oxidising.
ii) High basicity of slag.
iii) High FeO content in the slag.
iv) Low ~~temp~~ temp. in moderate temp.
v) High concentration of carbon.

Removal of Sulphur →

Sulphur has also very low vapourisation temp. i.e 445°C. When it make compound with iron i.e. iron sulphide, then the melting temp. increased to 1200°C. It has unlimited solubility with iron. If the sulphur percentage is more than it produces hot shortness.

* { When sulphur is present in the steel it makes a compound with iron sulphide having the melting point 1200°C. This FeS make an eutectic reaction with temp. 988°C. During hot rolling at the temp. of 1000–1100°C, it is melted & blows out from the rolling which is called hot shortness. }

The different desulphurisation reactions are –

(i) Addition of Mn

$$FeS + Mn \longrightarrow Fe + MnS$$

(ii) Addition of lime (CaO)

$$FeS + CaO \rightarrow FeO + CaS$$

(iii) Direct reaction O_2

$$S + O_2 \rightarrow SO_2$$

(iv) Oxidation by dissolved O_2

$$S + 2O \rightarrow SO_2$$

The equilibrium constant $K = \frac{a(S^{2-}) \cdot [O]}{a[S] \cdot a(O^{2-})}$.

Removal of Silicon :-

If excess silicon enters basic steel making furnace, either slag blushing may be required or more than one slag may be make. Alternatively the high silicon bearing pigiron is treated outside the blast steelmaking process. This is known as external desiliconisation of hot metal.

Silicon is an impurity which is largely present in pigiron. Silicon content decides the grade of pig iron. It strongly interacts with iron to produce appreciable negative deviation from ideality. Silicon is easily oxidised because of its high affinity to oxygen.

Silica is a very stable oxide and hence once silicon is oxidised to silica the danger of its reversion doesnot usually arise in refining slags.

The different de-siliconisation reactions are —

(i) By dissolve oxygen

$$Si + 2O \rightarrow SiO_2$$

(ii) By iron oxide in slag

$$Si + 2FeO \rightarrow SiO_2 + Fe$$

(iii) Direct oxidation by oxygen

$$Si + O_2 \rightarrow SiO_2$$

If the oxygen percentage in low during refining then silica reduction may take place. i.e.

$$SiO_2 + 2C \rightarrow Si + 2CO_2$$

The equilibrium constant $K = \frac{1}{a_{(Si)} \cdot a^2_{(O)}}$

If excess silicon is entered into the steel making process which increases the consumption of lime & it also decreases the life of refractory. So, If high silicon pig iron is produced by B/F then the hot metal is subjected to external desiliconisation.

Removal of Mn :→

Next to silica MnO is most stable oxide product during refining of pig iron. Manganese is soluble in iron in any proportion. Mn is easily oxidied. MnO has extensive solubility in slags.

The different demanganization reactions are —

(i) Mn oxidation by dissolve oxygen

$$Mn + O \rightarrow MnO$$

(ii) Mn oxidation by iron oxide in slag

$$Mn + FeO \rightarrow MnO + Fe$$

(iii) Direct oxidation by oxygen

$$Mn + \tfrac{1}{2} O_2 \rightarrow MnO$$

The equilibrium constant for the Mn reaction is

$$K = \frac{a(MnO)}{a(Mn) \cdot a(O)}$$

It is fashionable to describe manganese distribution as $FeO + Mn = MnO + Fe$ for which $K = \frac{a(MnO) \cdot a(Fe)}{a(FeO) \cdot a(Mn)}$

Removal of carbon :-

The carbon oxygen reaction plays a dominant role in steelmaking. The activity of carbon in liquid iron-carbon alloy shows a ~~native~~ negative deviation from ideality. The presence of carbide forming elements like Nb, V, Cr, W, Mo etc. decrease whereas the presence of non-carbide formers like Cu, Ni, Co etc. increase the activity coefficient of carbon in iron melts.

The different decarburization reactions are —

(i) Oxidation of carbon, dissolve in metal by dissolve oxygen

$$C + O \rightarrow CO$$

(ii) Oxidation by iron oxide in the slag

$$C + FeO \rightarrow Fe + CO$$

(iii) Direct oxidation by oxygen

$$C + \frac{1}{2} O_2 \rightarrow CO$$

The equilibrium constant of carbon reaction is :

$$K = \frac{P_{CO}}{a_C \cdot a_O}$$

where, K = equilibrium constant

P_{CO} =

a_C = activity of carbon

a_O = activity of oxygen

It is thus possible to produce steels with less than 0.1% C using pure oxygen as an oxidizing reagent.

~~The carbon content could be decreased much below the above level~~

Raw materials for steel making

The chief raw materials for steel for steelmaking are as follows :-

1. Source of metallic iron
2. Oxidising agents
3. Fluxes
4. Sources of heat
5. Deoxidisers and alloying additions
6. Furnace refractories

1. Source of metallic iron :-

The steelmaking process requires iron units or metallics as is referred to in the parlance of iron and steelmaking. In other words it is the basic raw material of steel making. The primary source of ~~mat~~ metallics is in the form of molten iron, essentially from blast furnace, it is also known as hot metal.

Pig iron —

The composition of pig iron produced in an integrated steel plant is always controlled, as otherwise permissible, to suit the steel making process.

If the iron contains less than 0.05% phosphorus acid steelmaking could be adopted. This is known as acid ~~or~~ 'hematite' or 'Swedish iron'.

Iron containing more than 0.05% P is called basic iron and basic steelmaking process is needed to refine this iron. A special category of basic iron that contains more than 1.5% P is known as 'Thomas iron'.

Steel scrap –

The secondary source of metallic iron is steel scrap. Steel plant itself generates scrap in the form of spillage, sheared ends, rejected material etc. to the tune of about 30-45% of its ingot production. This is variously called as new scrap, home scrap, home returns, plant returns, circulating scrap, etc. and which must be recycled into the steel making.

It is absolutely necessary and positively economical to use the home scrap as a part of the charge in an integrated steel plant.

Sponge Iron –

Sponge iron is very porous and hence is very susceptible to oxidation in steelmaking. Due care must therefore be taken while using this material for steelmaking. Some special techniques have been developed for its effective use without serious oxidation in steelmaking.

Copper above 0.05 - 0.1% and tin above 0.05% are not acceptable in steels as residuals. The sponge iron is free from such residuals because it is made from virgin raw materials.

2. Oxidising agents:-

The oxidising agents used for steelmaking are iron-oxide, air & oxygen gas.

Iron oxide is used in the form of lumpy hematite ore and mill scale. Mill scale is the oxide of iron produced during hot fabrication of steel and is readily available in an integrated steel plant.

The usual analyses of both iron oxide & mill scale are as follows :—

	Iron oxide	Mill scale
% Fe	60-69	71
% S	0.03	0.10
% Volatiles	0.5	4.5
others	Gangue oxides (Should be low in silica)	Miner impurity oxides

The oxide ores are generally low in sulphur & high in gangue oxide whereas the mill scale is nearly pure form of oxide but it may contain a high proportion of sulphur.

The use of iron oxide as an oxidising agent results in improving the yield of the process but it needs thermal energy to dissociate itself and make oxygen available for refining process.

The purity of oxygen should at least be 99.5 %. Nitrogen present in the air gets dissolved in steel and makes it strain brittle. Linked-Frankle process use for the

production of tonnage oxygen (purity more than 99.5% oxygen) at cheap rate. It has now become a useful oxidising agent in the BOF processes.

3. Fluxes :-

Typical analyses of fluxes used in steelmaking

	% CaO	% S	% MgO	% SiO_2	LOI
Lime	90-95	0.1-0.2	2-3	1.5	< 3-5
Limestone	50	0.01	1	1	≅ 40-45
Calcined dolomite	55	0.1	34-38	3-4	< 3-5
Ganister	0.5	—	0.1	94	≅ 5

(LOI means loss on ignition)

A flux is a substance added during smelting and refining to bring down the softening point of the gangue materials, to reduce the viscosity of slag and to decrease the activity of some components to make it stable in the slag phase.

Lime/limestone is generally added during steelmaking to make the slag basic enough to retain phosphorous & sulphur. Fluorspar and bauxite are added to decrease the viscosity of refining slags.

During steelmaking limestone gets ~~calcined~~ calcined and CaO thus breed acts as a flux. Generally calcined lime i.e. CaO ~~rather~~ rather than limestone is used as a flux if furnace heat is to be conserved.

4. Sources of Heat :-

The sources of heat are :

(1) Chemical –

(i) Solid – pulverised fuel

(ii) Liquid – oils, tar, etc.

(iii) Gas – producer, water, coke oven, natural and blast furnace gases.

For economic reasons the chemical fuels should be burnt with excess air and thus the furnace atmosphere would always be oxidising.

(2) Electrical –

(i) Induction heating

(ii) Resistance heating

(iii) Arc heating

The electric furnaces have no atmosphere of their own and hence oxidising as well as reducing conditions can be maintained in the furnaces with the help of ~~fluid~~ suitable slags.

5. Deoxidisers and Alloying Additions :—

Elements like Al, Si, Mn etc. are added primarily as common deoxidisers. Elements like Zr, B, Ti etc. are added for deoxidation in special cases. Elements like Cr, W, Mo, Ni, Nb, etc. are added generally as alloying additions. Carbon is added to recarburise steel or as a deoxidiser under vaccum. Excess additions of Al, Si, Mn, Ti etc. above what is consumed for deoxidation, can also remain in the melt as alloying additions.

Some alloying agents & oxidisers :-

(i) Silicon →

It is used as an primary ~~oxidiz~~ deoxidising agent in a furnace where a reducing slag is to be made. It is also used as a common deoxidiser in the furnace or in the ladle when killed or semi-killed steels are being made. This is a very effective common deoxidiser and is used in the form of ferro-silicon.

Silicon is also added as alloying element for better strength & toughness, hardenability & electrical properties. Typical use is for making transformer grade steels.

(ii) Manganese →

It is a weaker deoxidiser than silicon. As an alloying element it gives strength & toughness. It is added as ferro-manganese of various grades. Typical use is for making Hadfield and structural steels.

(iii) Aluminium →

It is a very effective deoxidiser and is used in the form of slabs, rods, pellets, wires, powder, etc. Chemically it is used as ferro-aluminium & aluminium-silicon compounds with 90-97% purity. It is an alloying addition is heat resistant steels e.g. Kanthal.

(iv) Nickel →

It doesn't act as a deoxidiser. It is added as an alloying addition in stainless steel. It can be added any time during the heat. Carbonyl nickel is preferred to electrode nickel for its low adsorbed hydrogen content.

(v) Chromium →

It is used as an alloying addition for stainless and heat resistant steels. It is available in the form of ferro-chrome of several grades. It can act as a deoxidiser but is costly to used for this purpose. It increases hardness, strength, yield-point & elasticity of steels.

(vi) Titanium →

It is a strong deoxidiser and neutralises the effect of nitrogen on steel by bonding it into stable insoluble nitride compounds. Titanium steels are useful for aircraft industry for its lightness coupled with strength.

(vii) Vanadium →

It is a strong deoxidiser. It ~~in one~~ increases the strength, plasticity and resistance to attrition and impact. It is usually added in structural, tool & spring steels. It is added as ferro-vanadium.

(viii) Tungsten →

It is a strong deoxidiser. As an alloying addition it increases hardness, strength and elasticity of steel. It is used in tool steels, high speed steel, cemented carbide alloys, etc. It is added as ferro-tungsten.

(ix) Molybdenum →

It is only an alloying addition to improve the mechanical properties. Its presence ensures uniform microcrystalline structure, augments hardenability and eliminates post-temper brittleness. It is used for shafts, gears, rolls etc. Like Ni it can also be added at any time during refining.

(x) Zirconium →

It is used as a deoxidiser. It decreases the deleterious effects of nitrogen and sulphur in steel. It is added in the form of zirconium-ferrosilicon having minimum 40% Zr. It has a ratio Si/Zr of not over 0.55 and Al/Zr equals to 0.20.

(xi) Boron →

This is used as a deoxidiser. As an alloying element it enhances the mechanical properties & hardenability of steel. It is added to steel in almost negligible amounts (0.0025-0.0030%) in the form of ferroboron and ferroboral.

(xii) Niobium →

The addition of niobium to stainless and heat resisting steels enhances their plasticity and corrosion resistance. It improves welding properties of structural steels and has stabilising influence on stainless steels. It is added in the form of ferro-niobium-tantalum.

(xiii) Cobalt →

It is used as an alloying addition for magnetic steels and like Ni or Mo, it can also be added at any time during the heat. It is added in elemental form.

(xiv) Carbon →

Coke, graphite & anthracite are used as recarburiser. Coke is also used to prepare reducing slags in an electric arc furnace.

6. Furnace Refractories *

Steelmaking furnace is lined by suitable refractory materials. The lining is made either by laying bricks (or blocks) or by shaping the required contour in situ using a refractory mix. Freshly mixed, warm tarred dolomite or magnesite is used for making furnace bottom in situ in hearth furnaces.

The bricks are generally made in the following forms.

1. ~~Chemic~~ Chemically bonded, unfired and reinforced.
2. Fired at usual or at higher temperatures.
3. Directly bonded (high strength)
4. Made from presintered and crushed mix
5. Melted, cast & cut to required shapes.

The materials used for the lining acid furnaces & acid vessels or basic furnaces are essentially silica-sand, ganister etc. Since the bulk steel production comes from basic processes, dolomite & dolomite enriched with magnesite are extensively used as lining materials for basic furnaces.

Fire bricks for insulation and chromite as neutral bricks are also used in steelmaking furnaces.

All the basic refractory materials for lining BOF's essentially belong to the CaO-MgO system and that the % (CaO+MgO) together should not be less than 90%.

Steel making by L.D converter

Different raw materials of L.D process :-

→ The name LD stands born linz and Donawitz, these were the two places in Austria where the process was born.
→ This process is also known as Basic Oxygen Process.
→ LD process is a refining process which is carried out in a LD vessel or converter.

Different Raw materials of LD process :-

In L.D process the charge consists of molten metal, cold pig-iron, steel scrap, lime/limestone, dolomite, fluorspar, bauxite, iron ore, mill scale, gaseous oxygen, etc.

Iron bed :-

We mainly used cold pig iron, scrap & hot metal in iron bed.

~~Hot metal~~ → The product of B/F is directly feed to the L.D converter. molten irons are ideally suited as a charge material for L.D process because it decreases the blowing period. The silicon content of such iron must below 0.5% but usually below 1.0%. The temp. of the hot metal at the time of charging is ~~around~~ usually around 1250 - 1300°C. The proportion of hot metal charged varies in the range of 75-90%, i.e 10-25% scrap depending over its availability.

As scrap mainly home scrap generated in the plant is charged. LD process can take upto 25% of the charge as scrap.

Scrap & cold pigiron are used as coolants to best utilize the excess heat energy available during refining. Under certain ~~circumstances~~ circumstances it may be necessary to include cold pigiron in the charge to consume the excess of pig iron produced in the plant.

If granulated pigiron / cold iron is charged while blowing it should be possible to absorb all the iron in an integrated steel works to balance iron & steel production.

If large amount of cold pigiron is charged, then it may be increase the blowing period because these are in solid form & settle at the bottom of the hearth so its melting & refining required more time then hot metal.

Fluxes →

Lime (95% + % CaO) and dolomite (58% CaO, 39% MgO) are the two primary fluxes for LD process.

Use of limestone as a flux is, therefore, discouraged. Another reason to prefer lime as a flux is lime is straightaway available for fluxing and formation of slag. If limestone is added as a flux, lime will available only after calcination, i.e. The slag formation will be delayed.

Use of bauxite, silica sand and fluorspar as fluxes is to bring lime quickly in solution. Use of dolomite as a flux may be useful in safe-guarding the lining but it adds to one more item to be handled on the shop floor.

Lime consumption varies around 2 to 5% of the weight of metal charge. The flux addition depends upon the amount of Si & P to be oxidised from the charge during the refining.

Oxygen →

It has been observed that nitrogen content of the bath increases with decreasing purity of oxygen. Oxygen of 99.5% purity is always desireable to keep nitrogen level of finished steel below 0.001%.

The consumption of oxygen per tonne of steel made, varies with proportion of scrap and ore added as coolants, and also with single and multi-hole lance designs.

If ~~the~~ iron ore is added as the ~~hole~~ sole coolant the oxygen consumption comes down by about 4-5 m^3/t of steel.

Basic operation in LD process →

Step involved in LD process -

1. Charging
2. Blowing
3. Sampling
4. Tapping
5. Slag off

1. Charging →

* charge materials -

(i) Scrap :

→ Home scrap generated in the plant is charged.

→ It acts as a coolant & utilizes the excess heat energy generated during refining.

→ LD process can take upto 25% of the metal charge as scrap.

(ii) Hot Metal (75-90%) :

→ The analysis of iron required to use in LD process as follows.

C → 4.10 – 4.30 %

Si → 0.50 - 0.85 %

Mn → 0.50 - 0.80 %

S → 0.02 - 0.03 %

P → 0.10 - 0.25 %

(iii) Fluxes :

→ Lime (95% CaO) and dolomite (58% CaO, 39% MgO) are the two primary fluxes.

(iv) Coolants :

→ Limestone, scrap, iron ore, and sponge iron are all potential coolants that can be added to a heat that has been overblown and is excessively hot.

(v) Oxygen :

→ 99.5% of pure oxygen is used as refining agent.

2. Blowing →

→ After charging, the vessel is rotated to vertical position. Lance is lowered to blowing position and O_2 is turned on.

→ Oxygen blows at a pressure of 9-11 atmospheric pressure. Which increases temperature (1600°C) and burns off impurities.

→ The blow continues for nearly 15-25 minutes.

→ Oxygen consumption : 50-60 Nm^3/t of steel.

3. Sampling →

→ Slag and metal samples are taken out for analysis.

→ Temperature of the bath is measured by immersion of thermocouple.

4. Tapping →

→ If the analysis & tapping temperature are in the required range, then the molten steel is tapped in the laddle.

→ Deoxidizers and alloying additions are made in the laddle.

→ Tap-to-tap time is 40-50 min.

De-oxidation of converter steel →

* De-oxidation is the final process in which dissolved oxygen in the steel is removed.

* The de-oxidizers i.e. Al, Fe-si and Fe-Mn are added to the steel, which combines with dissolved oxygen and forms their oxides.

$$FeO + Al \longrightarrow Fe + Al_2O_3$$
$$FeO + Fe\text{-}si \longrightarrow Fe + SiO_2$$
$$FeO + Fe\text{-}Mn \longrightarrow Fe + MnO$$

5. Slag-off:

* After tapping steel into the ladle, and turning the vessel upside down and tapping the remaining slag into the "slag pot".

Construction of a LD plant:-

A LD plant consists of the following major constituents:

1. The vessel including foundations, rotating gears etc.
2. The lance including its auxiliary gears.
3. The hood and the waste gas treatment plant.
4. The material handling and storage facilities.
5. Instrumentation and control pulpit.
6. The vessel lining and wrecking accessories.

Construction of LD converter →

There are two major constituents in LD converter →

(i) LD vessel →

→ The vessel in which refining carried out in a LD process is nearly similar to the Bessemer converter.

→ The vessel is divided into three segments. These are the spherical bottom, the cylindrical body and the conical top.

→ Each of these is a welded construction of non-ageing steel plates.

→ The height of the vessel varies from 7-10 m.

→ LD vessel has a basic lining of magnesite bricks (Permanent lining) & dolomite Bricks (working lining).

(ii) Oxygen lance →

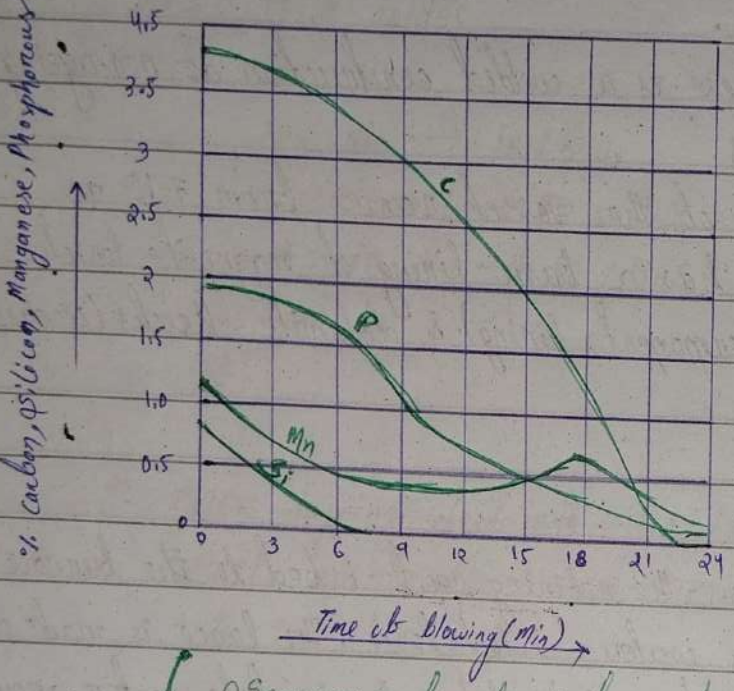
→ Oxygen gas - the refining agent - is fed to the furnace through a water cooled lance. The lance is made of three concentric steel tubes to circulate water around the central tube and pass oxygen through the most inner tube.

→ The lance is nearly 8-10 m. long and its diameter varies with furnace capacity in the range of 20-25 cm.

→ The lance is suspended by a wire rope and can be inserted in or withdrawn from the furnace by means of an electrically operated lance gear. Jigs are used to hold the lance in a fixed blowing position.

The refining reaction in LD converter with reference to decarburization and dephosphorisation →

The LD process in its classical form or the modified bottom agitated form is a unique ~~technique~~ process and the way it functions and carried out the refining is way different from the earlier hearth or the pneumatic processes.



(Sequence of elimination of impurities in a LD blow)

Chemical reactions →

1. $[Fe] + [O] = (FeO)$
2. $[C] + [O] = \{CO\}$
3. $[Si] + 2[O] = (SiO_2)$
4. $[Mn] + [O] = (MnO)$
5. $2[P] + 5[O] = (P_2O_5)$
6. $[FeS/MnS] + (CaO) = (CaS) + (FeO/MnO)$

There are 2 zones are formed in LD vessel during refining. These are (a) Emulsion zone (b) Bulk ~~2~~ zone.

Decarburisation →

De-carburisation rate increases with the increase of emulsion formation. But it is delay due to lack of dissolved O_2 in the bath.

Decarburisation rate curve begins to fall since not enough CO is formed to sustain the emulsion from within.

Dephosphorisation →

Dephosphorisation is very rapid in the emulsion because of the increased interfacial area and efficient mass transport. Phosphorous should, therefore, be fully eliminated before the emulsion collapses.

The rate of dephosphorisation depends on the basicity of slag, thickness of the slag & oxidising condition with low temp.

Advantages of LD converter :-

(i) LD process is about ten times faster than the open hearth process.

(ii) Instead of air pure oxygen is used, this eliminates the harmful effects of nitrogen.

(iii) It produces steel with low %S & P content from raw materials of ordinary quality.

(iv) It doesnot use an external source of heat or fuel.

(v) Economical as compared to other processes.

Disadvantages of LD converter :-

(i) The major disadvantage of L-D process is that the charge must include a considerable quantity of molten pig, thus limiting the amount of %scrap that can be used.

(ii) %Steel wastage due to %splashes by oxygen lancing is more.

(iii) Insufficient depth of penetration of O_2, leads to thermal gradient in the bath.

Limitation of LD converter :-

- It can't refine thomas grade iron.
- Almost 99.9 % pure O_2, must be required for the process.
- Large amount of %scrap can't be charged.
- %Slag %should be thin always.

Qn. Quality of steel in LD process →

LD process was earlier meant to produce only soft steels (C. > 0.15%) but now it has successfully been used to make even high carbon & alloy steels ~~including~~ including stainless steel.

LD steels are characterized by their low phosphorous nitrogen and carbon contents.

Composition of slag in LD process →

The slag composition in a LD vessel varies continuously during the blow. A typical set of basicity data in LD steelmaking are shown below:

Percentage of Blowing time	Basicity of slag
0 (mixed slag)	0.65
12	1.14
25	1.20
37.5	1.23
50	1.70
100	3.70

A typical composition of slag from a heat of dead soft steel at the time of tapping is as follow:

$CaO \rightarrow 47-52\%$	$SiO_2 \rightarrow 10-16\%$
$MgO \rightarrow 2-5\%$	$MnO \rightarrow 3-5\%$
$P_2O_5 \rightarrow 1-3\%$	$Fe \rightarrow 16-22\%$

The mass of slag formed in any steelmaking heat is normally not weighed to know its actual weight. It can

however be estimated in the post-mortem of the heat by ~~blowing~~ knowing the slag analysis and the actual lime and/or dolomite added in the heat.

For SiO_2 it is empirically bound as

$$\text{mass of slag formed kg/t of steel} = \frac{\text{Total \% of } CaO + MgO + SiO_2}{90 - (16.6 \text{ basicity} - 30)}$$

For CaO or CaO + MgO empirically

$$\text{Mass of slag generated/t of steel} = \left[\frac{\text{kg of CaO added}}{\text{charge wt}}\right] \times \frac{2 \times 95}{100}$$

Different development of LD process :

(a) Bottom, top & combined blowing :

In bottom blowing ~~hot air~~ oxygen is blown from the bottom of the furnace. In bottom blowing ~~we can heat the metals more~~ the heat is pass through the metal so the metal heated easily.

In top blowing ~~hot air~~ oxygen is blown from the top of the furnace. In this process on surface metal is heated easily.

The combined blowing process also known as the top and bottom blowing process is characterized by both a top blowing lance and a method of achieving stirring from the bottom. This process is more ~~of~~ helpful to produce ~~steel with less in time~~ va various quality steels.

(6) Multi nozzle convenfer →

In multi nozzle convenfer more than one one nozzle are present in the lance. By using multiple nozzles we can uniformly asprayed the oxygen gas overy side of the surface of the a metallic charge.

By using multiple nozzle we can produced steel quickly.

OLP Process →

The OLP process (Oxygen lime process) is quite similar in principle & practice to LDAC. It was independently developed by the IRSID in France. If the IRSID design is adopted it is known as OLP or else if is popularly known as the LDAC process.

The LD process was modified by the CNRM in Belgium to refine Thomas iron and was put into commercial practice at the ARBED dulange works in Luxembourg. The process is known as the LDAC process.

Basically a process is called LDAC if iron containing more than 0.4% P is refined to produce at least one intermediate phosphoric slag that is removed from the vessel and, the the heat is finished by further addition of lime & oxygen blowing.

There is a lot of similarity between LDAC & LD plants in design & practice/operation. The vessel shape is however altered to a tulip shape with two tap holes at diametrically opposite positions. The vessel volume is more by nearly 20% over that of LD to accomodate extra slag volume generated in the process.

Operation of OLP :-

Hot vessel containing some slag from the previous heat is charged with scrap, ore, bauxite, hot metal and one-third of the total lime required for the heat. If silicon is low some silica may also be charged to form foamy slag quickly.

Blowing commences with lance at its highest position. ~~powered~~ Powdered lime (1-2 mm size) is added through the lance at a predetermined rate after five minutes of oxygen blowing from the high position. The lance is then carefully lowered to control the foam.

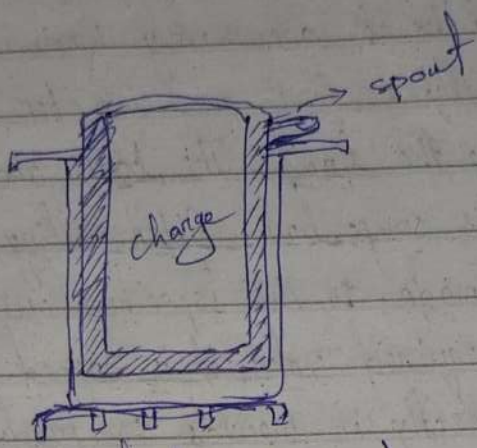
The blow is stopped after 15 minutes by which time carbon is brought down to nearly 1.5 to 1.7 % & phosphorous to 0.2 %.

The bath temperature being just over 1600°C. The slag is then drained out as completely as possible. Fresh additions of coolants, fluxes, etc. are made and the vessel is blown again for 5-8 minutes.

At the end of refining, sample is taken & analysed. Temperature is measured as usual and the heat is tapped leaving some or all of the slag in the vessel for the next heat.

Electric & Induction Furnace Processes →

Induction Furnace Practice →



(Induction furnace)

Construction :-

Induction furnace was first patented by Fernanti in Italy in 1877. It used a low frequency AC power source.

It consist of a crucible of usually a magnesite monolithic construction with a spout for pouring. The charge is placed in this crucible and it acts as the secondary winding.

The crucible is surrounding by several turns of water cooled copper tubing which carries the high frequency primary current. The size of the furnace, that is that of the crucible vary ~~for~~ from a few kilo to several tonnes.

Operation :-

The operation is quite simple. Light scrap is charged at the bottom and heavy at the top to prevent atmospheric oxidation of the scrap, as bar as possible. The charge must be of accurately known composition since there is generally no time provision for analysis of the sample during the heat. The bath analysis is controlled by the charges composition. After melting, necessary alloy additions are made to the specifications. As the temp. reaches the required value it is tapped in a teeming ladle or directly in moulds to produce casting.

Induction furnace :-

Induction furnace is an electric furnace in which the heat is applied by induction heating of metal.

Induction furnace capacity range from less than 1 kg to 100 tons & are used to melt iron & steel, copper, aluminium & precious metal.

Working of Induction furnace :-

In the Induction furnace a coil carrying alternating electric current surrounds the container or chamber of metals.

Eddy currents are induced with metal. The circulation of these currents ~~surrounds the container~~ producing extremely high temp. for melting the metals & for making alloys of exact composition.

The principle of induction furnace is the induction heating. Induction heating is a form of non contact heat for conductive materials. The principle of induction heating is mainly based on well known physical phenomenal : electro magnetic induction.

Advantages :-

The advantages of the induction furnace is a unclean, energy efficient & well controlled melting process, compared to most other means of metal melting.

The Induction heating process doesn't produce any byproducts. Heating will more at the corners of the workpiece

Disadvantages :-

(i) Cost of the equipments & cost of the process is very high.
(ii) Efficiency of heating is very poor.
(iii) Being less than 50% in many cases. Heating will be more in region of the workpiece / materials closer to heating coil, that means heating takes place in uniform manner.
(iv) Generally coil should have the shape of workpiece which can proob to be inconfinient practicle.

E.A.F

Introduction :-

Electrical energy is used in some furnaces for generating heat.

Electric furnaces are of three types -

a) Resistance furnace
b) Induction furnace
c) Arc furnace

Out of these 3 types, electric arc furnace is the mostly used furnace for steelmaking.

Generally electric arc f/c are 2 types.

a) Direct arc f/c

Ex :- ~~E.A.F~~ ~~J.E.S~~ R.F (Resistance f/c)

b) Indirect arc f/c

Ex :- E.A.F (Arc f/c)

Principle :-

When high current is supplied to the graphite electrodes, then in between the electrodes or electrode with the charge material an arc will create, which develope sufficient heat for the melting of the charge material for the E.A.F.

Types of slags :-

(Basically the slags are two types)

(i) Acid slag
(ii) Basic slag

Acid slag →

Acid slag is mainly generated in foundries. The slag type is $FeO - MnO - SiO_2$. The chief impurity is this slag is Si.

Basic slag →

This type of slags in mainly produced in Industries. The slag type is $CaO - FeO - P_2O_5$. The chief impurity is 'P'.

Steps of electric arc furnace heating to produce steel →

1. Charging →

The charge consist of steel scrap, metal, lime, limestone & ore. Light scrap is charged first followed by heavy scrap.

Ni & or Cu may be charged with scrap. Refractory alloying elements are shovelled directly into the arc region.

Generally 40% heavy, 40% medium & 20% light scrap is charge in a single charge.

2. F/c preparation →

After tapping the previous heat the lining is inspected. If damaged area found then it is repaired by using magnesite & dolomite powder.

Generally F/c door, Tap hole & spout area are required after every heat.

3. Melting :-

Melting starts below the electrode as the arc is struck. The electrode bore through the metallic charge & a pool of molten metal forms at the bottom.

The arc stabilizes when the charge below the electrodes melts completely.

The melting may be hastened by forcing the unmelted charge from the banks into the molten pool either by mechanical rabbling or by rotating the hearth by few degrees.

The power consumption is maximum during this period. Slag formation takes place with the increase in basicity during this period.

4. Refining & finishing :-

The slag formed during melt down period contains various oxides like FeO, CaO, SiO_2, MnO, Al_2O_3, etc.

Fluorspar CaF_2 is added to maintain adequate fluidity in the slag.

The refining process then takes place.

Advantages of E.A.F :-

(i) The ARC furnace tends to be larger & more powerful, less investment.
(ii) Quick to construct & fast cost recovery.
(iii) The temp. & the component of the molten steel can be controlled with accuracy.
(iv) The arc furnace can also melt various kinds of different steels.

Disadvantages of E.A.F.

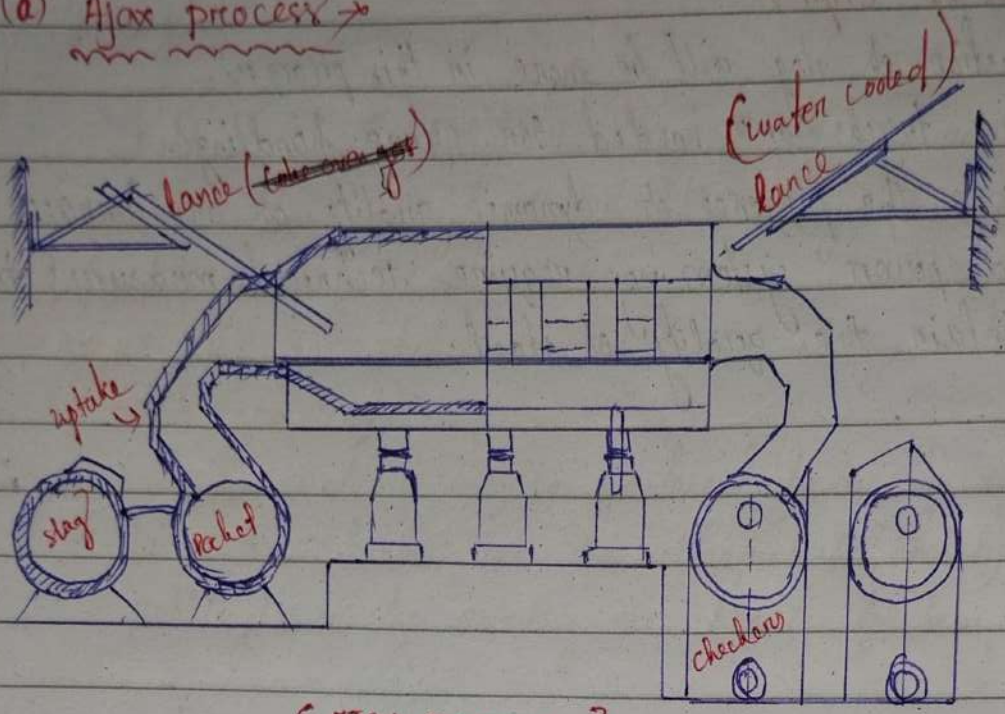
(i) Production of slag will be more in this process.

(ii) Heavy trucks are needed for scrap handling.

(iii) Due to the presence of dynamic quality of arc furnace load power system may require technical measures to maintain the quality of steel.

Other recent processes of steel making :-

(a) Ajax process :-



{ AJAX FURNACE }

It was essentially a tilting open hearth furnace. The end walls, ports, down takes, slag pockets and checkers were suitably altered keeping the general design of open hearth furnace in view.

It was mainly developed and used for Thomas grade iron but it could take all scrap ~~&~~ charge.

It took over three hours of lancing for a 200 t furnace & usually 2.0 - 2.5 hrs were required for charging, de-slagging, de-oxidation, tapping etc. It means tap-tap time is 5-6 hrs.

Operation →

The furnace was fired with cove oven gas through a pair of burners inserted on either side. One water cooled oxygen lance was provided on each end. It was used alternatively in ~~conjuction~~ conjunction with the direction of fuel firing and were completely withdrawn when not blowing. The lance was ~~we~~ held at an angle of 27-34° to the surface during blowing ϕ. Oxygen gas was blown at 5-6 atmos pressure during blowing blow rate is about 30-35 m^3/min.

The blowing therefore continued till carbon drops to 1% or so and phosphorous to 0.1-0.15%. By this time the fertilizer grade slag was ready and was removed. Fresh lime ϕ ore were charged to continue the process to form the second slag. Blowing was continued again till carbon was down to 0.4-0.5% ϕ bath temp. around 1570°C. At this stage oxygen lancing was stopped and the heat was finished as in conventional open hearth ~~furnace~~ practice.

Merit →

~~This furnace is very suitable for continuous operation,~~ and if

Merit of Ajax furnace →

(i) This furnace is very suitable for continuous operation
(ii) The process was fast enough and at the same time retained all the desirable features of the open hearth practice.
(iii) The tilting design helped to remove the slag in between when required.
(iv) The cost was reduced to 60-70% of the standard open hearth practice.

Demerit of Ajax furnace :-

(i) The iron content of the slag was between 15-20% as against the 9-10% in stand and open hearth practice.

OBM Process - (Oxygen bottom blowing)

The OBM vessel is essentially a Bessemen-like converter fitted with a special bottom. The tuyeres are inserted from the bottom in such a way that the oxygen would be surrounded by a protective hydrocarbon gas like propane. On entry propane cracks down in an endothermic reaction and takes up some of the heat generated by the entry of oxygen.

The other product of cracking is hydrogen. The amount of hydrogen thus dissolved increases particularly towards the end of the blow.

The tuyere arrangement in such and coupled with the provision of hydrocarbon and oxygen for usual blowing. The tuyeres are generally made of stainless steel pipes embeded in magnesite bottom.

Operation →

The operation of the vessel is more like the Thomas process since it has been developed for Thomas grade iron (1.8%P)

After charging scrap & hot metal, blowing is started. Lime is added immediately afterwards from an ~~overheated~~ overhead chute. The blow is divided into three distinct parts. The first lasts for 16-17 minutes and at the end of which a high phosphoric slag, 18-22% P_2O_5 and 12-15% FeO is raked off. The carbon and phosphorous are analyzed by taking a sample. The analysis is generally 0.3% C and 0.08% P at this stage. Fresh lime is added and blowing continued for about a minute when the carbon comes down to 0.1% and phosphorous upto 0.025%. The final blowing ~~of~~ is of nitrogen without protective gas and thereby the bath averages finally 0.0004% H_2 & 0.0005% N_2.

Merit of OBM →

(i) 50% of the hydrogen burns with dissolved oxygen & there-by generates heat.
(ii) The setup cost is nearly 30% lower than that for LD shop.
(iii) Fume formation is much less than in LD

Demerit of OBM →

(i) The construction of tuyeres & its maintainance is a big headache.
(ii) Dead soft steels can't be made by this process due to high nitrogen content.

Spray steel making process →

In spray steel making process we used spray Forming. It is also known as spray deposition. Spray forming is a manufacturing process that involves coating a workpiece with semi-solid particles of metal.

Spray forming begins with the heating of an alloy. The alloy is melted in a furnace of induction oven. Next, the newly molten metal is poured through a tundish connected to a nozzle that's able to blast the workpiece with the semi-solid particles.

Merits →

(i) It supports a wide variety of materials.
(ii) Spray forming can also be used on workpieces in a variety of shapes.
(iii) Ability to protect the workpiece from degradation.

Demerits →

(i) Erosion of melt delivery ~~to~~ tube.
(ii) Frequent Freezing.

Cracking is a reaction in which greater structural hydrocarbon molecules are broken down into smaller more functional hydrocarbon molecules. Some of which are unsaturated alkenes are the initial starting hydrocarbons.

Deoxidisers & their uses →

Deoxidiser is a compound used in a reaction to remove oxygen. These products contain one or more elements that are scavengers for oxygen distill in the pressure of dissolve oxygen ~~ex~~ in the molten metal. It is also known as degasibiers.

It can remove oxygen & other unwanted gases such as hydrogen.

Aluminium →

It is a very effective deoxidiser & is used in the form of stars, rods, pellets etc. Chemically it is used as ferro-aluminium & aluminium-silicon compound. It used to increase resistance to oxidation & skinning.

Silicon →

It is used as a primary deoxidising agent. It is used in furnace where a reducing slag is to be made. It is used in the production of killed & semi-killed steels. It is used to increase the hardenability, strength & electrical properties.

Vanadium →

It is a carbide forming element & deoxidiser used with nickel & chromium to increase strength, hardenability. It comined with carbon to form wear resistance micro-constituents. Vanadium is used in the production of tool steel, spring steel, high speed steel & pearlite chromium steel.

Killed steel →

Killed steels are completely deoxidised steels & the commonly used deoxidising elements are silicon & chromium. ~~They are~~ Their solidification doesn't cause the formation of CO. Ingots & casting of killed steel have a homogeneous structure & no gas porocity (Blow holes).

Semikilled steel →

Semikilled steel is deoxidised but less than killed steel. This results in the presence of just enough oxygen in the molten steel. This oxygen reacts with carbon forming sufficient CO to counter balance the solidification shrinkage.

Rimming steel →

Rimmed steels are low carbon steels that is partially deoxidised or non-oxidised carbon content to less than 0.25% & manganese content ~~is~~ to is less than 0.6% in rimmed steel.

Rimmed steels evolved a sufficient amount of carbon-monoxide during solidification.

Pit side practice →

Teeming →

Teeming means pouring of liquid steel in an ingot mould. The method of teeming affects the ingot quality. Three different methods are used in teeming to produce ingots.

(i) Direct pouring
(ii) Trendish teeming
(iii) Bottom teeming

Direct pouring →

~~The metallic steel is~~

The metal is teemed from the mould directly in the mould. The rate of pouring can be controlled by the use of different sizes & designs of nozzles. The rate of teeming increases as the nozzle diameter increases due to erosion. The size of the nozzle employed varies with the type of steel to be teemed.

remedies →

The metal stream directly hits the bottom plate of the mould, the wear of the bottom plate is quite severe in direct teeming.

This is used for teeming rolling ingots.

Tundish teeming :-

The ingot should be teemed by a pipe like metal stream at a ~~unique~~ uniform rate to minimise ingot defects. A tundish is, therefore, inserted between the ladle and the ingot mould to ensure uniform metal stream while teeming from top.

The tundish is the last metallurgical vessel through which molten metal flows before solidifying in the continuous casting mould, during the transfer of metal through the tundish.

Molten steel interacts with refractories, slag & the atmosphere. Tundish are often made of steel & are lined with some kind of liner, which is always a refractory material often in brick form.

A stopper may be provided in the tundish to further regulate the flow.

Tundish is used teeming forging ingots & specially alloy steel ingots.

Bottom teeming :-

This is also known as uphill or, indirect teeming. Steel is teemed into a vertical runner which is connected at the bottom to a horizontal through runner, the end of which with an elbow shape, opens up in the bottom of the mould.

The vertical runner is a cast iron pipe. The horizontal runner is also a cast iron pipe but in two halves cottered together. In some designs a square shape from outside is used.

The benefits of bottom pouring -

a) Reduce slag in casting
b) Easier fill-up of mould
c) Controlled & faster pouring

Use of bottom teeming is economically justifiable only if the superior quality of the ingot is necessarily required.

Countinuous Casting of steel →

Continuous casting is also called strand casting, in the process where by molten metal is solidified into a "semifinished" billet, bloom or slab for subsiquent rolling in the finishing mills. It is used to cast metals of uninterrupted lengths.

Continuous casting has been widely accepted as the most important production process in the steel industry. In the casting process, molten steel from the ladle flows through the tundish into a mould. Within the mould, the molten steel breezes against the water-cooled copper mould walls forming a solid shell.

Principle & Operation →

* The equipment for continuous casting of steel consists of →

a) The ladle to hold steel for teeming
b) The tundish to closely regulate the flow of steel in the mould.
c) The mould to allow adequate solidification of the product.
d) The withdrawal rolls to pull out the ingot continuously from the mould.
e) The cooling sprays to solidify the ingot completely.
f) The bending / cutting device to obtain handlable lengths of the product.
g) The auxiliary electrical / mechanical gear to help run the machine smoothly.

operation →

The mould is open at both ends and is water cooled. The operation is started by fixing a dummy plug-bar to temporarily close the bottom of the mould. Steel is ~~slowly~~ slowly poured in the mould via a tundish and as soon as the mould is full to a certain level withdrawal of the plug begins. The rate of withdrawal must exactly match with the rate of pouring for smooth operation of the machine. Uninterrupted pouring and simultaneous withdrawal gives rises to the whole cast being poured in the form of one piece which may be cut into smaller pieces as per the requirement.

In order to expedite the process ingot does not completely solidify in the mould. As soon as a sufficiently thick skin, which would be able to stand the pressure of liquid core is formed, the withdrawing from the mould commences. It is then cooled by (secondary cooling.

Principle →

The principle of moving the mould is known as Junghan's principle. In this mould is moved up & down variously, through a stroke of 3-10mm, depending upon the characteristic of steel being cast. The speed of downward to upward stroke is generally dissimilar & the ratio may vary in the range of 25-50 %.

Different types of casters :-

Different types of casting machines are :-

a) The vertical type
b) The vertical-mould & horizontal-discharge type.
c) The curve mould ('S' type)

Vertical type -

It is the 1st continuous casting system where in the mould and the discharge are both vertical. Liquid steel is brought to the machine in a stopper controlled ladle & is teemed in a stopper controlled tundish which regulates the flow of steel to the mould. Below the mould is the secondary cooling zone in which rollers are set to make close contact with the ~~ingot~~ ingot. The water spray nozzles are interspersed in between those rolls. It is also known as roller apron. These hold the product fairly tightly to support the withdrawal rolls are situated just below the roller apron. The cut-off torch travels at the same speed as that of the withdrawal by clamping the product.

The vertical-mould & horizontal-~~dis~~ discharge type :-

This is a modification over the earlier vertical design to reduce the overall height of the machine. The mould, the roller apron design and the pinch are similar to those in a vertical machine. After the product emerges from the pinch rolls it is bent to obtain the discharge horizontal. The cutting torch moves horizontally.

A horizontal set of straightening rolls become necessary. A saving of 30% in height is thus possible by this design. This was popular for small & medium size cross sections.

The curved mould (S-Type) →

This is the latest design now almost universally adopted for continuous casting of almost any section like billets, blooms and slabs.

The characteristics of this machine are -

a) The mould is itself curved mould rather than straight one employed in the earlier two design.

b) The strands come out of the mould in curvilinear fashion with a fixed radius.

c) It is bent before the entire cross-section is solidified.

d) The curved strand is in fact straightened after it is fully solidified and cooled to the designed extent.

The withdrawal rolls carry out bending as well and hence should be of adequate strength. It is also called "low head" machine. The S-type machine is however more popular name.

The radius of curvature of the strand should be as high as possible to help smooth operation.

Mould →

The mould is made out of drawn copper tube or machined out of a solid block or is a welded plate construction of high conductivity electrolytic grade copper. The mould is water cooled. It has open bottom & hence is closed by a dummy plug bar in the beginning. The strand withdrawal begins by withdrawing this dummy bar. It is nearly 75-140 cm. in length.

The primary function of mould are -

1. To obtain enough shell thickness of solidified steel.
2. To equalize temperature all through liquid steel mass.
3. To ensure internal and surface quality of the product.

Mould maintainance →

The modern moulds are tapered to narrow down ~~through~~ towards the bottom. This is to accommodate the shrinkage effect on solidification & yet remain as far as possible in contact with the steel surface & thereby effectively extract heat.

Moulds are ~~invenib~~ invariably lubricated to assist stripping. Moisture free rape-seed oil is almost exclusively used because of its minimum smoke & flame. For smooth operation a film of about 0.025 mm in thickness over the mould walls is essential. The oil is supplied continuously from a ring similar in shape to that of the

cross-section of the mould, during casting.

Advantages of continuous casting :-

(i) Reduce weight
(ii) Faster machining speeds for improve productivity
(iii) Better surface finish
(iv) Longer tool life
(v) Compact lead free chips
(vi) Enhance wear resistance
(vii) Improvement of steel quality
(viii) Better yield
(ix) Saving of energy and manpower.

Disadvantage of continuous casting :-

(i) The biggest & only disadvantage is the cost of setup.
(ii) It is not practicle to use this method for small quantities or special shape of a product.

Mould maintainance :-

Mould maintainance refers to the ~~clo~~ cleaning, repair, problem shooting, disassembling & assembling.

Maintainance is perform when any problem arises & it is also depending over the life of the mould.

Bloom →

The casters used in bloom casting are -

a) Conventional bloom caster
b) blown bloom caster
c) beam block caster
d) Semi continuous bloom caster

Bloom casters solidified sections of 300/400 mm. & beam block caster produced large, dog bone like sections that are directly poured into an 'I'-beam or 'H'-beam rolling mill.

Billets →

Billets are solid lance of metal with square & circle cross sections. They can be made of virtually any type of metal & alloy to virtually any size to suit the part & production specification. Billets are produced by continuous casting or hot rolling method.

Slab →

The production of flat products liquid steel is generally cast in form of slabs usually in the thickness range of 150 mm. to 350 mm. These slab are inspected, scarfed & then reheated in slab reheating furnace to the rolling temp. before being rolled to hot rolled coil in a semi-continuous or continuous hot strip mills.

AOD process → (Argon Oxygen Decarburization)

It is a process primarily used in stainless steel making and other high grade alloy with oxidisedable elements such as chromium & aluminium.

After initial melting the metal is then transferred to an AOD vessel, where it will be subjected into 3 steps of refining ① decarburization ② reduction ③ desulphurization.

AOD process → (Argon Oxygen Decarburization)

This is carried out in a special AOD converter which is solid bottom vessel with tuyeres provided on the sides. The tuyeres are few in number depending upon the capacity. The vessel is lined with basic magnesite refractory. Molten charge from arc furnace is transferred to this vessel and blown, with argon-oxygen mixture, the proportion of which varies from 1:3 in the beginning through one or two discrete stages to 3:1 for the final part of the blow. The temp. of the bath is nearly 1710°C.

Total duration of an AOD heat is around 2 hrs and the lining life is around 80 heats. It is also effective in obtaining good sulphur removal by using argon stirring at the end.

VOD → (Vaccum Oxygen Decanburization)

Extensive decanburization is achieved by vaccum oxygen decanburization (VOD) of unif.

The VOD system essentially consist of a vaccum tank, a ladle furnace with or without argon stirring a lid with oxygen lancing facilities etc. The ladle has a free board of about a metre to contain vicknt agitation of the bath during lancing. The charge ingradients are similar to those in AOD process.

The charge is melted in an arc furnace and the molten metal with around 0.7-0.8% carbon is transferred to the ~~VOD process~~. The VOD system. This unit is normally used furthen decanburization of high alloy steel grades usually to remove carbon without affecting the content of chromium in the production of stainless steel grades.

The carbon can be lower to around 0.02%. at around 15-18% chromium at a temp. 1600°C & the time taken of VOD process is about 2-2½ hrs.

1. Extensive decanburization of low chromium losses.
2. Flexibility to use high carbon alloying materials of lower cost.
3. High rate of chromium recovery by proper addition
4. Chemical heating of liquid steel.
5. Improve conditions for desulphurization by proper addition.
6. Improve conditions for Inclusion floatation.

VAD → (Vaccum Arc Degassing).

This process was originally used for H_2 removal from the liquid steel but presently it is ~~being~~ also being used for (secondary refining pressure ~~depends~~ depended reaction are the reason for the treatment of liquid steel in this process.

Degassing is carried out either by placing the steel ladle under ~~vaccum~~ vaccum by recirculation of liquid steel in vaccum. Some N_2 removal from liquid steel during vaccum degassing is possible provided the steel is fully killed & has lower sulphur content.

Degassing process →

In degassing process inert gasses are ~~done~~ pumped into aluminium melts to remove hydrogen & prevent subsequent porosity in cast parts. Generally, the gasses are diffused through rotors to maximize gas efficiency.

Degassing is a crucial step of process after mixing to eliminate residual pores in the slurry. These pores can be introduced during either mixing or the chemical reaction, or they can form as a result of entrapped air during casting.

Commonly nitrogen, argon, helium, and other inert gases are used for ~~deg~~ degassing. Inert gases like argon / ~~ar~~ nitrogen are used into the molten metal to remove

hydrogen. As inert gas bubbles move up to the molten metal hydrogen diffuses into the inert gas & essentially disappears.

Working of degassing process:-

As the vaccum degassing system withdrawal all the gases from the vapour phase, it reduces the system pressure below atmospheric; which promotes the dissolved gas molecules in the liquid to diffuse into vapour phase. Thus, the concentration of gas in the moltenmetal/liquid is reduced.