GENERAL PLANT AWARENESS

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STEEL AUTHORITY OF INDIA LIMITED

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Chapter – 1

RAW MATERIAL HANDLING PLANT

1.1 Introduction

Raw Material Handling Plant(RMHP) or Ore Handling Plant(OHP) or Ore Bedding and Blending Plant(OBBP) play a very important role in an Integrated Steel Plant. It is the starting point of an integrated steel plant, where all kinds of raw materials(Except Coal) required for iron making/steel making are handled in a systematic manner, e.g., unloading, stacking, screening, crushing, bedding, blending, reclamation, etc.

Different types of major raw materials used in an integrated steel plant are:

- Iron Ore
- Lime stone
- Dolomite
- Manganese Ore
- Ferro and Silico manganese
- Quartzite
- Coal

For Blast Furnace route Iron Making the main raw materials required are:

- Iron ore lump
- Blast furnace grade lime stone
- Blast furnace grade dolomite
- Coke
- Sinter
- Scrap
- LD Slag
- Mn Ore
- Quartzite

The main objective of raw material handling plant (RMHP)/ore handling plant(OHP)/ore bedding and blending plant(OBBP) is to

- Homogenize materials from different sources by means of blending
- Supply consistent quality raw materials un-interruptedly to different customers
- Maintain buffer stock.
- Unloading of wagons/rakes within specified time norm as permitted by railway
- Raw material preparation (like crushing, screening etc.).

The main functions of RMHP/OHP/OB&BP are :–

- Unloading& stacking of raw materials,
- Screening of iron ore lump & fluxes material,
- Crushing of coke/flux for base mix/ sinter mix preparation,
- Dispatch of processed inputs to customer units

Different types of raw materials such as iron ore lump, iron ore fines, limestone, dolomite, manganese ore, etc, are supplied by SAIL mines (JGOM of BSL, OGOM of RSP and BGOM, BSP) or purchased from outside parties.

1.2 Different Raw Materials and their Sources

Sl. No.	Raw Materials	Sources
1.	Iron Ore Lumps (IOL)	Barsua, Kalta, Taldih, Kiriburu, Meghahatuburu, Bolani, Manoharpur, Gua, Dalli, Rajhara, Rowghat
2.	Iron Ore Fines (IOF)	Manoharpur, Gua, Dalli, Rajhara Barsua, Kalta, Taldih, Kiriburu, Meghahatuburu, Bolani, Rowghat
3.	Blast Furnace (BF) grade Lime Stone	Kuteshwar, Nandini
4.	BF grade Dolomite	Birmitrapur, Sonakhan, Bhawanathpur, Tulsidamar, Bhutan.
5.	Steel Melting Shop (SMS) grade Lime Stone	Jaisalmer, Imported lime-stone from Dubai & Oman.
6.	SMS grade Dolomite	Belha, Baraduar, Hiri & Bhutan
7.	Quartzite	Bobbili (AP)
8.	Manganese Ore	Barjamunda, Gua Ore Mines, MOIL(Purchased)
9.	Mixed Breeze Coke	Generated inside the plant (Blast Furnace & Coke Ovens), also inter plant transport as per requirement
10.	Mill Scale	Generated inside the plant
11.	Flue dust	Generated inside the plant
12.	LD Slag	Generated inside the plant

Recent trend in Raw Material Usage: Usage of pellet in Blast Furnace
Pelletising:

Pelletization is an agglomerating process by balling in the presence of moisture and suitable additives like bentonite, lime etc. into 8-20 mm or larger size. These green pellets are subsequently hardened for handling and transportation by firing at 1200 – 1350^0C. Many times cement is added and pellet can be divided into

a) Acid Pellets &
b) Basic Pellet

Low grade iron ore, iron ore fines and iron ore tailings/slimes accumulated over the years at mine heads and generated during the existing washing processes, need to be beneficiated to provide concentrates of required quality to the Indian steel plants. However, these concentrates are too fine in size to be used directly in the existing iron making processes. For utilizing this fine concentrate, pelletization is the only alternative available.

ADVANTAGES OF PELLETS:

Iron ore pellet is a kind of agglomerated fines which has better tumbling index as compared to that of parent ore and can be used as a substitute for the same.
Iron ore pellets are being used for long in blast furnaces in many countries where lump iron ore is not available. In India, the necessity of pelletisation is realized because of several reasons and advantages. The excessive fines generated from the iron ore mining and crushing units for sizing the feed for blast furnace and sponge iron ore plants are mostly un-utilized. Pelletisation Technology is the only route that is going to dominate the Indian steel industry in future.

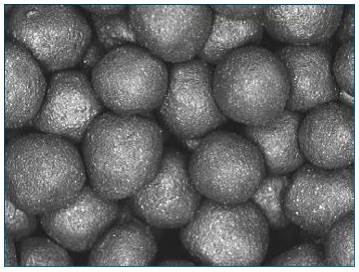
Pellets have:-

• Good Reducibility:
Because of their high porosity that is (25-30%), pellets are usually reduced considerably faster than hard burden sinter or hard natural ores/lump ores.
• Good Bed Permeability:
Their spherical shapes and containing open pores, gives them good bed permeability. Low angle of repose however is a drawback for pellet and creates uneven binder distribution.
• High uniform Porosity (25-30%):
Because of high uniform porosity of pellets, faster reduction and high metallization takes place.

• Less heat consumption than sintering.
Approx. 35-40% less heat required than sintering.
• Uniform chemical composition & very low LOI:
The chemical analysis is to a degree controllable in the concentration processing within limits dictated by economics. In reality no LOI makes them cost effective.
• Easy handling and transportation.
Unlike Sinter, pellets have high strength and can be transported to long distances without fine generation. It has also good resistance to disintegration.

Pellets

Green Balls



Fired Pellet
Good Quality

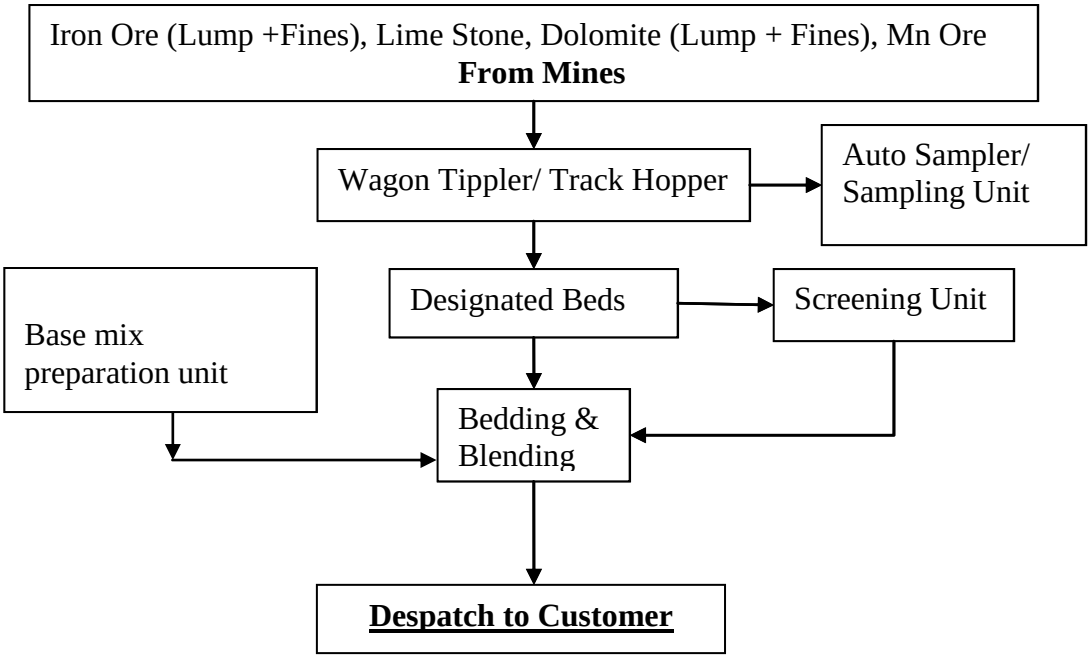
Fired Pellet
Bad Quality

Right quality raw material is basic requirement to achieve maximum output at lowest operating cost. Quality of raw materials plays a very important and vital role in entire steel plant operation. Quality of raw materials (incoming) and processed material (outgoing) is monitored by checking the incremental samples collected from the whole consignment Samples are collected at Auto Sampling Unit or Sampling Unit. The samples prepared after quarter and coning method are sent for further analysis.

1.3 Quality Requirement of Raw Materials

Sl. No.	Material	Chemical	Physical
1.	Iron Ore Lumps	Fe SiO_2 Al2O3 62.3-63.2 % 1.8-2.8% 2.6-3.0 %	-10mm= 5% Max +40mm= 5% max
2.	Iron Ore Fines	Fe SiO_2 Al2O3 62-63% 2.3 – 3.6% 2.8 – 3.3%	+10mm= 5% Max - 1mm= 30 % max
3.	Lime Stone (BF) grade.	CaO MgO SiO2 43 - 50% 2.25-5% 3.5-6.5%	-5mm= 5% max +40mm= 5% max
4.	Dolomite (BF) grade.	CaO MgO SiO2 30% 18% 5%	-5mm= 5% max +50mm= 5% max
5.	Lime Stone(SMS) grade(Jaisalmer), Imported(Dubai)	CaO MgO SiO2 52% 1% 1.5 %	-40mm= 7% max +80mm= 3% max
6.	Dolomite(SMS) grade	CaO MgO SiO2 29 % 23.5% 2.5 %	-40mm= 5% max +70mm= 5% max
7.	Mn Ore	Mn= 30% min	10-40mm size
8.	Coke Breeze	Fixed C>70%, SiO2-12-15% Moisture- 10-15% max	< 15mm

1.4 Process Flow Diagram of RMHP/OHP/OBBP



1.5 Material Handling Equipments

Major equipment which are used in RMHP/OHP/OBBP are-

Sl. No.	Major Equipments	Main Function
1.	Wagon Tippler	For mechanized unloading of wagons
2.	Car Pusher/ Side Arm Charger	For pushing/pulling the rakes for wagon placement inside the wagon tippler for unloading
3.	Track Hopper	For manual unloading of wagons
4.	Stackers/ Stacker cum Reclaimer (SCR)	For stacking material and bed formation
5.	Barrel / Bucket Wheel Reclaimer /SCR	For reclaiming material from the beds
6.	Transfer Car	For shifting equipments from one bed to another
7.	Screens	For screening to acquire desired size material
8.	Crushers	For crushing to acquire desired size material
9.	Belt Conveyors	For conveying different materials to the destination/ customers.

Unloading, Screening, Stacking and Blending of different Raw materials

Depending on the types of wagons, raw materials rakes supplied by the mines through railways are being placed either in wagon tippler or track hopper for unloading. The types of wagons for unloading in wagon tippler and /or track hopper is as given below –

For Wagon Tippler - BOXN, BOXC, BOST, NBOY

For Track Hopper - BOBS, NBOBS,

The material such as Iron Ore Lumps, Iron Ore Fines, Lime Stone, Dolomite, etc, unloaded in wagon tippler or track hopper is being conveyed through the series of belt conveyors to the designated bed and stacked there with the help of stackers/ Stacker Cum Reclaimer. Bed formation takes place by means of to and fro movement of stacker.

Number of optimum layers in a bed is controlled by stacker speed. Number of layers in a bed determines the homogeneity of the bed and is reflected in standard deviation of final bed quality. More is the number of layers; more is the bed homogeneity and lower the standard deviation.
Blending is the mechanized process of stacking & reclaiming to get optimum result in physical & chemical characteristics of raw material; this means that blending is a process of homogenization of single/different raw materials over a full length of pile/bed. Homogenization increases rapidly as the no of layers exceeds 400 & the effect becomes constant after 580 layers.

Iron Ore Lump Screening:

Screening of Iron Ore Lumps is necessary because Iron Ore Lumps coming from mines contains lot of undersize fraction (-10 mm.), which adversely affects the blast furnace operation. Therefore, this undersize fraction (fines) is screened out at Iron Ore Lumps screening section and then stacked in the designated Iron Ore Lumps beds, from which this screened ore is supplied to blast furnace. Screened Iron Ore Lumps is also called Sized Iron Ore.

Sized Iron Ore

Base Mix Preparation:

In some plants, base mix or sinter mix or ready mix for sinter is being prepared at RMHP/OHP/OBBP for better and consistent quality sinter and also for increasing sinter plant productivity. Base mix is a near homogeneous mixture of Iron Ore Fines, crushed flux (limestone and dolomite), crushed coke, LD slag fines, mill scale, flue dust, etc, mixed at certain proportion.

Flux:

Flux is a mixture of crushed Lime Stone and Dolomite in certain proportion required in sinter making. Fraction of (-3mm.) in crushed flux is 90% and more. The main function of flux is to take care of gangue in blast furnace and also to increases the rate of reaction to form the good quality slag. Flux acts as a binder in sinter making to increase the sinter strength. Hammer crushers are used for crushing Limestone & Dolomite Lumps to required size i.e.(-3mm.) > 90%.

BF Grade Dolomite

BF Grade Lime stone

Dolo-fines

Coke Breeze:

Another important ingredient in base mix is crushed coke of size fraction (-3mm.) 85% minimum. Coke for base mix preparation is received from coke ovens and blast furnace and is called mixed breeze coke. The size fraction (+ 12.5 mm.) is screened out and sent along with sinter to blast furnace as a nut coke. The under size material is crushed in the two stage roll crusher i.e. primary and secondary roll crusher to achieve requisite size fraction of (-3mm.) 85%.

1.6 Customers of RMHP

Sl. No.	Customer	Product/ Material
1.	Blast Furnace	Size Ore or Screen Iron Ore Lump
2.	Sinter Plant	Base Mix or iron ore fines, crushed Flux, crushed coke, nut coke
3.	Calcining/ Refractory Plant	SMS grade Limestone & Dolomite

1.7 Benefits of RMHP/OHP/OB&BP

Provides consistent quality raw materials to its customer and also controlling the cost by:

- Minimizing undersize in iron ore lump & flux by means of screening
- Consistency in chemical & physical analysis by means of bedding & blending
- Input quality over a time period is known
- Metallurgical waste utilization

1.8 Safety and Environment

RMHP/OHP/OB&BP is a dust prone department due to handling of various types of Raw materials and conversion of lumpy mass into fines by crushing & screening, hence use of dust mask, safety goggles, safety helmet, safety shoes etc. is must. To take care of surrounding area Dust Extraction & Dust Suppression system is installed. In some plants dry fog dust suppression system also used. Housekeeping is a major challenge for smooth operation in this department and requires special attention. Spillage of material, water, oil, belt conveyor pieces is to be controlled by effective housekeeping. This also leads to personal and equipment health and safety. It makes the surrounding area operation friendly.

Chapter – 2

COKE OVENS AND COAL CHEMICALS

2.1 Introduction

Coke making is the process to convert coking coal, through a series of operations, into metallurgical coke. The process starts from unloading of the coal at the wagon tipplers & ends at sizing & transportation of coke to Blast furnace.

Formation of Coal:

The plant & vegetations buried under swamp bottom during earthquakes or due to other environmental changes were subjected to heat & pressure. During the initial period plant & vegetations decay to form PEAT. Over a long period of time water is forced out due to tremendous pressure of the overburden & due to heat generation, converting the mass to LIGNITE. Continuous compaction & ageing converts the Lignite to Bituminous coal. This process takes million of years.

Types & Sources of Coking Coal:

Coals are primarily divided into two categories i.e. coking coals and non coking coals. Coking coals are mainly used in steel industries for coke making.

Indigenous coking coals are classified as:

- ✈ Prime Coking Coal (PCC)
- ✈ Medium Coking Coal (MCC)

While imported coking coals are classified as.

- ✈ Hard coking coals (HCC)
- ✈ Soft Coking Coal (SCC)

Coal is extracted from coal mines & processed in the coal washeries to lower down the ash content to make it fit for coke making.

The different sources of Indigenous coking coal are named after the respective washeries while imported coking coals are named after the name of countries and are as follows:

PCC	- Bhojudih	MCC	- Kathara
	- Sudamdih		- Swang
	- Munidih		- Rajrappa
	- Patherdih		- Kedla
	- Dugda		- Nandan
	- Mahuda		- Dahibari
	-Chasnala		
	- Jamadoba		
	- Bhelatand		
ICC (Hard)	– Australia	SCC	-Australia
	- USA		-USA
	-Mozambique (Benga)		
	- Indonesia		
	- Canada		

2.2 Properties of Coking Coal

Percentage of Ash: Lower the ash percentage better is the coal. Indian coal normally contains a high percentage of ash. This is reduced to some extent by suitable beneficiation process at the washeries.

Volatile Matter (VM): This is the volatile matters present in the coal which goes out as gas during carbonization.

Free Swelling Index (FSI): The free- swelling index is measure of the increase in volume of coal when heated under specific conditions. It is also known as Crucible swelling number (CSN)

Low Temperature Gray King coke Type (LTGK): The purpose of the test is to assess the caking properties of coal or coal blend and the yield of the various byproducts during carbonization.

Gieseler Fluidity: This test measures the rheological properties of coal. This test tells about the initial softening temperature, temperature at which maximum fluidity occurs, Plastic range, maximum fluidity and re-solidification temperature. This is expressed in dial division per minute (DDPM). This test tells about the compatibility of different coals in coal blend.

Inherent Moisture: This gives a very good idea about the maturity of the coal with advancement of rank the inherent moisture generally comes down.

Mean Max Reflectance (MMR): Rank of coal is determined by measuring the reflectance of coal, which is determined by MMR value. MMR is directly proportional to the strength of COKE.

Table -1: **Properties of incoming Indigenous and Imported coking coals**

Coal	Ash	VM	FSI	LTGK	Inherent moisture	MMR
PCC	19 - 23	21-23	>2.0	>E	< 1.5	1.10
MCC	20 – 25	23-25	>1.0	>E	< 1.5	0.85
Imported Soft	8-10	25-30	>5.0	>G4	< 1.5	0.9
Aust Hard	8-10	18-20	>5.0	>G4	< 1.5	1.25
USA Hard	8-10	24-26	>5.0	>G4	< 1.5	1.10
Mozambique (Benga)	12 - 14	24-26	>5.0	>G4	< 1.5	1.15
Indonesia Hard	10-12	24-26	>5.0	>G4	< 1.5	1.10

2.3 Coal Handling Plant

Coke is one of the most important raw materials used to extract iron from the iron ore. The success of Blast Furnace operation depends upon the consistent quality of coke, which is used in Blast Furnace. The quality of coke depends upon the pre-carbonisation technique, carbonization & post-carbonization techniques used in Coke ovens. Pre-carbonization technique is controlled by Coal handling Plant.

Unloading & lifting of coal:

Washed coals from washeries are received at the Coal Handling Plant by Railways wagons. Generally 59 wagons, called a rake, are brought to the plant at a time. These wagons get unloaded in wagon tipplers. Here the wagons are mechanically clamped & turned up to 172° to discharge the coal onto down below conveyors. Then through a series of conveyors the coal is stacked in coal yard through a Stacker or directly to the silos by tripper car. The coal yard is divided into separate segments where different types of coal can be stacked in respective earmarked areas. It is very important to stack different types of coal separately so as to avoid mix up of two types of coal. Mix up of coal is highly detrimental for coke making. From the coal yard, coal is reclaimed through Reclaimer & by a series of conveyors gets transported to either crushers or silos as per prevailing system in different SAIL plants.

In some plants, coal from different sources are tippled and carried by conveyors directly to the silos. Care is taken to load same grade of coal in the same silos, from where it is taken through weigh feeders to the hammer crushers and then the entire blended coal is transported to different coal towers by conveyors.

Crushing & Blending:

The sequence of crushing & blending is different in different SAIL plants. The system of crushing the coal & then blending is followed in RSP, whereas blending is done before crushing in other SAIL Plants.

Importance of Crushing:

Coal is a heterogeneous mixture of organic and inorganic materials. Finer crushing of good coal leads to increase in specific surface area of coal grains which will increase the quantity of plastic material required for wetting and enveloping the inert material. Courser crushing of inferior coals leads to generation of courser particles which are centers of weakness in coke matrix. Due to difference in the plastic and shrinkage behavior of these inert rich particles and rest of the charge, local stresses are developed and cracks appear adversely affecting coke quality. Crushing should ensure minimum differences between different size fractions. Organic materials-rich particles are softer than those of inorganic-rich or ash-rich particles. Ash or inerts content is higher in larger size particles (>5 mm size) and such particles needs finer crushing The mineral matter/inert reach component should be crushed to finer sizes compared to the reactive component for even dispersion of inert particles in the coal charge.

Fine crushing of coal is essential to homogenize the different inherent constituents of coal blend. Crushing of coal is done by hammer crusher. Crushing also influence the bulk density of coal charge in the ovens. Bulk density is the compactness or close packing of the coal charge in the oven. Higher the bulk density better is the coke strength. It is desirable to have 80% to 82% of -3.2mm size coal after crushing. This is known as crushing Index. However over crushing is not desirable as this reduces the bulk density & increases micro fines which cause jamming in gas off-take system.

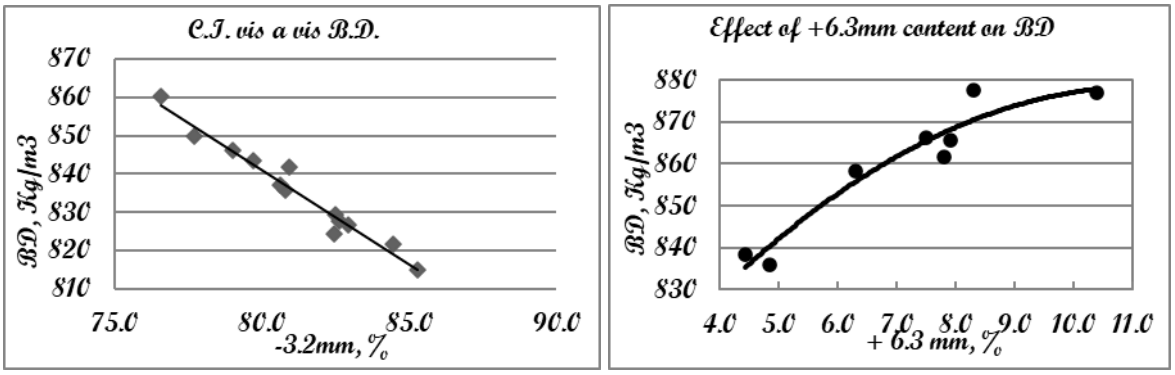


Fig : Bulk density variation with Crushing Index and +6.3 mm content in coal charge

Importance of Blending:

Different coal has different properties. Some coals may be good in coking properties but high ash and poor rank while others may have low ash and desired rank but poor coking properties. These properties are additive in nature except Fluidity. As evidenced from the table under properties of coal the Indigenous coals contain a relatively higher percentage of ash and poor coking properties & Imported coals contain a relatively lower percentage of ash and better coking properties. Hence blending of both types of coal is necessary for obtaining the desired quality of coal blend. Blending plays a vital role in producing good metallurgical coke. Blending is a process of mixing the different types of coal, i.e. PCC, MCC, Imported Soft & Hard, in different percentage to obtain the desired quality of the blend coal. However blending is to be done in a very accurate manner so that required coke property does not get adversely affected. Blending is generally done by adjusting the discharge of different types of coal from bunkers or silos to a common belt. The different type of coals gets thoroughly mixed during crushing where blending is done before crushing. In case where blending is done after crushing proper mixing takes place at several transfer points, i.e. during discharge from one conveyor to another conveyor through a chute, during transportation to coal towers or service bunkers.

COAL BLEND QUALITY:

ASH	12% max
VM	23 - 25%
MMR	1.15 to 1.20
SULPHUR	< 0.7 %

FSI	5 to 6
MAXIMUM FLUIDITY	300 to 600
MOISTURE	7 to 9 %

2.4 Carbonization Process

The process of converting blend coal to metallurgical coke is known as carbonization. It is defined as heating the coal in absence of air. It is also the destructive distillation of coal. The carbonization process takes place in a series of tall, narrow, roofed chambers made of refractory bricks called ovens. A specific number of ovens constitute a **Battery**. The ovens are mechanically supported by Structural & Anchorage.

A battery can be classified as per size & design. The most common classifications are:

a. **Tall Battery** – 7.0 m height.
   Small Battery – 4.5/5.0 m height.

b. **Recovery type battery** – Gas evolved during carbonization is collected and cleaned at by-product plant. This clean gas is then used as a fuel gas throughout the Plant. Different chemicals are extracted as by-products during cleaning of gas.

   Non-Recovery type battery – No by products are formed as the generated gas acts as the fuel.

c. **Top charge battery** – Conventional battery with charging from the top. The charging cars (machine that takes coal from coal tower to charge the ovens) run over the oven top and discharge the coal into the ovens through charging holes on the oven top.

   Stamp charged battery – A cake like mass is formed by ramming the coal and is charged by pushing the cake into the oven from Pusher/Ram side.

Blend coal from coal tower is charged from top to the ovens. Each oven is sandwiched between two heating walls from which heat is transmitted to the coal charge inside the oven. When coal is charged inside an oven, it gets heated up to form a plastic mass which re-solidifies to form coke near the heating walls. The heat passes to the next layer of coal and so on till they meet at the center. During the process of carbonization the coal charge first undergo de-moisturisation (drying) upto a temperature of 250°C. Then it starts to soften at around 300°C. It then reaches a plastic or swelling state during 350°C to 550°C. The entrapped gasses are then driven out at 400°C to 700°C. The calorific value (CV) of Coke ovens gas is around 4300 kcal/m^3.The gas is cooled to 80^0C by ammonia liquor/ flushing liquor. The mass inside the oven then re-solidifies (shrinkage) beyond 700°C. Finally coke is produced as a hard & porous mass at around 1000°C.The total time taken for full carbonization is called coking time or coking period. The hot coke is then pushed out from the ovens. The hot coke is then cooled by water spray or dry nitrogen purging. This process is called quenching of coke. Generally coke is cooled by water spray for a period of 90 seconds and termed as quenching time. The cooled coke is then sent to Coke Sorting Plant for proper sizing & then to Blast Furnace.

Major Equipments:

Major equipment's/machines used in the process of coke making are:

- ✈ Charging car: It collects the blended coal from coal tower & charges to empty ovens.
- ✈ Pusher Car or Ram Car: Its functions are to level the charged coal inside the oven during charging & to push out the coke mass from inside the oven after carbonization.
- ✈ Coke Guide Car: It guides the coke mass during pushing to the Quenching car.
- ✈ Quenching Car: It carries the hot coke to quenching tower & dumps the coke in the wharf after cooling.

These machines have a lot of mechanical and electrical engineering devices in them. They have hydraulic operating systems run by VVFD (Variable voltage and variable frequency drive) drives controlled by PLC (Programmable Logical Controller) system. They are connected by radar based communication system which involves state of art technology.

Quenching of Coke:

There are two method of quenching the hot coke:

1. **Wet Quenching**: This is the conventional quenching system, where the red hot coke is cooled by spraying it with water (phenolic water / BOD water). The coke thus produced contains around 5% of moisture.
2. **Dry Quenching:** In this system, the red-hot coke is discharged into a closed chamber, where it is cooled by purging nitrogen into it. The sensible heat of the hot coke is recovered to produce steam. The coke thus produced contains around 0.2% of moisture and is of good quality.

2.5 COKE SORTING PLANT:

The coke, after wet quenching is dumped from the quenching car to a long inclined bed called wharf. The Quenching car operator should dump the quenched coke uniformly on the wharf from one end to the other. Quenched coke should be allowed to remain in the wharf for about 20 minutes (retention time) so that the heat remained inside the coke comes out & evaporates the surface moisture. To maintain this retention time, wharf is to be emptied out from one side & gradually progressing to the other side. If any hot coke remains after quenching, then they are cooled by manual water spray and is known as spot quenching. However this spot quenching is undesirable as it increases the moisture content in coke. The cooled coke is then taken to an 80 mm screen. The +80mm coke fractions are sent to coke cutter / crusher to bring down the size. The hard coke of size +25mm to -80mm size are then segregated to send to Blast Furnace. Coke fraction of +15mm to -25mm, which is called Nut coke, is also segregated & sent to Sintering Plants. The -15mm fractions, called fine breeze or breeze coke, are also sent to Sintering Plants.

In case of dry quenching, the coke is discharged from the chamber and passes through the same process of sizing and screening.

2.6 PROPERTIES OF COKE

ASH:

Ash in coke is inert & becomes part of the slag produced in the Blast Furnace. Hence, ash in coke not only takes away heat but also reduces the useful volume of the furnace. Hence it is desirable to have lower ash content in the coke. The desired ash content is less than 15%.

VOLATILE MATTER (VM):

The VM in coke is an indicator of completion of carbonization & hence the quality of coke produced. It should be as low as possible, i.e. < 1%

GROSS MOISTURE (GM):

It has got no role to play in the furnace. It only takes away heat for evaporation. Hence least moisture content is desirable. However during water quenching certain amount of moisture is inevitable. A level around 4.5% is desirable.

MICUM INDEX:

Micum index indicates the cold strength of coke. M_{10} value indicates the strength of coke against abrasion. Lower the M_{10} value better is the abrasion strength. A M_{10} value of around 8.0 indicates good coke strength. M_{40} value indicates the load bearing strength or strength against impact load. Coke having lower M_{40} value will crumble inside the furnace which will reduce the permeability of the burden and cause resistance to the gasses formed in the furnace to move upwards. A good coke should have a M_{40} value more than 80.

COKE REACTIVITY INDEX(CRI):

Coke reactivity determines percent weight loss of coke, as a result of carbon dioxide action on the coke at temperature 1100℃. It is the capacity of the coke to remain intact by withstanding the reactive atmosphere inside the furnace. Hence less the CRI value, better is the coke. Desirable value should be in the range of 21 - 24.

COKE STRENGTH AFTER REACTION (CSR):

It denotes the strength of the coke after passing through the reactive environment inside the furnace. CSR for a good coke should be in range of 64-66. It is also known as hot strength of coke.

CRI &CSR are also known as hot strength of coke.

COKE SIZE:

The size of coke is most important to maintain permeability of the burden in the furnace. The required size for Blast Furnace is more than 25mm size & less than 80mm size. If the undersize is more the permeability decreases as smaller coke pieces fill up the voids & increase the resistance to the flow of outgoing gasses. If the oversize is more the surface area of coke for the reactions reduces. Hence the size of the coke is to be maintained between +25mm & -80mm

ROLE OF COKE IN THE BLAST FURNACE:

Coke plays a vital role in Blast Furnace operation. For stable operation of the furnace, consistent quality of coke is most important. Variation in coke quality adversely affects the Blast Furnace chemistry. The roles of coke in Blast Furnace are:

- It acts as a fuel.
- It acts as a reducing agent.
- It supports the burden inside the furnace.
- It provides permeability in the furnace.

2.7 Coal Chemicals

Process of heating coal in absence of air to produce coke is called coal carbonization or destructive distillation. Purpose of coal carbonization is to produce coke whereas co-product is coke oven gas. From coke oven gas, various by products like tar, benzol, naphthalene, ammonia, phenol, anthracene etc. are produced. Generally high temperature coal carbonization is carried out in coke oven battery of integrated steel plants at temp of 1000-1200 deg. Centigrade.

In the by-product plant major byproducts like tar, ammonia and crude benzol are recovered from the coke oven gas evolved during coal carbonization. The output of the gaseous products, their composition and properties depend on the coal blend used for coking, the heating regime & the operating condition of the battery.

Tar separated out of coke oven gas as a mixture of large quantities of various chemical compounds. From tar, a number of products are separated in the tar distillation plant which have market demand. Among the tar products, naphthalene is the costliest item & its yield is 50-55 % of the tar distilled. Other tar products are road tar, Anthracene, pitch creosote mixture, medium hard pitch & extra hard pitch etc.

Ammonia in the coke oven gas is recovered as Ammonium sulphate, which is used as a fertilizer in agriculture sector. Output of crude benzol depends on the V.M content in the coal blend and temperature of coking. Light crude benzol is rectified in benzol rectification plant and the benzol products obtained are benzene, toluene, xylene, solvent oil etc. Yield of benzol products varies from 86-88% of the crude benzol processed. The by products recovered in the process are very important and useful .Tar is used for road making and as fuel in furnaces. Pitch is used for road making. The benzol products like benzene, toluene, phenol, naphthalene and xylene etc. are important inputs for chemical industries producing dyes, paint, pharmaceutical, insecticide, detergent, plasticiser and leather products.

The coke oven gas from Coke ovens contain lot of impurities, which needs to be properly cleaned before being used as a fuel gas for Coke Oven heating as well as elsewhere in Steel Plant. The impurities in

coke oven gas are mainly tar fog, ammonia, naphthalene, hydrogen sulphide, benzol, residual hydrocarbon and traces of HCN. Cleaning of coke oven gas is done by passing it through a series of coolers & condensers and then treating the gas in ammonia columns, saturators, washers, tar precipitators, naphthalene washers, benzol scrubbers etc. for removal of these impurities. After the cleaning operation, the final coke oven gas still contains traces of impurities. Quality of coke oven gas depends on the contents of various impurities and its heat value. Typical analysis of impurities in good quality coke oven gas is as follows:-Tar fog: 30 mg/Nm^3 ± 10mg, Ammonia- 30 mg/Nm^3 ± 10mg, Napthalene- 250mg/Nm^3 ± 50mg, Hydrogen Sulphide- 200 mg/Nm^3 ± 50mg, HCN- Traces, CnHm- 1.5 to 2.5% .

2.8 By Products Plants of Coke Ovens

The Gas generated in the Coke oven batteries during carbonization process is handled and cleaned in the By Product Plant. During the process of cleaning the gas some By Products are separated out and clean Gas is used as fuel in the plant. Following process are involved in cleaning the gas.

TAR AND LIQUOR PROCESSING PLANT

The tar and liquor processing plant process the flushing liquor that circulates between the by product plant and the coke oven battery. It also processes the waste water that is generated by the coke making process and which results from coal moisture and chemically bound water in the coal. The main functions of these plants are as follows:

- Continuous rapid separation of a suitable flushing liquor streams. This is the very important function since flow is needed to cool the hot oven exit gases down to a temperature which can be handled in the gas collecting system.
- Separation of a clean and tar free excess ammonia liquor for further processing.
- Separation of clean tar essentially free from water and solids.

Since the flushing liquor supply is very important, stand by equipment are normally provided for flushing liquor decanting and recirculation. The flushing liquor flows into tar decanters where the tar separates out from the water and is pumped to tar storage for processing in tar distillation plant. Heavier solid particles separate out from the tar layer and these are removed as tar decanter sludge. The aqueous liquor is then pumped back to the battery, with a portion bled off from the circuit which is the coke plant excess liquor or waste water. This contains ammonia and after the further removal of tar particles, it is steam stripped in a still.

PRIMARY GAS COOLER

After separation of tar and ammonia liquor from gas, gas is fed into gas cooler where temperature of gas is lowered down by means water sprinkling. Primary gas cooler are two basic types, the spray type cooler and the horizontal tube type. In spray type cooler the coke oven gas is cooled by direct contact with recirculated water spray. As the coke oven gas is cooled, water, naphthalene and tar condensed out. The condensate collects in the primary cooler system and is discharged to the tar and liquor processing plant.

ELECTROSTATIC TAR PRECIPITATOR

As the raw coke oven gas is cooled, tar vapour condenses and forms aerosols which are carried along with the gas flow. These tar particles contaminate and foul downstream processes and foul gas lines and burner nozzles if allowed to continue in downstream. The tar precipitator typically uses high voltage electrodes to charge the tar particles and then collect them from the gas by means of electrostatic attraction. The Tar precipitator can be installed before or after the exhauster.

EXHAUSTER

Exhausters are installed which sucks the gas generated in the batteries and sends to the desired destination for further processing. Another function of the exhauster is to maintain steady suction as per requirement so as to maintain the hydraulic main or gas collecting main (GCM) pressure. The exhauster is of prime importance to the operation of the coke oven battery. It allows the close control of the gas pressure in the collecting main, which in turn affects the degree of emission in the battery like door emission. A failure of the exhauster will immediately result in venting to atmosphere all the generated the raw coke oven gas through the battery flares / bleeder.

AMMONIUM SULPHATE PLANT (ASP)

Due to the corrosive nature of ammonia, its removal is very much necessary in by-products plants. The removal of ammonia from coke oven gas results into yield of ammonium sulphate**.** The ammonium sulphate processes are basically involves contacting the coke oven gas with solution of sulphuric acid.
Raw coke oven gas from Exhauster outlet is passed through the saturators filled with Sulphuric Acid (H_2SO_4), where ammonia present in the gas is precipitated in the form of ammonium sulphate. Acidity of the saturator liquor is maintained at 3 % to 5 %. This ammonium sulphate is sold as Fertilizer.

FINAL GAS COOLER (FGC)

Final gas cooler removes the heat of compression from the coke oven gas which it gains while flowing through the exhauster. This is necessary since the efficiency of many of the by-product plant processes greatly improved at lower temperature. Gas coolers typically cool the coke oven gas by direct contact with a cooling medium.

BENZOL RECOVERY PLANT (BRP)

Benzol present in the raw coke oven gas is removed in this unit. The gas is passed through solar oil / Wash oil in the scrubbers. The benzol gets absorbed in the oil. Benzol rich oil is fed to distillation unit where oil and crude benzol are separated. The oil is reused in the scrubbers. The clean coke oven gas is used by the consumers through gas net work maintained by Energy Management Department.

NAPTHALENE REMOVAL

Naphthalene is removed from coke oven gas in a gas scrubbing vessel using wash oil. The vessel can be of packed type and it can be of the void type in which the wash oil is sprayed into the gas in several stages.

BENZOL RECTIFICATION PLANT

Light crude benzol from benzol recovery plant is further processed in this unit and following by products are recovered:

a. Benzene
b. Toluene
c. Xylene
d. Carbon di-Sulphide (CS_2)

TAR DISTILLATION PLANT (TDP)

Tar recovered from GCPH is further processed in TDP. The main products of TDP are:

(a) Tar
(b) Pitch
(c) Pitch Creosote Mixture (PCM)
(d) Naphthalene
(e) Anthracene oil

ACID PLANT

Sulphuric acid is produced in acid plant by DCDA (Double Conversion Double Absorption) process. In this process sulphur is converted to Sulphur tri oxide (SO_3) in presence of catalyst Vanadium pentoxide (V_2O_5) and then to Sulphuric acid. This acid is used in Ammonium Sulphate plant for removal of ammonia from raw coke oven gas.

PETP / BOD PLANT

In Phenolic Effluent Treatment Plant (PETP) or Biological Oxygen Demand (BOD) Plant, the contaminated water generated from whole of coke oven is treated to make it clean from the effluents with the help of Bacteria. The treated water is then used for quenching hot coke in the quenching towers. The norms for different effluent after treatment at BOD plant are:

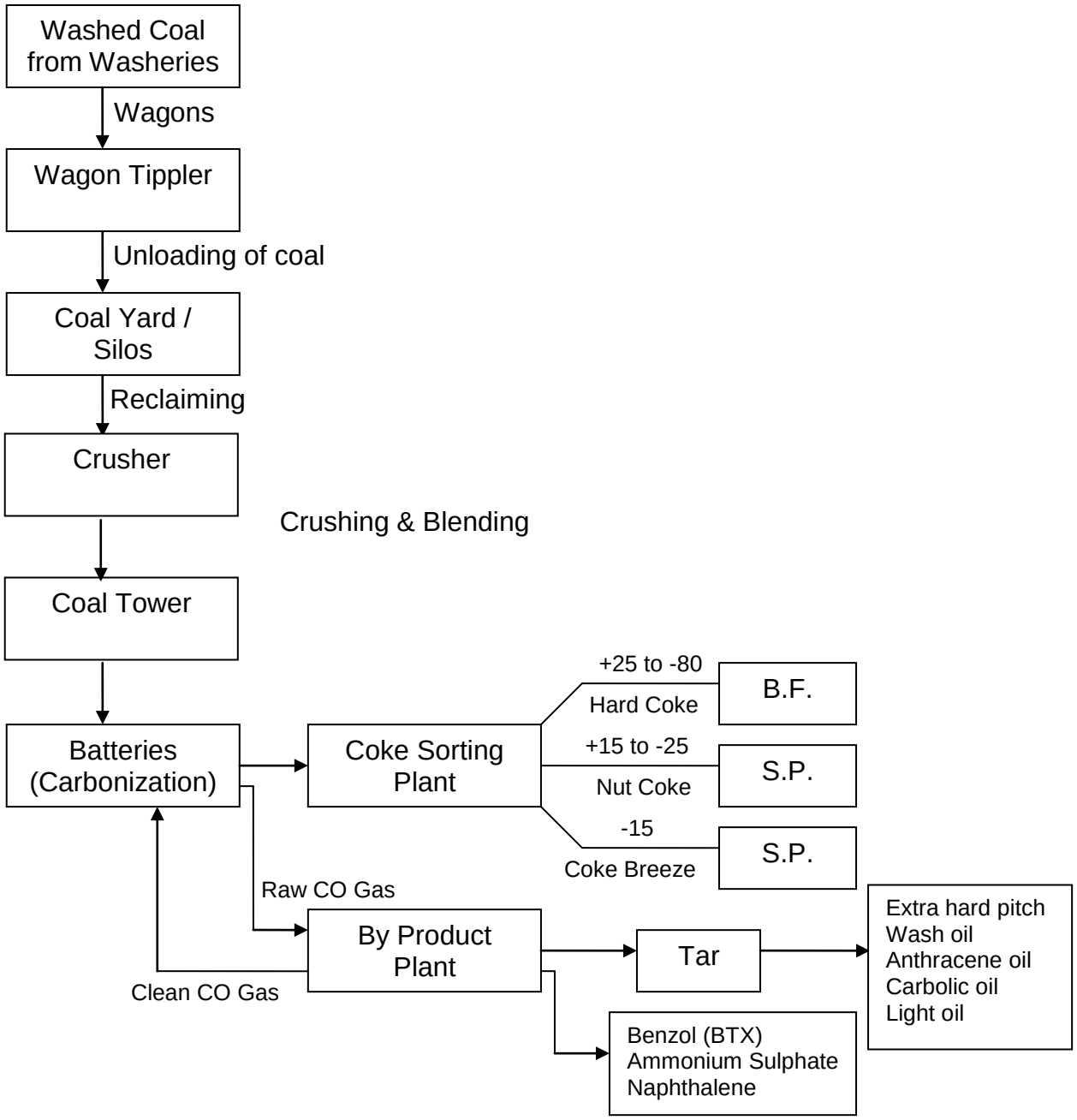
Ammonia	:	50 ppm
Phenol	:	1 ppm
Cyanide	:	0.2 ppm
Tar & Oil	:	10 ppm

Coke Oven Gas (CO Gas):

The most important byproduct of Coke oven is the raw Coke oven gas. The basic constituents of clean coke oven gas are:

Hydrogen	-	50 to 60%
Methane	-	25 to 28%
Carbon Monoxide	-	6 to 8%
Carbon Dioxide	-	3 to 4%
Other Hydrocarbons	-	2 to 2.5%
Nitrogen	-	2 to 7%
Oxygen	-	0.2 to 0.4%
Calorific value	-	4300 kcal / m^3

PROCESS FLOW DIAGRAM OF COKE OVEN & CCD


Washed Coal from Washeries
Wagons
Wagon Tippler
Unloading of coal
Coal Yard / Silos
Reclaiming
Crusher
Crushing & Blending
Coal Tower
Batteries (Carbonization)
Coke Sorting Plant
+25 to -80
Hard Coke
B.F.
+15 to -25
Nut Coke
S.P.
-15
Coke Breeze
S.P.
Raw CO Gas
By Product Plant
Clean CO Gas
Tar
Extra hard pitch
Wash oil
Anthracene oil
Carbolic oil
Light oil
Benzol (BTX)
Ammonium Sulphate
Naphthalene

2.9 Pollution Control Norms

To protect the environment, Central Pollution Control Board (CPCB) has laid down strict pollution control norms. The different norms for coke ovens with respect to PLD (Percentage Leaking Doors), PLO (Percentage Leaking Off take), PLL (Percentage Leaking Lids) and Stack Emission are as follows:

FACTORS	NEW BATTERY	EXISTING BATTERY
PLD	5	10
PLL	1	1
PLO	4	4
SO_2	800 mg/Nm^3	800 mg/Nm^3
Stack Emission	50 mg/Nm^3	50 mg/Nm^3
Charging Emission	16 sec/charge	50 sec/charge

ISO 14001: 2004 is an environment management system which deals with the ways and means to make the environment pollution free. Its main thrust is to make Land, Air & Water free of pollutants.

2.10 Safety

Safety is the single most important aspect in the steel industry. This aspect covers both personal as well as equipment safety. The use of PPE s (Personal Protective Equipment) is a must for the employees in the shop floor. The use of PPEs like safety helmet, safety shoes, hand gloves, gas masks, heat resistant jackets, goggles and dust masks are to be used religiously while working in different areas of coke ovens.

Different laid down procedures like EL 20 / permit to work, as followed in different steel plants, are to be strictly followed before taking any shut-down of equipment for maintenance.

The stipulated SOPs (Standard Operating Procedure) and SMPs (Standard Maintenance Procedure) should be adhered to strictly.

Persons should be cautious about the gas prone areas and should know about the gas hazards. EMD clearance is a must before taking up any job in gas lines or gas prone areas.

A life lost due to any unsafe act is an irreparable loss to the company as well as to the family which can not be compensated.

5-S SYSTEM (WORK PLACE MANAGEMENT):

5 S system is an integrated concept originated by the Japanese for proper work place management. Takasi Osada, the author of this concept says 5 s activities are an important aspect of team work applicable to all places.

1 S : **s e i r i** – It is the process of distinguishing, sorting & segregation between wanted & unwanted items in a work place & removal of the unwanted.

2 S : **s e i t o n** – It is the process of systematic arrangement of all items in a suitable place.

3 S : **s e i s o** – It is the process of proper house keeping of the work place including cleaning of all equipments.

4 S : **s e i k e s t u** – It is the process of standardization

5 S : **s h i t s u k e** – Literal meaning of shitsuke is discipline. It is the process of following the system meticulously.

2.11 ISO 45001:2018 (Occupational Health and Safety Management System)

OH&SMS provides a formalized structure for ensuring that hazards are identified, their impact on staff assessed and appropriate controls put in place to minimize the effect. It further assists a company in being legally compliant, ensuring appropriate communication and consultation with staff, ensuring staff competency and having arrangements in place to deal with foreseeable emergencies. It is not concerned with the safety of the product or its end user.

It is compatible with the established ISO 9001(Quality) and ISO 14001 (Environmental) management system standards. This helps to facilitate the integration of the quality, environmental and occupational health and safety management systems within the organization.

Impacts of fully implemented OH&SMS are:

(a) Risks and losses will be reduced and/or eliminated
(b) Reduced accidents, incidents and costs
(c) Reliable operations
(d) Compliance to rules, legislation, company standards and practices
(e) A systematic and efficient approach to health and safety at work
(f) Positive company image and reputation

Chapter – 3

SINTER PLANT

3.1 Introduction

Sinter Plant agglomerates iron ore fines with other fine materials at high temperature, such that constituent materials fuse together to make a single porous mass.
A large quantity of iron ore fines is generated in the mines, which cannot be chargeddirectly into the Blast furnace. Moreover many metallurgical wastes are generated in the steel industry itself, disposal of which is very difficult. In order to consume this otherwise waste fine materials, they are agglomerated together and made into lumps by a process known as SINTERING.

Sintering is the process of agglomeration of fines (steel plant wastes) by incipient fusion caused by heat available from the fuel contained in the charge. This technology was developed for the treatment of waste fines in the early 20^{th} century. Since then sinter has become the widely accepted & preferred Blast furnace burden material.

Raw materials used in Sinter Plant

1. Iron ore fines
2. Lime stone fines
3. Dolomite fines
4. Coke breeze fines
5. B.O.F.Sludge
6. Burnt Lime
7. Mills Scale
8. B.O.F.Slag / L D slag
9. BF Return fines
10. Internal Sinter Return fines

3.2 Sintering Process

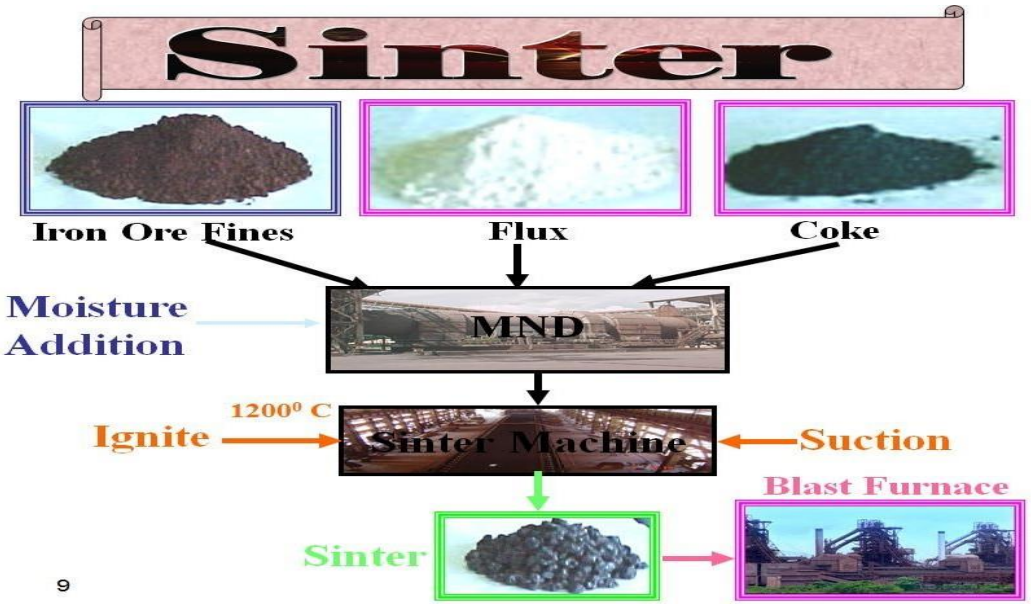
The Iron ore fines, lime stone fines, dolomite fines, lime dust, coke breeze and other metallurgical wastes are proportioned based on charge calculation. These charge thus mixed in a balling drum with the addition of water and then loaded into grates of moving pallets. The purpose of Balling drum is to mix the raw materials (called base mix) with water and make balls. After mixing and ball formation(nodulization
) this base mix (now called green mix) is loaded on moving sinter machine pallets. HEARTH LAYER which consists of finished sinter of size fraction 10 to 20mm forms the bottom layer. Green mix is loaded above the hearth layer. As soon as these raw materials reaches the ignition furnace, Top layer of green mix charge is ignited in the IGNITION FURNACE by burning of gases mainly CO gas . Air is drawn

downwards through Exhausters or Waste Gas Fans. The heat from top layer is gradually transferred to subsequent bottom layers. . Due to burning of coke particles bonding take place between the grains and a strong & porous aggregate is formed known as “SINTER”. This sintering process is over when bottom layer coke fine burning is completed.

The sinter cake is then crushed, cooled, screened and dispatched to Blast furnace. The ideal size of sinter required in blast furnace is in between 5mm to 40mm. The - 5mm size sinters are screened & returned back to sinter bins.

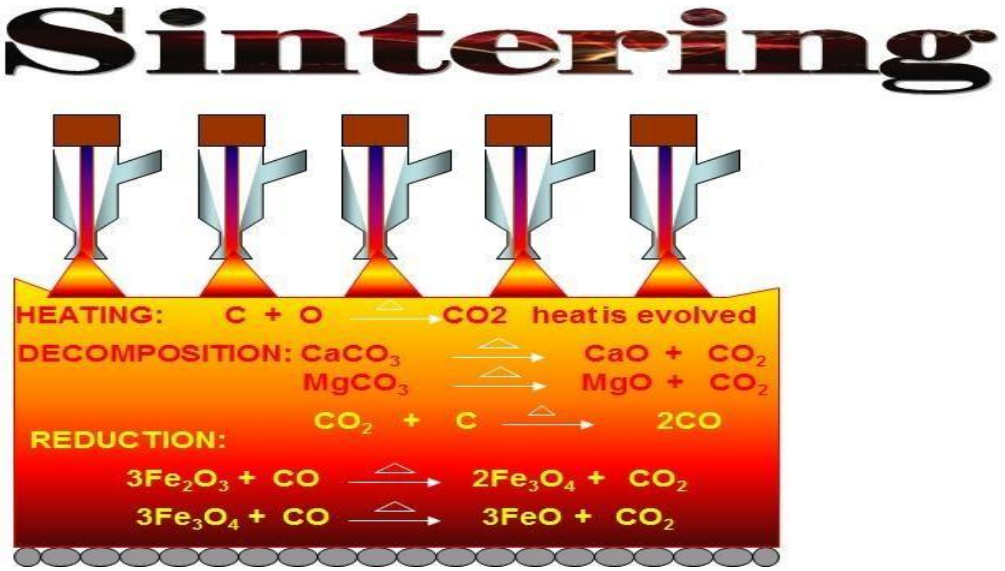
Fig1: Sinter Machine at SP3 , Machine 1

Sinter Making



Sintering of fines by the under grate suction method consists of the mixing of fines

with finely crushed coke as fuel and loading the mixture on the pallet grates. Ignition of the fuel proceeds on the surface of charge by a special ignition arrangement, called ignition furnace (where gaseous fuel is burnt to produce high temperature to ignite the fuel in sinter mix)



The gases used in ignition furnace are mainly coke oven gas or mixed gas. Mixed gas is combination of coke oven gas and blast furnace gas. Further the combustion is continued due to suction of air through the layers of the charge by means of Exhausters. Due to this, the process of combustion of fuel gradually moves downwards up to the grates.

From the scheme obtained in a few minutes after ignition, it is observed thatthe sintering process can be divided into six distinct zones:

1. Zone of Cold Sinter (60 to 100 ^{0}C)
2. Zone of hot Sinter (100 to 1000 ^{0}C)
3. Zone of intensive combustion of fuel (1000 to 1350 ^{0}C)
4. Heating zone (1000 to 700 ^{0}C)
5. Zone of Pre-heating of charge (700 to 60 ^{0}C)
6. Zone of Re-condensation of moisture (60 to 30 ^{0}C)

In all the zones except the zone of combustion, the reactions taking place are purely thermal wherea s in the zone of combustion reactions are thermal and chemical.

The maximum Temperature attained in the zone of combustion will be 1300-1350 ^{0}C. The vertical speed of movement of the zones depends on the vertical speed of sintering.

Heat from the zone of ready sinter is intensively transmitted to the sucked air. In the

zone of combustion of fuel hot air and preheated charge comes into contact with each other which with the burning fuel will result in the formation of high temperature. Maximum temperature will be developed in this zone and all the physical-chemical process takes place resulting in the formation of Sinter. In the zone of pre-heating thecharge is intensively heated up due to transfer of heat from the sucked product of combustion. In the zone of re-condensation of moisture, the exhaust gases during cooling transfer excess moisture to the charge. Temperature of this zone sharply decreases and will not increase till all the moisture is driven off.
As the fuel in the zone of combustion is burnt away, Sinter, the height of which increases towards the grates, is formed above this zone from the red hot semi-fluid mass, forcing out subsequent zones. Disappearance of the zone of combustion means the end of sintering process.

The sinter cake is then crushed, cooled, screened and dispatched to Blast furnace. The ideal size of sinter required in blast furnace is in between +5mm to 40mm. The -5mm size are screened & returned back to sinter bin. **(**Called In plant return fines)

Following Approximate charge proportion will be required to make one ton of sinter (Wet basis):-

Ore fines	: 750-825kg
Coke	: 65-70 kg
Mill scale + fines	: 26 Kg
Lime stone	: 150-180 kg
B.O.F. Sludge	: 02kg
B.O.F. Slag	: 20Kg
Dolomite	: 3 0 - 4 0 kg
Burnt Lime	: 20 kg
BF Sinter return	: 100 kg
In plant sinter return	: 456 kg

Note- All above mentioned data varies in different plants under SAIL. **Factorsaffecting sintering process:**

1. **Quality of Input raw materials**

a. Quality of Iron ore fines :
: +10 mm should be nil
: -1mm should be 30% maximum
: Alumina (Al_2O_3) 2.55% maximum
: Silica (SiO_2) 2.91% maximum

Increase in +10mm fraction will result in weak sinter & low productivity Increase in –1mm fraction will decrease bed permeability resulting in low productivity Increase in % of Alumina increases RDI (Reduction Degradation

Index) resulting ingeneration of –5mm fraction & also resulting in chutejamming.(Due to high Alumina in
Base/Mix.
With increase of SiO2 level in Iron ore fines, glassy phase in sinter increases andcauses brittleness in sinter.

b. Quality of Flux
: -3mm fraction should be 90% minimum (Crushing index)
: Less crushing index results in free lime, causing weak sinter

c. Quality of Coke
: -3mm fraction should be 85% minimum (Crushing index of coke)
: +5mm fraction should be nil
: Increase in 5mm fraction decreases the productivity
: Increase in less than 0.5 mm particle size in coke causes increase in coke consumption during sintering

2. Moisture :

Moisture in the form of water is added in the base mix in Mixing/Nebulizing drum. Water acts as binder of base mix. Addition of water in base mix plays an important rolein sinter bed permeability. Ideally 7 to 8% of total base mix of water is used. Higher % of water results in low permeability & less sintering speed. Less % of water results in less balling, hence less permeability, resulting in low productivity.

3. Ignition furnace temperature:

Ignition of sinter mix is carried out through ignition hearth where a temperature of 1150 to 1250 ^{0}C is maintained by burning gaseous fuel by the help optimum air/gas ratio.

32.5% of CO gas & 67.5% of BF gas is used to maintain calorific value 1900kcal/m^3. Now a day Sintering Plant, Bhilai Steel Plant uses Coke Oven Gas of calorific value 4150 Kcal/Nm3.

Very Higher hearth temperature results in fusing of sinter at top layer. This reduces the bed permeability, hence low productivity. Low hearth temperature results in improper ignition. The sintering process will not be completed, hence –5mm fraction will increase, i.e. re-circulating load will increase.

Note- BF&CO gas mixing ratio and calorific value varies in different plants of SAIL

4. Coke rate :

Coke acts as a solid fuel in base mix in the sintering process. It is normally 3.5 to6% of total charge. Higher coke rate will fuse the top layer, thereby decreasing the bed permeability. Sticker formation will increase. Low coke rate will result in incomplete sintering.

5. Machine speed :

The speed of sinter machine can be varied as per the condition of sintering process. BTP (Burnt Through Point) temperature decides the completion of sintering process. It is observed

normally in second last wind box from discharge end side of sinter machine where the temperature reaches up to 400 ^{0}C (approximately). Higher machine speed, lower BTP causes more–5mm generation, hence lower productivity. Lower m/c speed, higher BTP temperature causes low productivity.

Note: BTP: Exhaust gas temperature which indicates the completion of sinteringprocess iscalled BTP. It is approximately around 400 degree centigrade.

Crushing, Cooling & Screening of Sinter

The finished Sinter cake is then crushed to the size of 100mm by using crushers. Cooling of finished crushed Sinter is then done on cooler by means of air blowers (forced draught fans), so that cooler discharge end temperature is about 60-80 degree centigrade. For effective cooling, bigger size of sinter should be on bottom portion &smaller size should be on the top.

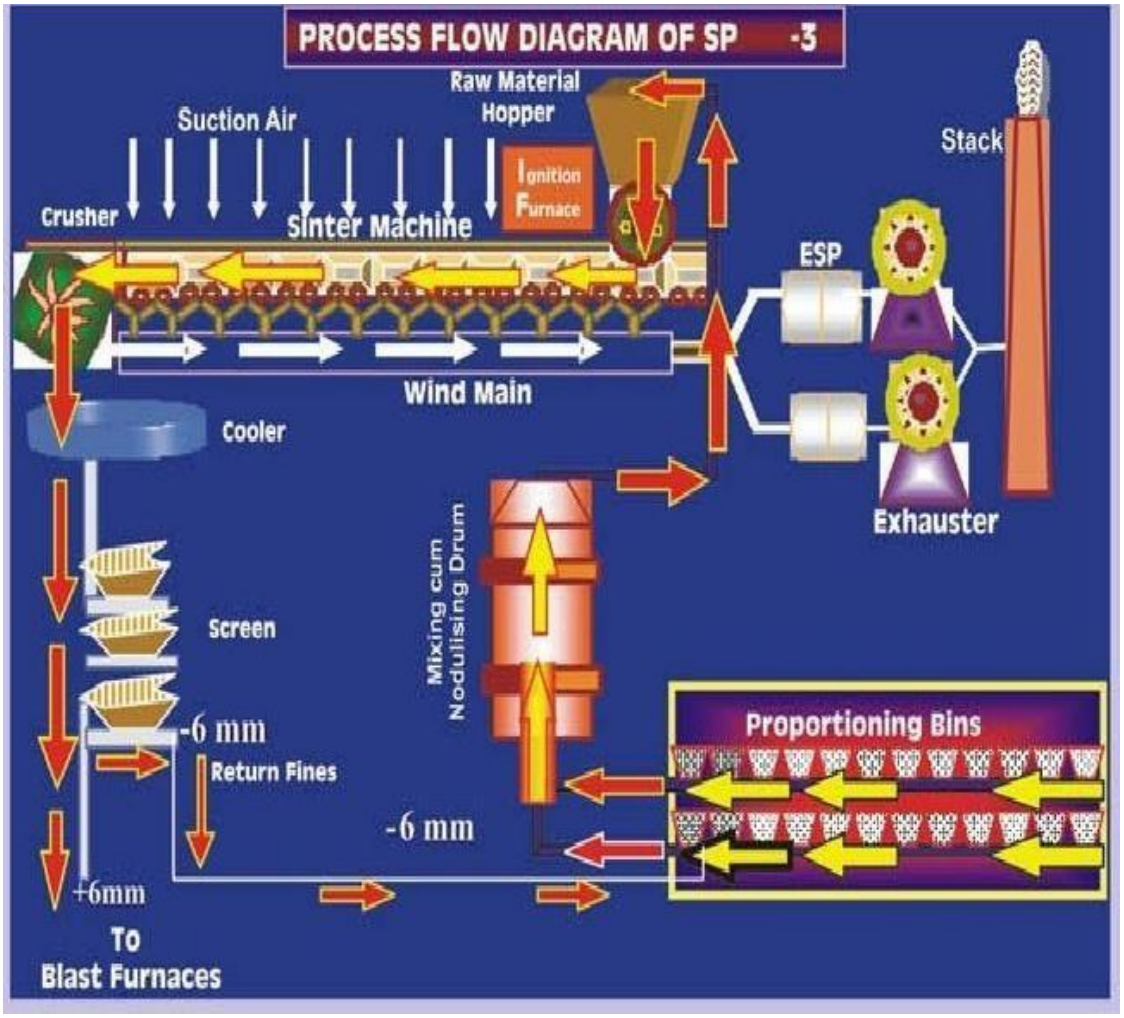
Finally various fractions of Sinter are screened out. -5mm fraction of sinter, returns back to bunkers. 15 to 20mm fraction is also screened out to be used as hearth layer. Rest sizes goes to blast furnace. After screening, +10mm fraction should be 65%minimum and –5mm fraction should be 6% maximum as per requirement of blast furnace.

Advantages of using Sinter

1. To utilize the ore fines generated at mines to transform to an acceptable feed in blastfurnace
2. To utilize economically all the metallurgical wastes like Mill scale, L.D slag, B.O.F slurry, Flue dust, Ferro scrap etc.
3. To utilize the coke breeze generated in coke screening at coke ovens as fuel, otherwise has no metallurgical use
4. As the calcination of flux takes place in sinter strand, super-fluxing saves much more coke in the furnace.
5. Increase of sinter percentage in Blast Furnace burden, increases the permeability, hence reduction and heating rate of burden increases, so the productivity also increases. Coke rate is also reduced in Blast furnace.

6. Minimal fraction of total mass of impurities, Viz. sulphur, phosphorous, zinc, alkali isreduced .
7. Improved quality of hot metal.
8. The softening temp. of sinter is higher and melting zone is narrow. This increases the volume of granular zone and shrinks the width of cohesive zone consequently,the driving rate of BF become better.

PROCESS FLOW DIAGRAM OF SINTER PLANT



3.3 Quality Parameters of Sinter (Subject to Requirement of BF)

	Chemical composition		Physical composition	
1.	FeO %	8.0 to 11.0	Sinter size	5mm to 40mm
2.	MgO %	2.6 to 3.0	Mean size	18mm to 21mm
3.	Available lime (CaO-SiO2)%	3.4 to 6	DTI	70% MIN

4.	As per BF Requirement		RDI	30% MAX
5.	SiO2 %	4.8 to 5.2	+ 10 mm	65 % min.
6.	Al2O3 %	3.0	+40 mm	9 % max.
7.	Basicity.	1.6 to 2.1	- 5 mm	6% max.

Note*- Quality parameters of sinter varies in different plants under SAIL.*

Quality parameter definitions:

Tumbler index (DTI): The cold strength of sinter is determined by the tumbler test ,and depends on the strength of each individual ore component, the strength of the bonding matrix components and the ore composition. This test determines the size reduction due to impact and abrasion of the sinters during their handling, transportation, and in the blast furnace process. Studies of the fracture strength of several mineral phases have allowed the following order to be established: primary (or residual) hematite > secondary hematite > magnetite > ferrites. Cold mechanical strength is directly related with the tendency for fines to form during transportation and handling between the sinter machine and the blast furnace throat.

Reduction Degradation Index (RDI)

Sinter degradation during reduction at low temperature is more usually determined by the RDI static test ,which is carried out at 550 °C. Low values are desirable for this index. The RDI is a very important parameter that is used as a reference in all sintering work and servesto predict the sinter's degradation behavior in the lower partof the blast furnace stack.

Some critical terms/parameters used/monitored in sinter plant:

Coke crushing index	Percentage presence of –3mm fraction of coke in any sample is termed as coke crushing index. For better sintering process coke crushing index should be more than 85%
Flux crushing index	Percentage presence of –3mm fraction of flux in any sample is termed as Flux crushing index.For better sintering process Flux crushing index should be more than 90%
Burn Through Point (BTP)	Burn through point temperature indicates the completion of sintering process. It is normally around 400 degree Celsius and is normally found in second last of wind box from discharge end of sinter machine.

3.4 Main Areas & Equipment

Main Areas	Equipments	Functions
Sinter making & Cooling bldg.	Balling drumsSinter pallets Screens Crushers Coolers	To mix & pelletize Sintering takes on it Screens out diff. sizes Crushes sinter cake Cools/ Normalize sinter
Exhausters	High capacity fansBattery cyclones ESP	To suck air below gratesTo clean Exhaust air To clean Exhaust air
Proportioning Bins	Electronic feeders Conveyors Bunkers	For adjusting feedingTransport charge mix. Store raw materials
Coke & Flux Crushers	Roll crushers Rod Mills Hammer crushers Grab cranes	For crushing coke For crushing coke For crushing Fluxes For lifting coke

Techno Economics

1. Specific Productivity : Sinter produced per square meter per hour
2. Specific Heat consumption : Gas consumed per ton of sinter
3. Specific Power consumption : Power consumed per ton of sinter
4. Specific Coke consumption : Coke consumed per ton of sinter
5. Specific Flux consumption : Flux consumed per ton of sinter

In order to produce sinter at less cost, specific productivity of sinter should be as high aspossible & all other four parameters should be as low as possible keeping quality parameters under consideration.

Advantages of Sintering

1. Better use of the huge quantity of iron ore fines generated at mines.
2. Gainful use of various metallurgical wastes like flue dust, mill scale, lime dust, sludge, etc.
3. Use of super fluxed sinter eliminates raw flux from the blast furnace burden. This leads toconsiderable coke saving and productivity improvement in blast furnaces.
4. Due to the higher reducibility of super fluxed sinter, direct reduction of iron oxide is enhanced, which contributes to further coke saving.
5. The softening temperature of sinter is higher and the softening melting zone is narrower. This increases the volume of granular zone and shrinks the width of the cohesive zone. Consequently, the driving rate of the blast furnace improves.
6. Hot metal quality (from the SMS point of view) improves due to lower silicon content and higher hot metal temperature. A higher hot metal temperature

contributes to better sulphur removal from the hot metal.

7. Material handling in the charging section of the blast furnace is reduced, and fewer logistics are needed.
8. Blast furnace operation is more reliable and efficient

3.5 Safety hazards at Sinter plant

1. Dust pollution : As lot of finer particles are used in sintering, there causing lots of dust pollution. Efficient running of ventilation is must. Use of dust mask is essential. Chimney Stack Emission is 50mg/nm^3. Fugitive Emission(ambient) is 2mg/nm^3
2. Gas safety : Gases (usually Mixed gas & Coke oven gas) are used for igniting charge mix, It is very important to follow all the protocols for gas safety. Use of gas mask and Carbon mono oxide (CO) gas monitor while working on gas line is must.
3. Noise pollution: Tremendous amount of air is sucked through exhauster fans. Slight leakages anywhere in suction line or exhauster results in high level of noise. Air compressor, chiller unit, hammer crusher, coke crusher are also high noise generating areas in Sinter plant. Use of Ear plug is essential.

3.6 ISO 45001:2018 (Occupational Health and Safety Management System):

OH&SMS provides a formalized structure for ensuring that hazards are identified, their impact on staff assessed and appropriate controls put in place to minimize the effect. It further assists a company in being legally compliant, ensuring appropriate communication and consultation with staff, ensuring staff competency and having arrangements in place to deal with foreseeable emergencies. It is not concerned with the safety of the product or its end user.

It is compatible with the established ISO 9001(Quality) and ISO 14001 (Environmental) management system standards. This helps to facilitate the integration of the quality, environmental and occupational health and safety management systems within the organization.

Impacts of fully implemented OH&SMS are:

a) Risks and losses will be reduced and/or eliminated
b) Reduced accidents, incidents and costs
c) Reliable operations
d) Compliance to rules, legislation, company standards and practices
e) A systematic and efficient approach to health and safety at work

Positive company image and reputation.

Chapter – 4

BLAST FURNACES

4.1 Introduction

BF is a counter current heat and mass exchanger, in which solid raw materials are charged from the top of the furnace and hot blast, is sent through the bottom via tuyeres. The heat is transferred from the gas to the burden and oxygen from the burden to the gas. Gas ascends up the furnace while burden and coke descend down through the furnace. The counter current nature of the reactions makes the overall process an extremely efficient one in reducing atmosphere. The real growth of blast furnace technology came with the production of high strength coke which enabled the construction of large size blast furnaces.

4.2 Raw materials and their quality

In India steel is being produced largely through the blast furnace. Iron ore, sinter and coke are the major raw materials for blast furnace smelting.

Raw materials:

The following **raw materials used**for the production of pig iron: -

(i) Iron ore
(ii) Limestone / L D Slag
(iii) Dolomite
(iv) Quartzite
(v) Manganese ore
(vi) Sinter
(vii) Coke
(viii) Pellets
(ix) Scrap (Steel / Iron)
(x) Coal Dust / Coal Tar

Iron ore: Iron bearing materials; provides iron to the hot metal. Iron ores is available in the form of oxides, sulphides, and carbonate, the oxide form known as hematite (red in colour) is mostly used in SAIL plants. It is the principal mineral in blast furnace for extraction of pig iron, generally rich in iron content varying from 62 % to 66 % associated often with naturally occurring fines (-10 MM) to the extent of 20 %. Although relatively free from impurities like phosphorous, sulphur and copper, they have high aluminaand silica contentas gangue. The high alumina content makes the slag highly viscous and creates problems for stable furnace operation.

Limestone / LD Slag: Acts as flux. Helps in reducing the melting point of gangue present in the iron bearing material and combines effectively with acidic impurities to form slag in iron making. LD slag is a substitute for limestone which is easily available in a steel plant. Its usage helps in waste utilization and thus reduces production cost.

Quartzite: It acts as an additive.Quartzite is a mineral of SiO_2 (silica) and under normal circumstances contains about 96 – 97 % of SiO_2 rest being impurities. Quartzite plays its role in counteracting the bad effects of high alumina in slag through maintaining optimum slag basicity.

Manganese ore: It acts as additive for the supply of Manganese in the hot metal. Manganese ore is available in the form of combined oxides of Mn and Fe and usual content of Mn is about 28 – 32 % for steel plant use, However Manganese ore available with SAIL is having high alkali contents so it should be used judicially.

Coke: Itacts as a reductant and fuel, supports the burden and helps in maintaining permeable bed. Coke (metallurgical) used in blast furnace both as fuel & reducing agent. The Indian coal is characterized by high ash (25 – 30 %) and still worse, a wide fluctuation in ash content, poor coke strength leading to excessive generation of fines, rapid fluctuation in moisture content etc. The problem of poor quality coke has been tackled by adding imported coal (75-95%) in the indigenous coal blend to get a coke ash of 13 – 16 %.

Sinter: It is iron bearing material. Fines that are generated in the plant/mines are effectively utilized by converting them to sinter. It provides the extra lime required for the iron ore and coke ash that is charged in the blast furnace. Sintering is the process of agglomeration of fines (steel plant waste and iron ore fines) by incipient fusion caused by heat available from the coke contained in the charge. The lumpy porous mass thus obtained is known as “sinter”.

Scrap (Steel / Iron): Scrap is generrated in the process of product making in a steel plant which is gainfully utilized by back charging in the Blast Furnaces. It increases the furnaces productivity and reduces the production cost.

Pellets: It is also an iron bearing materials. The micro-fines which cannot be used for sinter making can be used for pellet manufacturing and the pellets formed will be charged in the BF.

Coal dust Injection: It acts as an auxiliary fuel, reduces coke consumption in the blast furnaces. The coal is injected through the tuyeres.

Different sources of raw materials

Sl. No.	Raw material	BSP	RSP	DSP	ISP	BSL
1.	Iron ore	Dalli Rajhara Raoghat Meghahatubur u Kiriburu	Barsua Kalta Meghahatuburu Kiriburu	Bolani GuaMeghaha tuburu	Gua Bolani Meghahatubu ru	Kiriburu Meghahatubur u Bolani Barsua Gua Manoharpur
2.	Limestone	Nandini Kuteswar Jaisalmer Imported	Kuteswar Jaisalmer Imported	Kuteswar Jaisalmer Imported	Jaisalmer Imported	Nandini Kuteswar Jaisalmer Imported
3.	Dolomite	Hirri Imported	Baraduar Belha	Baraduar Imported	Belha Baraduar Imported	Birmitrapur Belha Imported

Quality of raw materials

Material	Chemical Analysis	Specification	Size	Other properties
Iron Ore(Lumps)	Fe	61.0% min.	10 – 40 mm	Softening Melting range:
	SiO_2	2.5 ± 0.5 %		1100 - 1400˚C
	P	0.10% max.		
	Al_2O_3/SiO_2	0.70 max.		
Sinter	Fe	50-58%	5 – 40 mm	RDI(Reduction Degradation Index) <30
	FeO	7-10%		RI(Reducibility Index) >65
	SiO2	4-6%		Tumbler Index >70
	Al_2O_3	2-3%		Softening Melting range:
	CaO	9 – 13%		1200 – 1450^oC
	MgO	2 – 3%		
Coke	Ash	13 – 15%	25 – 80 mm	CRI(Coke Reactivity Index): 21-23
	VM(VOLATILE MATTER)	< 1 %		CSR(Coke Strength after Reduction) > 64
	Moisture	5 ± 0.5%		M40>80%
	S	0.5 - 0.6%		M10<6%
	FIXED C	82- 85%		
Limestone	CaO	38 % min.	10 – 40 mm	
	SiO_2	6.5 ± 1%		
	MgO	8.5 ± 0.5%		
LD slag	CaO	40.8 ± 1%	10 – 40 mm	
	MgO	10.5 ± 0.5%		
	SiO_2	15.50%		
Mn ore	Mn	30% min.	25 – 50 mm	
	SiO_2	30% max.		
	Al_2O_3	5% max.		
	P	0.30% max.		
CDI coal	FIXED C	60-70%	80 % <90 microns	
	VM(VOLATILE MATTER)	20-25%		
	Ash	9 – 11%		
Quartzite	SiO_2	96% min	25-50 mm	
	Al_2O_3	1.5% max		

Charging:

High lines and Stock House

High lines: The main responsibility of high lines section is to receive the raw materials required for the production of hot metal from various sources, storing and transporting them to the top of the furnace in time, for the smooth running of the furnace.

Raw materials arriving to the blast furnace department from various sources are unloaded in the RMHP (Raw Material Handling Plant). The ore yard is meant for stocking and averaging of materials. The materials from RMHP are transported to Blast Furnace with the help of wagon tippler, conveyors, stakers and reclaimers.

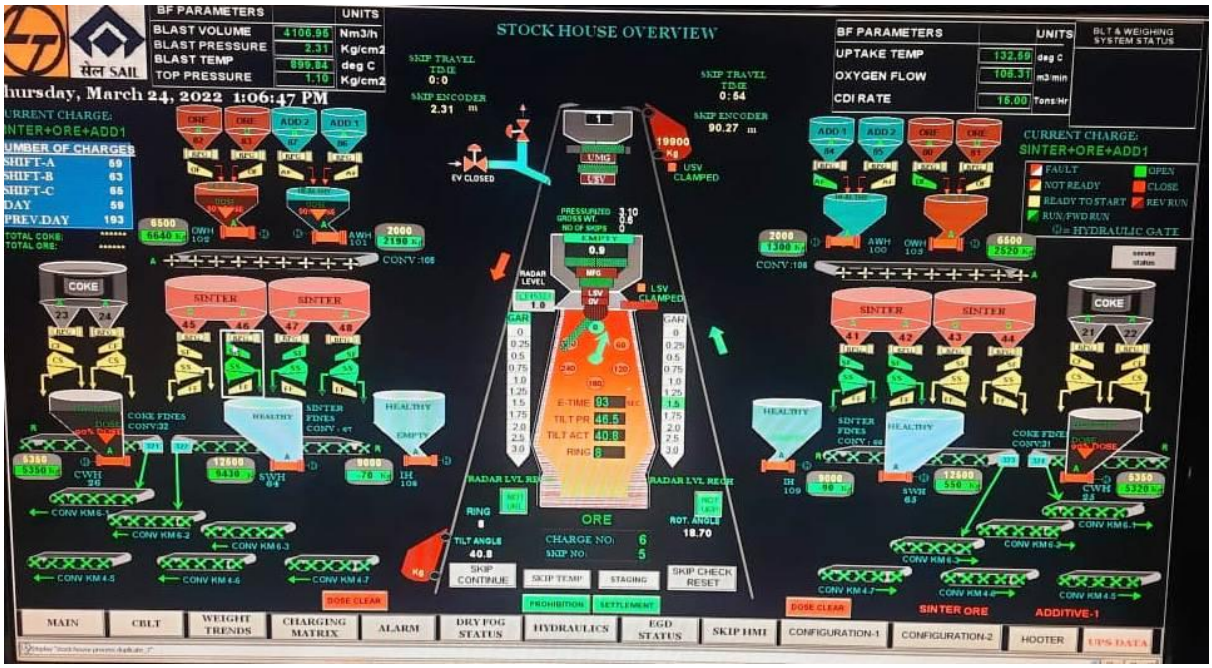
Raw materials from the ore yard are charged by suitable means into the respective bunkers. Alternately in some plants iron ore is received in a wagon Tripler, stack in to piles, and reclaimed using reclaimers.

Sinter from bunker located on the extension tracks of high line is collected in transfer cars moving on rail tracks or sinter comes by means of conveyor belt and is stored in a receiving hopper.

Sinter is screened in stock house, and the fines are returned through conveyor belts.

Coke (25 – 80 mm) from coke sorting plant (CSP) is supplied to the coke bunkers of the blast furnace with the help of conveyor belts and the undersize are returned through conveyor belts.

Stock house: The bunkers are provided with a vibrofeeder, which feeds the material to the conveyor belt/screen. The BF size material is fed to a weighing hopper through ore discharge conveyor. The weighing hopper discharges the material into the skip. There are conveyors to remove the return fines from the system.



Hoist house:

For taking charged materials to the furnace top, two-way skip hoist with 2 skips are provided. The hoist house operates the skip that is driven by two motors. Bell hoist, equalizing valves, test rods etc. are also operated from hoist house.

Flow of material to charging skip are

Bunkers →vibro feeder→ conveyor belts→ weighing hopper→ skip car.

Bunkers →vibro feeder→ weighing hopper→ skip car.

Raw materials including coke are transported and collected into high line bunkers/Stock house placed near the furnaces and then properly screened and weighed. Weighing is done either by scale car or by load cell. These batched proportions of the raw materials are conveyed to the top of the blast furnace via skip car or conveyors and are charged in the blast furnace. The distribution is maintained in such a fashion that alternate layers of coke and iron-containing burden (sinter and iron ore and fluxes) are formed inside the blast furnace.

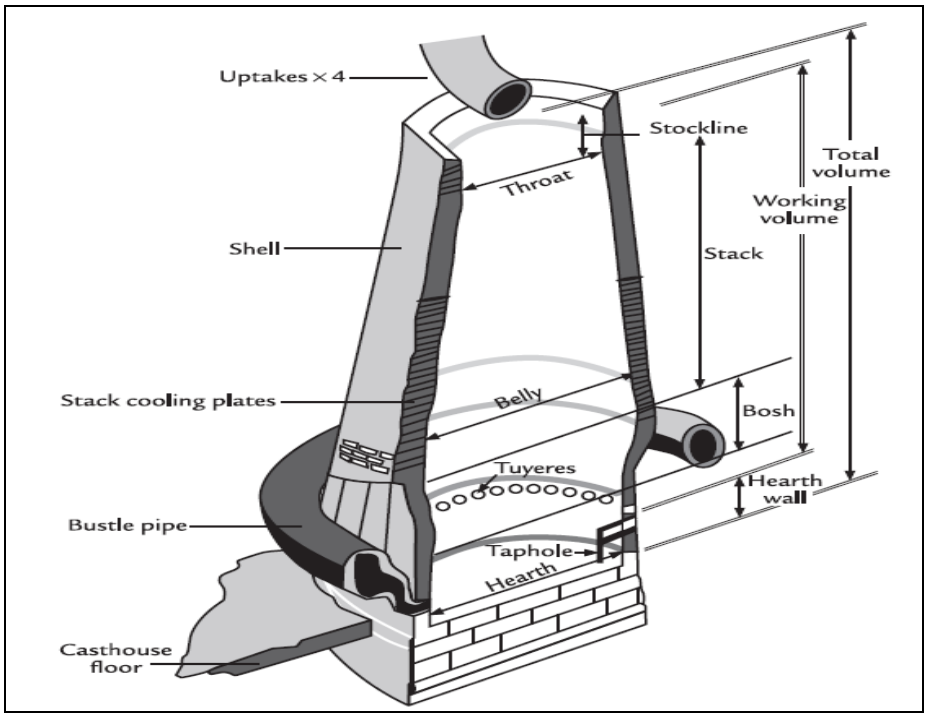
4.3 Blast Furnace and accessories

Blast furnace is basically a counter current apparatus, composed of two truncated cones placed base to base.

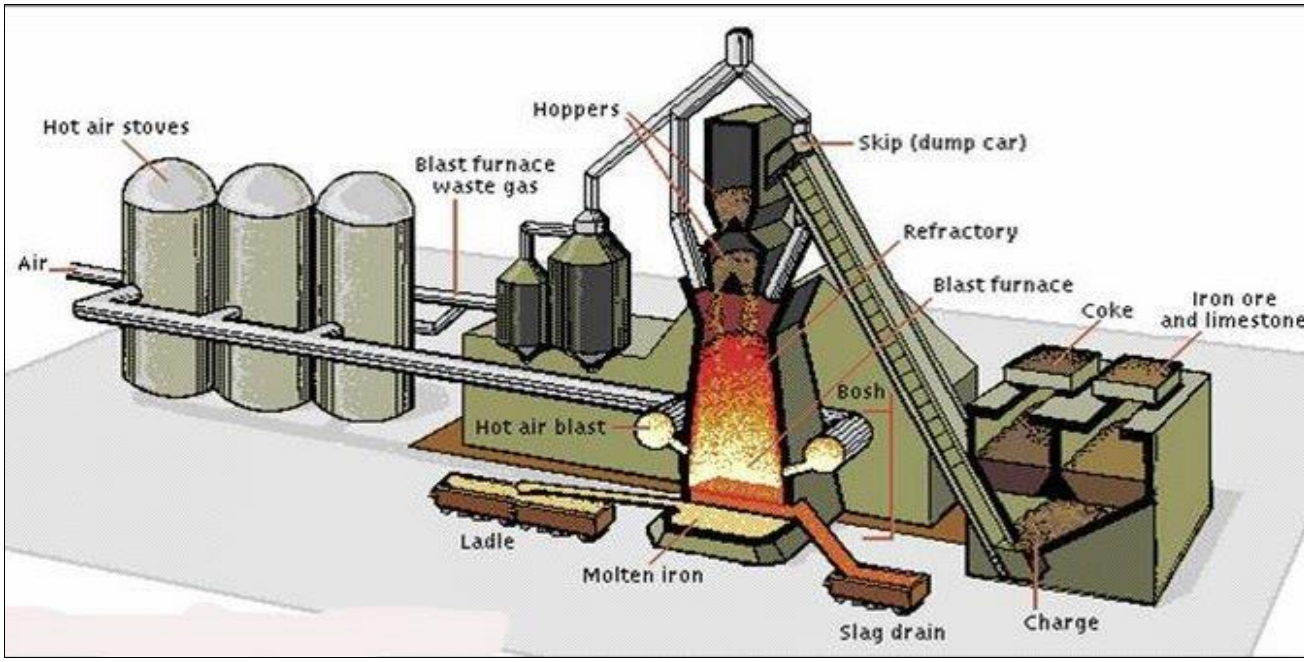
The sections from top down are:

- Throat, where the top burden surface is.
- The shaft or stack, where the ores are heated and reduction starts.
- The bosh parallel or belly, where the softening melting takes place.
- The bosh, where the reduction is completed and the ores are melted down.

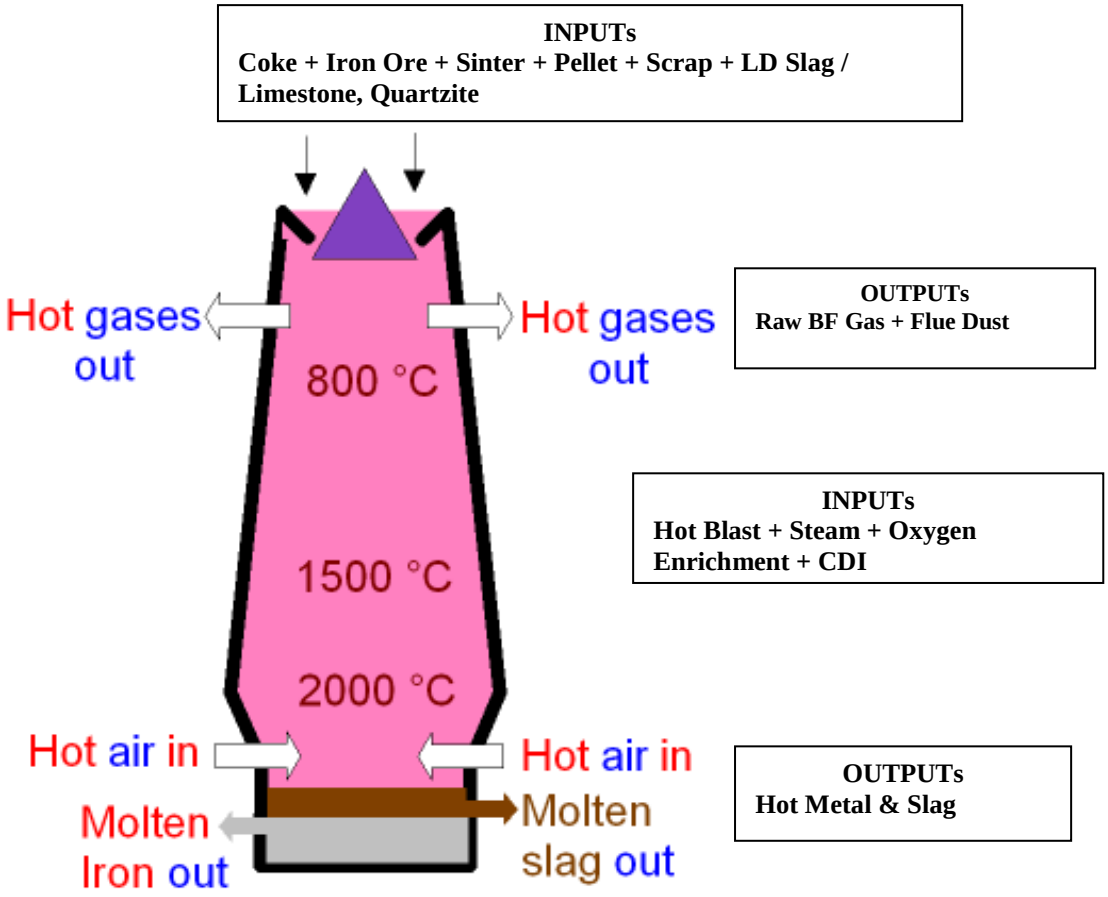
- The hearth, where the hot metal and slag is collected and is cast via the tap holes.



BF complex in a nutshell



BF Proper



The entire furnace is lined with suitable refractory and in addition to refractory lining, there are water coolers, designed to enhance the life of the furnaces. **In a blast furnace, fuel, Iron ore, sinter and flux (limestone) are continuously supplied through the top of the furnace**, either through 'double bell system' or 'bell less system'**.** In the hearth, there is a tap hole of suitable dimension and length, for the purpose of tapping the hot metal.

Since blast furnace is basically a counter current apparatus the descending stream of raw materials extract heat from the ascending stream of gas generated from the burning of coke at the tuyere level. The ascending stream of gas contains CO (carbon monoxide), nitrogen and hydrogen. The ascending reducing gas (CO and H_2) comes in contact with the iron ore thus reduction (this reduction is called indirect reduction) of iron ore takes place at the upper part of the stack (temp less than 900 °C). Coke in the form of C also takes part in the reduction (temp greater than 900 °C) and this reduction is called direct reduction. In the hearth there are multiple tapholes at about 3-4 meter below tuyeresfor flushing out hot metal and slag at regular intervals. Tapholes are also extensively water cooled. The number of tap holes, their positioning and dimension will depend upon the capacity of the furnace. Many modern furnaces are having 2 – 4 tap holes.

The furnaces are equipped with tuyeres (water cooled copper construction for admission of hot blast of air) through which preheated air blast at a temperature of about 850 °C – 1200 °C is introduced for burning of coke. Before preheating, the blast of cold air supplied by turbo blowers from power and blowing station and it is introduced into hot blast stoves at a pressure up to 1.8 - 4.5 kg / cm^2 (gauge pressure) wherein the air is pre – heated. The air blast then passes from the bustle pipe through gooseneck and then tuyere stocks / blow – pipes into tuyeres. The pressure of the blast and its flow rate is dependent upon the capacity of the furnaces and permeability ofraw material.

As the stream of the charged material descends down through different temperature zones it gives two products:-

1. Hot Metal in the liquid condition.

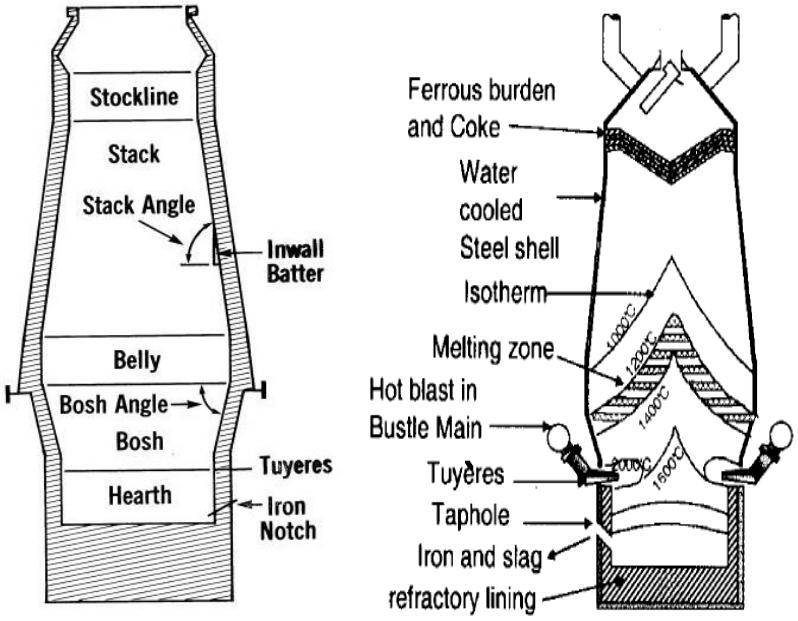
2. Slag, in the liquid condition having less density thusfloats at the top of metal.

Besides, we get one more important gaseous product from the top of the furnace known as BF gas. It generally comprises of 20 – 24 % CO; 18 - 20 % CO_2, 48-52 % of N_2, H_2 4-5 %, O_2 0.1-0.3%. The temperatures of top gases are in the range of 100 – 200 ^oC.

After cleaning, BF gas is used in blast furnace for stove heating and other area of plant like coke oven heating, and as a mixture with CO gas it is used in refractory materials plant, sintering plant, steel making shop and reheating furnace of rolling mills as a fuel.

Liquid iron collected in the hearth is taken out by opening the tap hole with power driven/Hydraulic drill and oxygen lancing(as per requirement) after regular interval into a train of ladles kept below the runner of the cast house. Slag that comes along with the metal is skimmed off with the help of skimmer plate towards slag runner and collected in slag ladles or to slag granulation plant of cast house (CHSGP). Slag ladles are then sent to the dump yard or slag granulation plant. Metal ladles are either sent to Steel Melting Shop or Pig Casting Machine and Foundry depending upon the requirement.

Schematic Cross Section of the Blast Furnace



Refractory:

Blast furnace is a vertical shaft furnace, enclosed in a welded shell, lined with fire-clay bricks of high alumina content. The hearth bottom, hearth, bosh, belly and the shaft are cooled by means of coolers of various designs. Steel refractory lined plates protect the walls of the furnace top. The bigger furnaces are lined with carbon blocks in the hearth and in the periphery of the hearth bottom. High alumina or Si-Carbide refractory are used in bosh and lower shaft. The design and operation of blast furnace results the high productivity and long life of blast furnaces. The safe and reliable operations are secured by state–of–the–art blast furnace cooling and lining designs

Top charging equipment:

The burden material which reaches to the top of the furnace by skip car or by charging conveyer is to be distributed into the furnace through double bell charging system (Fig-1), rotating charging unit (RCU) (Fig-3) or with Paul-wurth bell less top (BLT) (Fig-2,4) charging system. In BLT charging bells are replaced with charging bins, upper material gate, upper sealing valve, lower material gate and lower sealing valve. This system also has a gearbox to operate the rotating chute. The latter distributes the material inside the furnace periphery in different rings or sector charging, point charging etc. This facilitates better burden distribution inside the furnaceas per the "Charging Cyclogram or Pattern" desired by the furnace operator for continuous efficient operation of the furnace.

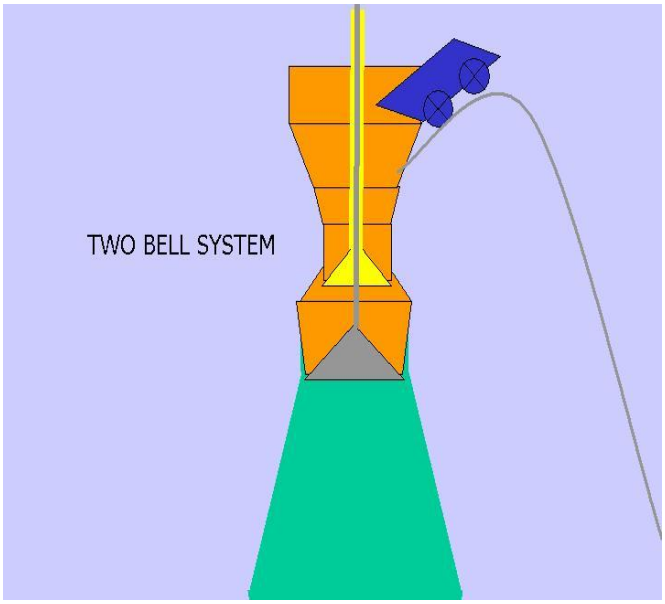


Fig-1. Double Bell

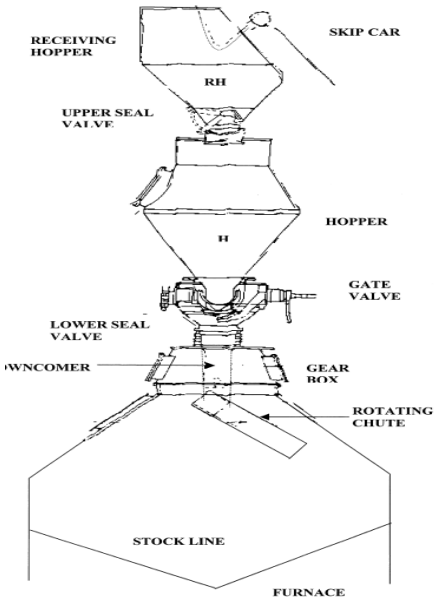


Fig-2 BLT systems

Fig-3 Rotary Charging Unit (RCU)

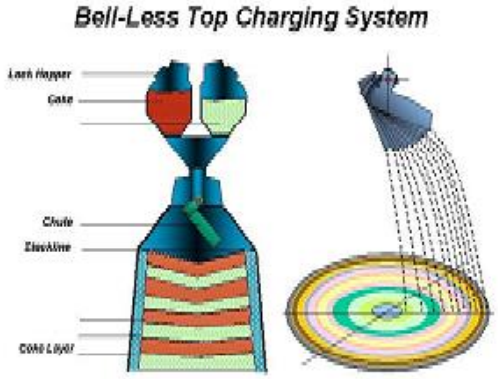


Fig-4 BLTCharging

Charging Sequence: to facilitate smooth working of furnaces, the coke and the non-coke material is to be distributed in a particular fashion in the whole circumference of the blast furnace in accordance to the Charging Cyclogram/ Pattern as determined by the furnace operator. For those different charging sequences is followed. A typical charging sequence is given below:

Sequence 1: COC / COOCC / CCOCC

Sequence 2: CCOO

Each charging cycle consists of 5/6 sequences of either 1 or 2 exclusively or in combination depending on the periphery conditions. Generally in bell-less top furnaces the 2nd sequence is followed i.e. CCOO. C=Coke; O=Non-coke(Ferrous burden) i.e. ore, sinter, Mn ore, Lime Stone or Quartzite etc. The material is distributed in the bf in different rings/sectors as per requirement

Furnace Foreman Control Room (FFCR):

All the activities burden distribution; stoves, cast house, auxiliary fuel injection etc. are controlled from FFCR located in the furnace. Level –0, Level –1 and Level-2(Modern furnaces) automation facilities are there in all BF. All the details regarding the furnace are monitored using HMI/SCADA and mimic panels kept in the FFCR.

Auxiliary Sections:

The auxiliary section of blast furnace consists of following sections:

1. Ladle Repair Shop(LRS)
2. Pig Casting Machine(PCM)
3. Cold Pig Yard (CPY)
4. Clay Mass Shop(CMS)
5. Coal Dust injection Facility(CDI)
6. Cast House Slag Granulation Plant(CHSGP)
7. Slag Dump Yard(SDY)
8. Area Repair Shop (Mech/Elec)
9. Torpedo Ladle Repair Shop(TLRS)

Ladle Repair Shop: Ladle repair shops provided for relining, repairing and cleaning of the iron ladles. Shop contains an EOT cranes for speeding up the job.

Pig Casting Machine: These are double strand pig casting machines. Each machine contains no. of moulds in one belt with lime coating arrangement underneath the machine. Moulds are filled with the hot metal from the ladle at the spout, cooled by water sprays on the bed while on movement and the pigs are separated from mould chain by knockout arrangement.

EQUIPMENTS of PCM

- Winch to lift the loaded liquid metal ladle.
- Two stands (frames) to hold the ladle firmly, with the paws attached in both the sides of the ladle.
- Runner to receive the liquid metal and to pour into the moulds through spouts.
- Lime spray units to make a thick coating of lime on the moulds to avoid sticking of cold metal with the moulds.

- Individually operated steel belt conveyors to receive the liquid metal and to dispose after pigs are made.
- Chutes to receive the cold pigs and to drop the same into Wagons/Flat car.
- Capstan system at the discharge end to move the loading wagons during pigging.

Cold Pig Yard: Cold pigs from PCM come here. These are stacked according to their quality, and loaded in box wagons with the help of EOT cranesfor dispatch to stack yards of customers.

Clay Mass Shop: Here, refractory mass required for blast furnace department is made and stored e.g. mud gun clay, tap hole frame mass and runner mass etc.

Slag Dump Yard: The slag ladles from BF is sent to the dump post for emptying the ladles. Provision exists at the yard for tilting and hammering out the slag with the help of cranes.

CHSGP: Slag granulation plants are attached with the cast houses and the slag generated is granulated at CHSGP. This granulated slag is transported via conveyor belts to the granulated slag yard from where it is sold to the customers (i.e Cement Industries).

Area Repair Shop: Both Mechanical and Electrical Section have their repair shop where necessary supporting repair works are done.

Torpedo Ladle Repair Shop: Torpedo Ladle repair shops provided for relining, repairing and cleaning of the torpedo ladles. Shop contains an EOT cranes, tilting drives for the job.

Auxiliary Fuel Injection

In the present competitive environment, there is a lot of pressure on BF operators to lower the operating costs and maximize **productivity**. One way to achieve this is by injecting auxiliary fuel into the blast furnace. The fuels used for this purpose maybe coal dust, coal tar, natural gas, coal bed methane etc. In SAIL generally coal dust injection (CDI) is being used as auxiliary fuel injection.

The challenge now is to achieve high CDI rates with available quality raw materials, without losing hot metal quality, productivity or BF availability.

Economic and operational benefits achieved by using coal dust injection (CDI) include:

- Lower consumption of expensive coking coals. replacing coke with cheaper soft coking or thermal coals reduces reductant costs;
- Extended coke oven life, since less coke is required to be produced. This is important as many coke ovens are reaching the end of their useful life and significant investment is required to replace or maintain them;
- Higher BF productivity(Ton/m^3/Day), that is, the amount of hot metal produced per day (in conjunction with other operational changes);

- Greater flexibility in BF operation. for instance, CDI allows the flame temperature to be adjusted, and the thermal condition in the furnace can be changed much faster than would be possible by adjusting the burden charge at the top of the furnace;
- Improved consistency in the quality of the hot metal and its silicon content;
- Reduced overall emissions, in particular, lower emissions from coke making due to decreased coke requirements.

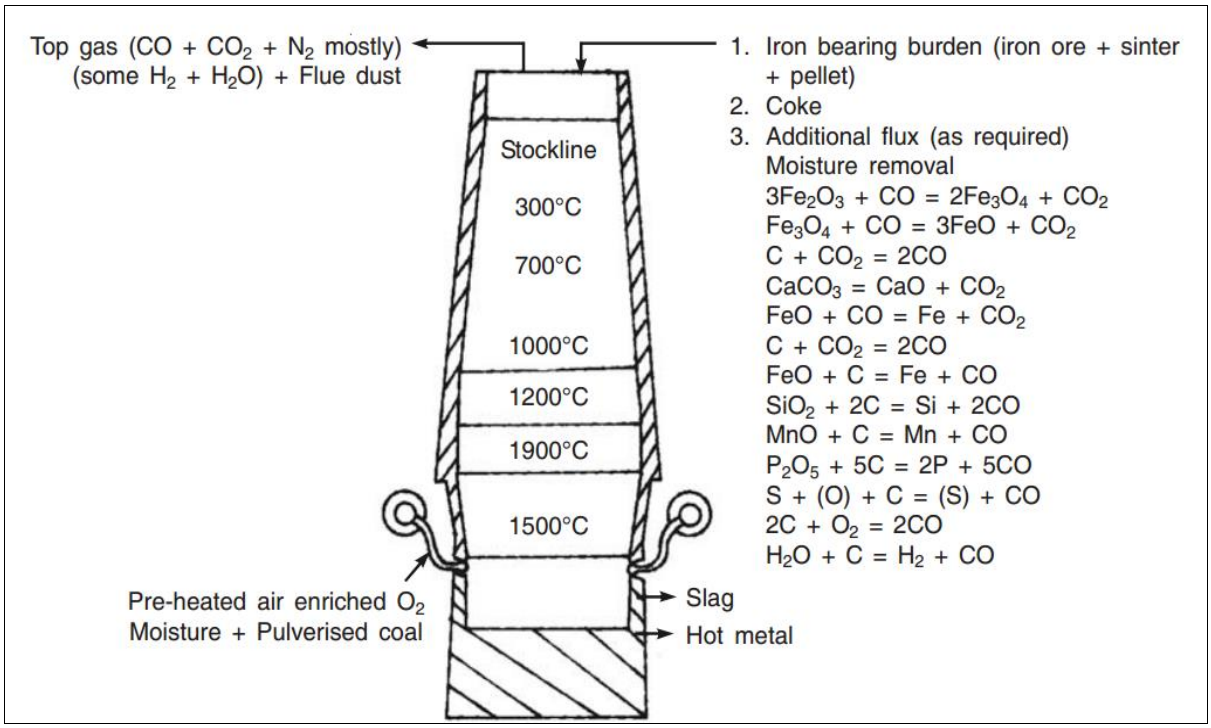
Gas Cleaning Plant:

The other product BF gas contains lot of dust in it and it is cleaned in dust catcher, ventury washer and scrubber and finally in electro static precipitator. This activity is done under the supervision of energy management department. The cleaned BF gas is sent to the gas network and is used as a fuel all over the plant.

Flow of BF gas to GCP is
BF Gas → Uptake→Down Comer→Dust Catcher→Ventury Washer→ Scrubber →Electro Static Precipitator→ Cleaned BF Gas →Gas Main

4.4 BF Zones and chemical reactions

Reactions in the Blast Furnace:



UPPER STACK ZONE

- Reduction of Oxides
- Carbon Deposition
- Decomposition of Carbonates
- Decomposition of Hydrates Water
- Gas Shift Reaction

MIDDLE STACK ZONE

- Indirect/Direct Reduction
- Gas utilization

LOWER STACK ZONE

- Calcinations of Limestone
- Reduction of Various elements
- Reduction of unreduced Iron
- Reduction of Silicon
- Reduction of Mn, P, Zn etc
- Formation / melting of slag, final reduction of FeO and melting of Fe.

COMBUSTION ZONE

- Burning and combustion of Coke
- Complete reduction of Iron Oxide

RACEWAY

- Combustion of Coke and Hydrocarbons.
- Combustion of CDI.
- Large evolution of heat.

HEARTH

- Saturation of Carbon with Iron
- Final Reduction of P, Mn, Si and Sulphur
- Reaction impurities reach their final concentrations
- Falling / drop of Metal and Slag bring heat down into the Hearth.

The liquid products hot metal and slag settle in the hearth. These two products are removed periodically from the blast furnace. The process is called tapping the blast furnace.

The golden rule of blast furnace operation is that the furnace conditions should not be disturbed. If for one reason or the other, the quality of charging materials fluctuates, the furnace will be affected. The moisture of coke should be continuously measured and corrective action to be taken. Once the tapping is opened and liquid level begins to fall, the blast pressures drops correspondingly. During the tapping itself, burden descent is fast and irregular. The rise and fall of blast pressure will cause raceway distortions. Similarly, the bosh gas distribution is affected when the burden descent rate increased or decreased. As stock line is not maintained many a time unprepared burden enters the melting zone and increases the thermal requirements. The effect of all these is the disruption of the configuration of the cohesive zone, increase in coke rate and decrease in productivity. Continuous monitoring of the top gas analysis will give an indication about the furnace efficiency.

Common difficulties in operation:

Furnace performance is linked with the smooth operation of the furnace which gets disturbed very often due to various kinds of fluctuations taking place in operating parameters.

Results the number of Irregularities may observed during the operation of furnace like:

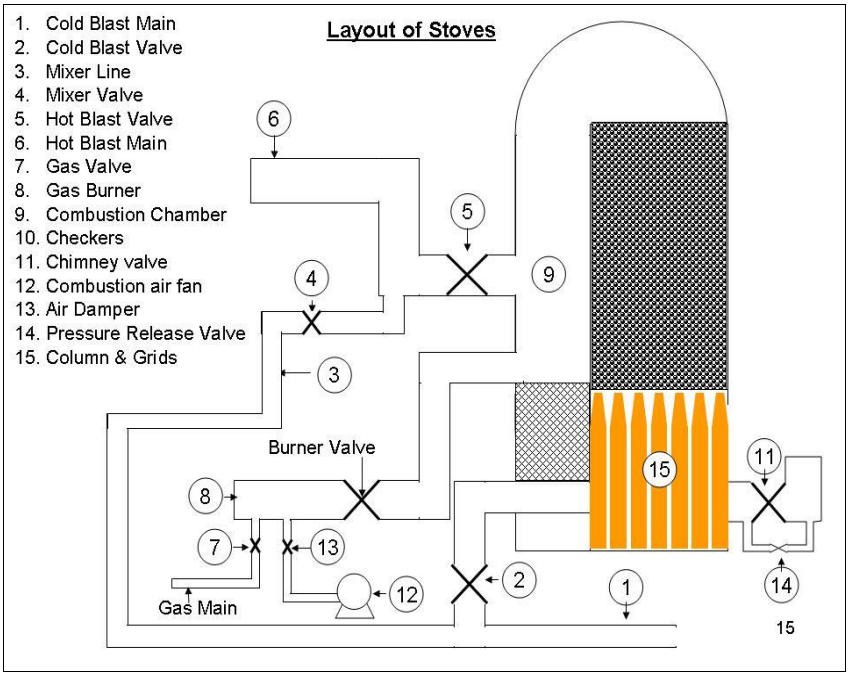
- Channelling
- Scaffolding
- Hanging
- Slipping
- Choking of Hearth
- Chilling of Hearth
- Burning of Tuyeres
- Coke rush through tap-hole.

4.5 Hot blast stoves

The function of Hot blast stove is to preheat the air before admission into the furnace through tuyere. Air is preheated to temperatures between 1000 and 1200 °C in the hot blast stoves.

There are 3 or 4 stoves for each furnace. Each stove consists of a combustion chamber and refractory checker brickwork. Combustion chamber lined with fire bricks and checkers are by alumina brickwork.

For controlling cold and hot blast there are several valves given on the stove. They are: cold blast valve (1), hot blast valve (5), chimney valves (11), by-pass chimney valves (14), gas control valve (7), gas burner (8), and air fan (12).



Hot Blast Stove and its Valve Arrangement

There are two cycles in the stove operation.

1. On gas: stove in the heating mode
2. On blast: stove in the blast mode

In the first cycle the stoves are getting heated by using BF gas and / or coke oven gas. The flue gases (200-350°C) will be carried out through the chimney. This stage is called **'on-gas'**. When the dome temperature reaches to the desired level (1100-1350°C) the gas is stopped and cold blast that is coming from the power and blowing station is sent thorough the cold blast valve, this cycle is called **'on blast'**. The sensible heat that is stored the checker brickwork is carried away by the cold blast and is getting heated. Thus hot blast is produced and this blast is sent into the blast furnace through hot blast valve via hot blast main, bustle pipe, compensator, tuyeres stock and to the tuyeres. The stove kept 'On blast' will continue for ¾ hrs - 1¼ hrs and will be followed by "on gas' cycle (1½ hrs – 2½ hrs). Thus at any point of time one or two stoves are kept 'on blast' and two stoves are 'on gas' and the cycle is repeated continuously. Heated stove kept isolated, as ready for on blast cycle.

A **snort valve** is located on the cold blast main, regulates the volume of blast. The steam is injected for the humidification of the blast before pre-heating in the stove. Oxygen enrichment is also done whenever necessary through the blast itself. A mixer valve which regulates the flow of cold blast enables to maintain the desired hot blast temperature.

The hot blast reacts with coke and injectants', forming a cavity, called raceway in front of the tuyeres and different reactions takes place in various zone to produce hot metal.

4.6 The Cast House and Slag Granulation Plant

Function

The cast house is the most labor intensive area in the entire blast furnace operation. Its design must be fully integrated with the expected hot metal production, hearth volume, and tapping practice whilst minimizing use of labor, maintenance, materials and improving working environment.

The function of cast house is to tap the liquid metal and slag via the tap hole from hearth on scheduled time and separate the metal and slag by skimmer block with siphon hole in trough which is made up of refractory mass (Castable) and direct metal to metal ladles and slag to the slag ladles or CHSGP.

Process and parts of cast house:

In the BF of single tap hole, there is a provision to flush the slag through the slag notch (called **monkey**) situated at a height of 1400 mm - 1600 mm from the axis of the tap hole. The monkey is equipped with pneumatic or manual cinder stopper. Increasing the number of tapings can reduce flushing operation.

Cast house consist of tap hole, trough, iron and slag runner, rocking runner and their spouts and various equipments (such as EOT crane, Pusher Car, Rocking Runner Tilting Mechanism, Drilling Machine, Mud-gun, JCB / Poklain (excavator) etc). The hot metal is tapped out at an interval of 1-2 hrs depending upon the furnace condition. The tapping time will be around 90 – 120 minutes. Generally 8 -9 tapings will be done in a day. The usual way of opening the tap hole is to drill the tap hole until the skull is reached then oxygen lancing is carried out to melt the skull to get good flow of hot metal.

Generally the tap hole is located in such a way that after tapping minimum amount of metal should remain in the hearth. So it is almost at the bottom most part of the hearth. After opening the tapping hot metal will comes out first. After some time the liquid level in the hearth decreases and the slag that will be floating on the metal comes out of the tap hole. The skimmer plate separates the slag from the metal and diverts the slag into the slag ladles / SGP through slag runners. The hot metal continues to flow down the bend runner from which it is diverted into individual metal ladles. The control of this operation is accomplished by cutters located in the runners or with the help of rocking runner and pusher car. At the end of the tapping the tap hole is closed with the mud gun, which is electrically or hydraulically operated

The hot metal is collected in a refractory lined vessel called hot metal ladle/torpedo ladle and for safety reasons it is filled up to 85 – 90 %. Using these ladles hot metal is transported from blast furnace to mixers in SMS, PCM and foundry as per requirement.

Similarly slag is collected in slag ladles and is dumped in the dump post or sends to slag granulation plants (SGPs) in which slag is granulated, and this granulated slag is sold to cement manufacturers.

The equipments available at the cast house are:

1. Drill Machine → Hydro-pneumatic or electric drilling machines are used for opening the tapping
2. Mud-Gun → Hydraulic or electric drilling machines are used for closing the tapping with anhydrous or water bonded tap hole mass
3. Cast House Crane → for material handling during cast house preparation
4. Rocking runner → to divert the metal into a different metal ladle (tilting runner)
5. Pusher car → used for local placement of the metal ladle

Analysis of hot metal, slag and top gas

Hot Metal		**Slag**		**BF gas**	
Si	0.6 - 0.8 %	SiO_2	34 – 36 %	CO	20 – 24 %
Mn	0.05 - 0.10 %	Al_2O_3	16 – 20 %	CO_2	18 – 20 %
S	0.050 % max.	CaO	34 – 36 %	N_2	48 – 52 %
P	0.05-0.15 %	MgO	8 – 10 %	H_2	4 – 5 %
C	4 – 5 %	MnO	<1%		
		Basicity: CaO/SiO_2	0.98-1.00		

Modern technological developments

Some of the modern technological developments implemented at our plants are:

Beneficiation - To upgrade the quality of iron ore, special emphasis is for preferential removal of alumina from the gangue.

Bedding, Blending, Sizing and Screening of burden - Physical and chemical characteristic of iron ore, coal and limestone vary from deposit to deposit and also from one mine to another. For trouble-free operation of blast furnaces, it is essential to ensure supply of raw materials of consistent and uniform quality. The bedding and blending of the incoming raw is adopted before processing them.

Use of 70 – 80 % sinter in the burden - It has been proved that with the use of sinter in the burden the productivity of blast furnace increases. Along with sinter 10-15% pellet in burden mix will also give additional benefits.

Conveyor charging - All burden materials are delivered to the furnace top by conveyor. This is economical for bigger blast furnaces. All 3 bigger blast furnaces in SAIL i.e. BF-5ISP (4161m^3), BF-5 RSP (4060m^3) and BF-8 BSP (4060m^3) have conveyor charging facilities.

Bell less top - In place of conventional two bell charging system, two charging hoppers with rotating chute are installed. The rotating chute distributes the material in the desired manner. The system is easy to maintain. The system has been adopted in BF - 4, 5, 6, 7, 8 of BSP, BF # 1, 4 & 5 of RSP, BF # 3 of DSP and all the blast furnaces of BSL.

Movable throat armour - This is installed along with two-bell system. The distribution of material is controlled by positioning the throat armour at proper location. The system improves the burden distribution. BF # 2 & 4 of DSP has been provided with this system.

Amanoscope - The device is fitted at the top of the furnace. It emits a beam of infrared rays over the material surface of the stock and takes the photograph.

Furnace probes - Probes are fitted above (above burden probe) the stock level / below the stock level (under burden probe) in order to monitor temperature distribution and collect samples of burden material and gas.

Cast House Slag Granulation - In this design the liquid slag from cast house runner is led to the granulating unit located very near to the cast house. This would eliminate the need for maintenance of large fleet of slag ladles, reduce the cost of production, avoid delays and increase the yield of granulated slag.BF # 4, 5, 6, 7& 8 of BSP is having cast house slag granulation. This facility is installed in all furnaces of BSL. This facility already exists in BF # 1, 4 & 5 of RSP and BF # 3 & 4 of DSP.

Slag Granulation Plant marked by the following features:

- It facilitates dry tapping of the furnace; not being limited by ladles availability.
- Utilization of molten slag is very high (98%) compared to distant granulation (70%) and better slag granules quality. Safe, efficient and pollution free working environment by avoiding movement of ladles etc

The main advantages ofCHSGP are:

1. Very compact and requires less space.
2. Fully automatic, less manpower requirement.
3. Low electricity & compressed air consumption.
4. Completely covered installation from granulation unit to the dewatering station with connection to stack for the collection of stream & fumes and venting out the same to the atmosphere at high level

Coal Dust Injection - Non-coking coal is injected through tuyere using nitrogen as carrier. This reduces the coke rate and thus saves the valuable coking coal, which is also not abundantly available in India. Coal dust injection is normally associated with high blast temperature and oxygen enrichment.All furnaces ofSAIL plants have been provided with a coal dust injection system.

External Desulphurization of Hot Metal - With the introduction of continuous casting technology and increased demand for high quality steel, requirement of low Sulphur (less than 0.025%) hot metal has increased. For this purpose hot metal from BF is desulphurised

by injecting desulphurising agents such as calcium carbide, lime soda ash and magnesium in the hot metal ladle. One desulphurising unit has been installed at RSP, ISP, BSP& BSL (under installation).

Cast House Desiliconisation -Silicon from hot metal is partially removed by adding mill-scale, iron ore, along with lime in the hot metal runner. Such installations are working in Abroad.

De-Phosphorisation of Hot Metal – De-phosphorising agents like soda ash and lime based flux are added in hot metal in transport vessel to reduce phosphorous content of hot metal.

Automation & Computer control - In case of fully automatic operation, the computer (HMI system) is connected to PLC (Programmable Logic Controller)which receives signals from various sensors and determines the optimum point values and commands the equipments to operate automatically. Automatic control of charging & stoves are provided in furnaces**.**

As per the decision of SAIL management, to achieve targeted hot metal production the following measures have been envisaged in the blast furnace area.

1. Modernization/Upgradation of the BF with respect to refractory, cooling system, stoves ,auxiliary fuel injection and supporting equipments
2. Installation of a new and bigger furnace at a separate location along with a new stock house and new material handling facilities with modified sinter plant and coke ovens. New furnace has been commissioned in RSP, ISP andBSP.
3. Modification of the existing material handling system.
4. Introduction of torpedo ladles.
5. Improvement of logistics in blast furnace area etc.
6. Waste Heat Recovery System (recovery of heat from outgoing stove hot flue gases to heat up the Combustion Air and BF Gas and thus enhance the heating of stoves).
7. TRT (Top Gas Recovery Turbine to generate Power) is provided in new furnaces at ISP,RSP and BSP @ 14 MW power generation per day
8. Radar Stock Level Indicator enables to measure the stock level when the furnace is off-rod (beyond 3 meters) is provided in BF # 2 of BSL, BF # 6 of BSP and new furnaces at ISP,RSP and BSP

4.7 Safety and environment

The use of PPEs (Personal Protective Equipment) like safety helmet, safety shoes, hand gloves, gas masks, heat resistant jackets/coats, goggles and dust masks are to be used religiously while working in different areas of Blast furnace

Laid down procedures like “permit to work” are to be strictly followed before taking any shut-down of equipment for maintenance. The stipulated SOPs (Standard Operating Practices) and SMPs (Standard Maintenance Practices) should be adhered strictly.

Persons should be cautious about the gas prone areas and should know about the gas hazards. EMD clearance is a must before taking up any job in gas lines or gas prone areas.

Following do's and don'ts are to be followed for safe Operation of blast furnace.

DO's

1. Ring bell/hooter during crane movement
2. Safe distance should be maintained while looking through Tuyeres (wear safety glass)
3. Before putting any stove to gas mode if any gas leakage observed then remove the agency working in stove platform
4. Always carry CO-GAS monitor & gas safety man while going top of the Furnace for checking any abnormalities & during stove area inspection
5. Always monitor proper gas burning in tapholes, monkey, tuyeres, tuyere Coolers during running of Furnace
6. Shut Down Work for repair etc should be carried as per procedure (protocols) duly approved.

Don'ts

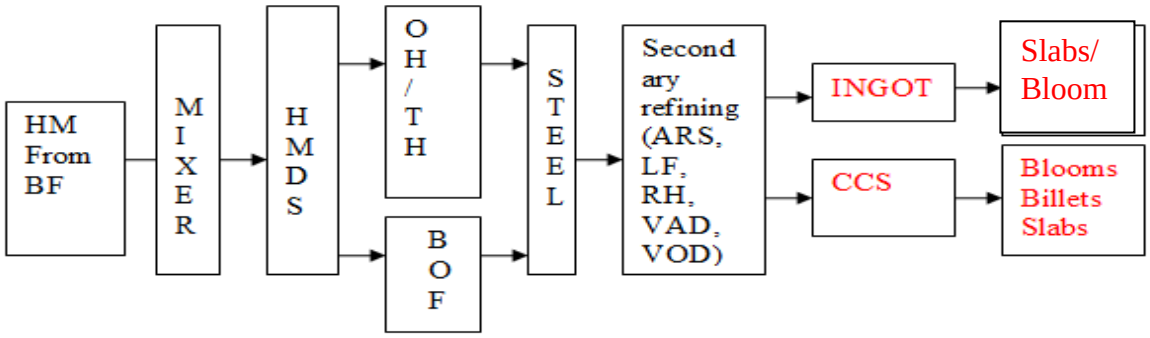
1. Don't allow any unauthorized person on stove platform.
2. Don't allow any one in Cast House area of blast furnace without safety appliances.
3. During any gas leakages don't allow anyone in the Cast House area & stove platform.
4. Don't Operate lift without proper knowledge of Mech./Elect. Operation of Lift, Always ask for lift--operator.
5. MCC panels should not be operated only by authorized personnel.

Chapter – 5

STEEL MAKING

5.1 Introduction

The Hot Metal also known as molten pig iron which is produced by Blast Furnaces contains various impurities. Main impurity present is Carbon and other impurities like phosphorus, sulphur, silicon, non metallic inclusions etc are also present. Steel making is the process of purification of this Hot Metal. Steel such produced is the pure form of metal. Hot Metal contains around 4% of Carbon which is to be reduced below 0.10% as per the requirement. Other impurities like sulphur, phosphorus are also removed and alloying elements such as Manganese, Silicon, Nickel, Chromium and Vanadium are added to produce the exact steel required. The schematic view and various processes involved in steel making are as follows:



HMDS—HOT METAL DESULPHURISATION
BOF—BASIC OXYGEN FURNACE
OH/THF—OPEN HEARTH/TWIN HEARTH FURNACES
ARS—ARGON RINSING STATION
LF—LADLE FURNACE
RH DEGASSER—RUHR –STAHL HERAUS (Process is named on a German town and a German scientist)
VAD—VACCUM ARC DEGASSER
VOD—VACCUM OXYGEN DECARBURISATION
CCS/CCP—CONTINUOUS CASTING SHOP/ PLANT

The Hot Metal from Blast furnace comes in Hot metal ladles / Torpedo Ladle to Steel Melting Shop by rail. It is poured into a vessel called Mixer. It is then taken out from mixer as per requirement of the Converter. It can either go through Hot metal desulphurization unit (HMDS) or directly to the process of steel making i.e. Basic Oxygen Furnace (BOF).

Advancements in Steel Making Process

Bessemer process > Open Hearth /Twin Hearth > LD Convertor

Hot Metal Desulphurisation

Sulphur is mainly present in iron ore and coal. Reducing the sulphur content to less than 0.020% in the blast furnace is difficult from an economical standpoint. As the steel quality often requires a sulphur content of 0.010%, the hot metal must be desulphurized in another way. In desulphurization methods lime or calcium carbide and magnesium reagent may be used in proper proportion. They are injected into the metal with a special designed lance under a gaseous stream. In this way, the Sulphur content can be reduced to levels below 0.005 %. Hot metal in a ladle is brought to Desulphurization unit by *EOT cranes or rail. After proper positioning of the ladle, injection lance is lowered deep into the metal. Then start injection of the said material through the lance and is continued for 5 to 10 minutes depending on sulphur content in hot metal. Sulphur impurity is removed in the form of magnesium sulphide in a violent reaction. Ladle is then taken to slag racking machine to remove the slag formed during the injection process. Hot metal is then sent to converter.

5.2 Open /Twin Hearth Furnaces

One of the oldest established process of steel making, most open hearth furnaces were closed by early 1990's, because of their fuel inefficiency, low productivity and cumbersome operation. Basic oxygen steel making (BOF) or LD process replaced open hearth furnaces.

Twin hearth furnace consists of two hearths separated by a bridge wall with a common roof. Twin hearth furnace works on synchronization between the two hearths, there by both the hearths are engaged in different operations. While one is in solid period, the other will be in liquid period.

The fundamental principle of Twin Hearth Furnace is physical and chemical heat generated during blowing in one hearth is utilized in the adjoining hearth for preheating the charge, making the process faster. The tap to tap time of THF is cut by half since the furnace is tapped from both the hearth alternatively at an interval of one half of the heat duration in one hearth. Operational efficiency of the furnace is based on the equal duration of the both cold and hot period i.e. in one hearth when melting starts the other hearth is ready to be tapped.

Activities in the furnace can basically be divided into two parts. Activities during cold period and activities during hot period run parallel at the same time for one of the two hearths in such a way that if one hearth is in cold period other will be in hot period. Cold period includes the time given to the furnace for tapping, fettling, charging and heating of the cold charge up to the end of pouring of hot metal in the furnace. The activities taking place during the hot period can be categorized into melting, refining and holding.

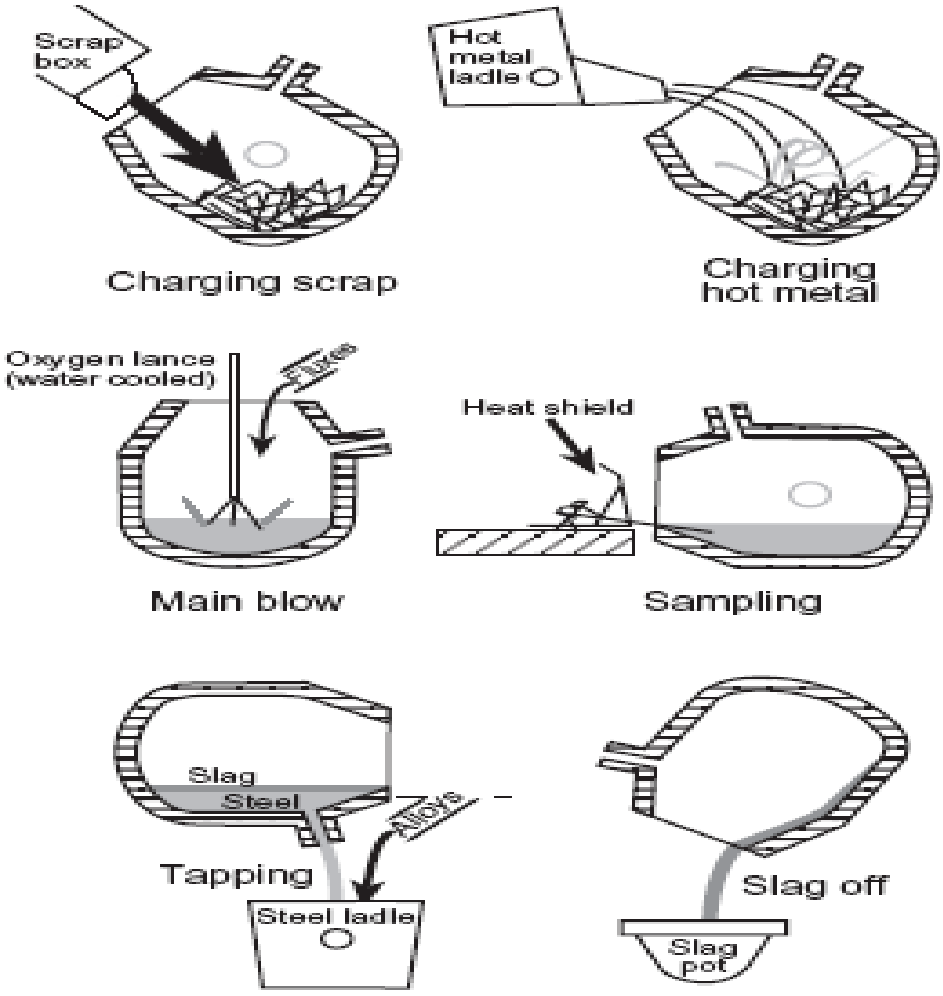
**EOT-Electrically operated Overhead Travel*

5.3 Basic Oxygen Furnace (BOF - LD Converter)

Sequence of operation in BOF

1. Lime/dolomite addition at converter bottom.
2. Scrap charging
3. Hot metal charging
4. Oxygen blowing
5. Addition of fluxes in batches during blow

6. After blowing oxygen lance is lifted and converter tilted for sample and temperature recording
7. Tapping in ladle
8. Addition of de-oxidiser in ladle during tapping



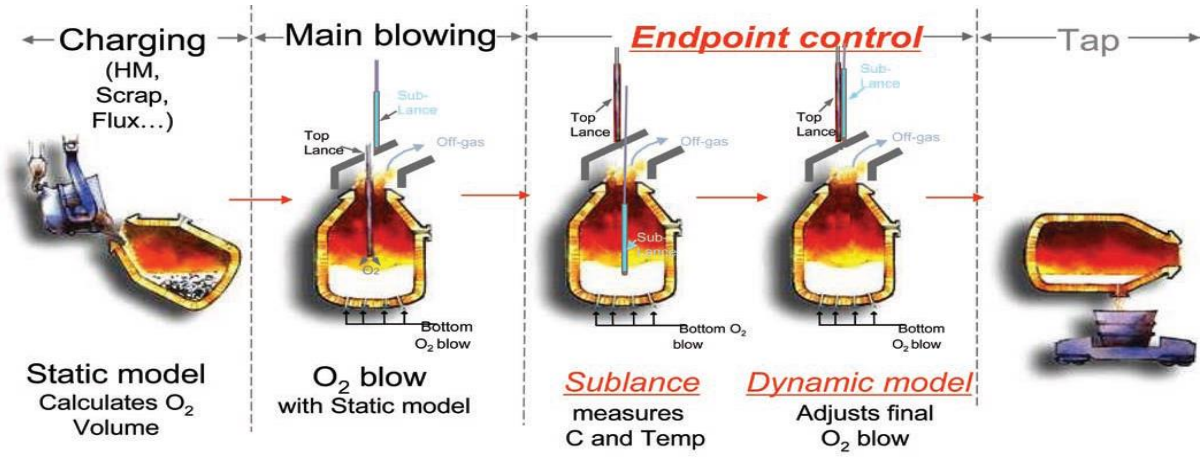
Basic Oxygen Furnace is commonly known as BOF process or LD process. It is named so because this process was developed in LINZ and DONAWITZ, two cities in Austria. The process is also called basic because of refractory type used for lining the vessel to withstand the high temperature of molten metal.

As compared to Open / Twin hearth, BOF process is fast, energy efficient and simple. It reduces the time of smelting, and increased labor productivity. Tap to tap time in BOF is around 45-50 minutes. The name BOF is derived from the manner in which the compositional adjustments are achieved. Oxygen is the reagent/fuel that is used to remove most of the undesirable elements via a number of complex oxidation processes. Basic refers to the fact that the reaction takes place in a Vessel called converter lined with basic refractory.

Inputs:

The major input materials in BOF or LD converter are:

- **Hot Metal:** Hot metal containing around 4% carbon is the main input in the BOF.
- **Scrap**: It is used as a coolant as the process is exothermic. The large thermal energy is produced during the process so as to get targeted end/tapping temperature, it is important to maintain the proper charge balance, the ratio of hotmetal to scrap.
- **Fluxes:** Fluxes such as calcined Lime, calcined Dolomite etc are used in the process for slag making. Slag is required to absorb/extract impurities from metal. An emulsion of metal and slag formed during blowing helps in refining.
- **Oxygen:** one of the important inputs comes mainly from captive Oxygen plants in addition to the purchased liquid oxygen. Oxygen purity should be more than 99.5%.
- **Nitrogen:** It is not directly taking part in the process but used for purging and ceiling purpose. It is also used for slag splashing to coat vessel refractory lining.
- **Ferro-Alloys:** while tapping the steel Ferro-alloy such as Fe-Si, Si-Mn, Fe-Mnetc are being added to make the desired grade of steel.



A complete cycle consists of the following phases:

1. **Scrap Charging,**
2. **Hot Metal Charging,**
3. **O_2 blowing,**
4. **Sampling & Temperature recording**
5. **Tapping.**

Process:

- **Mixer and Desulphurization:** The process start with mixer in steel melting shop. Metal is stored in Mixers and it is taken out as and when needed. Before charging it into BOF, external desulphurization is done as per requirement to reduce Sulphur content in Hot metal. Calcium carbide or lime powder and magnesium compound are injected into hot metal through a lance with Nitrogen as a conveying gas. After compound injection is over slag racking is done to remove the slag which is necessary to avoid reversal of sulphur.

- **Converter blowing:** The process of blowingmeans reaction of Oxygen with hot metal and fluxes in LD converter. The hot metal along with scrap is charged into converter with the help of EOT cranes by tilting the converter. A typical composition of Hot metal is C- 4.0%, Si – 0.60 %, Mn – 0.10 %, P- 0.15%, S-

0.050% and temperature is around 1300ºC. After charging, converter is kept vertical and lance is lowered in the converter through which oxygen is blown at a pressure of around 14-20 kg/cm^2. During the blowing process fluxes such as lime, Calcined dolomite, iron ore etc are added to make slag. The most important flux is lime. The slag is basic in nature. Main impurity carbon reacts with oxygen and is removed in the gaseous form (CO/CO_2) Impurities like Si, P, S and other non metallic impurities are removed in the form of slag, which is lighter than metal so it floats on metal surface. The blowing process usually takes 15-17 mints. When the blowing is complete converter is tilted to take out the slag in a slag pot. Sample and temperature is also taken manually. At the end of the blow the temperature is generally in the range of 1650ºC - 1690ºC and a typical bath analysis is C – 0.07 %, Mn – 0.08 %, P – 0.020 %, S- 0.030 %. When the desired composition and temperature is achieved the steel is tapped.

HEAT BALANCE in a Convertor i.e. Heat Input = Heat Output is balanced as:

Heat Input as

a. **Sensible heat of hot metal in BOF.**
b. **Oxidation of Carbon.**
c. **Oxidation of Silicon.**
d. **Oxidation of Manganese.**
e. **Oxidation of Phosphorus.**
f.

Heat output as

a. **Sensible heat of Steel.**
b. **Sensible heat of Slag.**
c. **Sensible heat of off gases.**
d. **Chemical heat of off gases.**
e. **Sensible heat of dust**
f. **Heat loses through convection and radiation of the converter**

- **Tapping**: Tapping means discharging the liquid steel into ladle through the tap hole present in the converter by tilting it. As per the grade of steel the Ferro-alloys are also added into ladle during tapping. As soon as the steel finishes the converter is lifted and tapping is complete. Good tap hole maintenance and slag free tapping devices like pre tap plugs,Slag Stopper,darts, electromagnetic slag detection sensors etc commonly used to prevent slag carryover into the ladle.

- **Nitrogen Splashing**: After tapping, the residual slag in the converter is splashed with the help of nitrogen along with addition of Lime and/or coke. Converter is kept vertical and lance is lowered. Through the same lance nitrogen is blown which splashes the basic residual slag in the converter and gives a coating on the refractory bricks. Main advantage of nitrogen splashing is to increase the lining life of the converter.

- **Chemical Reactions**: There are a lot of complex chemical reactions taking place in the BOF during blowing. Main reactions in simplified form are given below

  $Fe + O = FeO$
  $C + O = CO/CO_2$
  $Si + 2O = SiO_2$

$Mn + O = MnO$

$2P + 5O = P_2O_5$

These reactions are exothermic in nature. Lot of heat is evolved during blow. Scrap is used as a coolant to maintain the thermal balance. Due to addition of fluxes the chemical reaction with CaO from Lime and Dolomite and Si, Mnetc from hot metal takes place to make complex compounds which are basic in nature thus helping in making a basic slag which facilitates dephosphorisation.

- **Slag Composition:** The slag formed during the BOF process is basic in nature. It is a complex oxide compound of Ca along with Si, P and other non metallic inclusions. A typical slag analysis at the end of the blowing is as follows:

  CaO= 45-50%,
  MgO= 9-11%,
  FeO= 15-20%
  Basicity= $CaO/SiO_2 \geq 3.0$

- **Functions of Slag**
  a. To transfer the oxygen required for refining.
  b. To create favourable conditions for decarburisation of dispersed metal droplets.
  c. To provide a means of removing phosphorus from the liquid pig iron.
  d. To provide means of eliminating some sulphur from the bath.

- **Refractories**: Refractory plays a very important role in BOF shop. As liquid metal is handled in BOF Shop so all vessels like mixer, converter, ladles etc are lined with refractory bricks. It protects the shell of vessel and retains the metal temperature. Different types of refractory is used as per their usage are given below:

  - **Converter Vessel:** The bricks used here are basic in nature. Dolomite bricks or magnesia carbon bricks are commonly used in converter. In recent times magnesia carbon bricks have replaced dolomite bricks. Number of heats made in a converter from one new lining to next lining is known as the lining life of the converter. Now a days all plants are trying to achieve higher lining life. The tap hole in the converter is also made up of refractory, which wears with number of heats tapped. It is changed from time to time.

  - **Mixer:** The bricks used here are normally high alumina and magnesite bricks

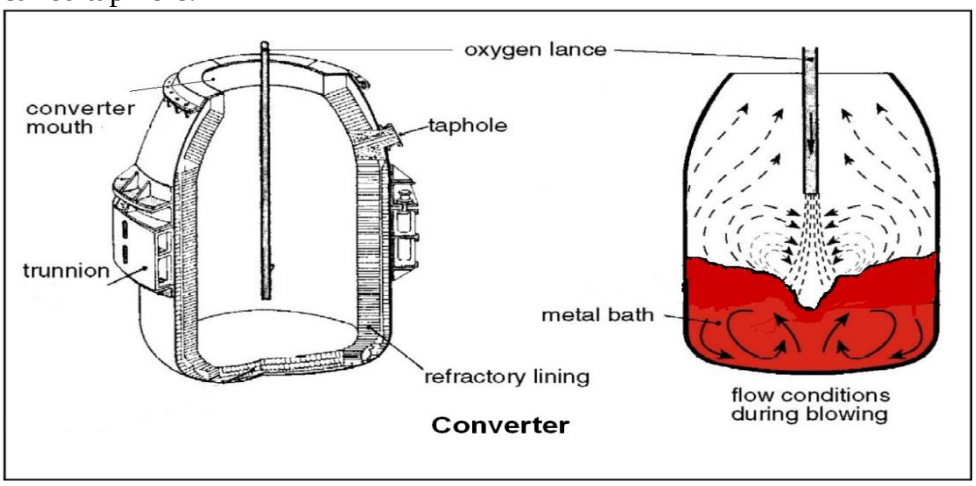
  - **Ladles:** The small vessel which carryHot Metal for charging the converter are called hot metal ladle. They are lined with high alumina bricks. The steel is tapped in steel ladles. This ladle carries steel to secondary refining and finally for casting. The bricks used are again high alumina and magnesia carbon.

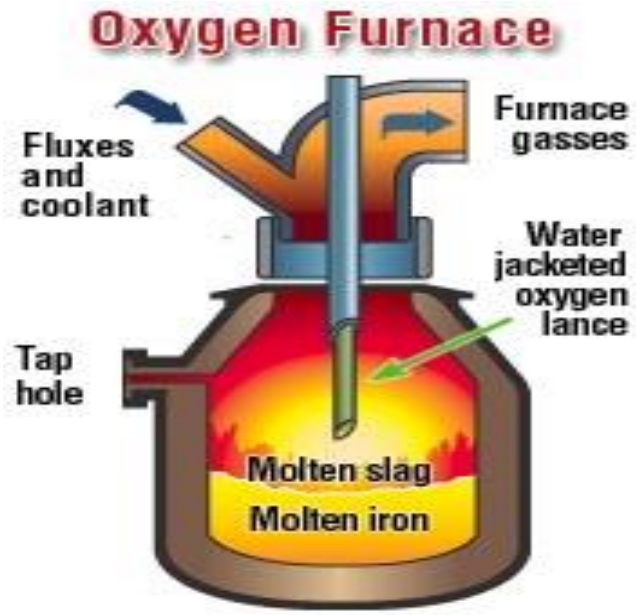
Equipments: Major equipments in BOF shop are:

- **Mixer:** A large cylindrical or rectangular refractory lined vessel with tilting mechanism, and it is used to store molten metal coming from Blast Furnace. Mixer has a Charging hole from where Hot metal is being charged into the mixer with the

help of EOT cranes and a spout to take out hot metal by tilting the mixer. Main functions of mixer are storage and homogenization. Mixed gas is supplied through side burners in order to maintain temperature in Mixers.

- **Converter:** A converter is an open pear shaped vessel made of steel and lined from inside with basic refractory bricks. It can be rotated through 360^0. Charging and deslagging is done through mouth where as tapping of steel is done through a hole called tap hole.





- **Lance:** It is made of three concentric steel tubes where water is circulated in the outer tubes and oxygen in the inner tube. Tip of the lance is made of copper. Generally 5 or 6 holes lances are used. A stand by lance is always provided in converter for continuous blowing operation.

- **Gas Cleaning Plant(GCP):**A huge quantity of waste gases with high temperature and containing dust particles, generated during theLD or BOF process is passed through the GCP. Primarily water is sprayed over the gases to separate the solid dust

particles and to cool and collect them. Cleaned gases are either collected in a gas holder or is burnt in the atmosphere to control air pollution.

- A large water cooled hood sits above converter. The vast quantity of waste gas produced during steel making pass through hood and then collected and cleaned. An ID fan is present which draws the gases up into hood. A movable skirt is attached to bottom of hood which closes the gap and sits on the converter mouth thus controlling the level of air ingress during the blow and avoids burning of CO gas at Convertor mouth.

Safety Aspects: As we deal with liquid metal in the Shop, personal as well as equipment safety is of large concern. We should strictly follow the safety norms.

- Before charging, converter must be inspected thoroughly and make sure that no liquid slag should be left in the converter. If there is liquid slag, it must be dried up by adding lime before charging.
- Do not allow anyone to stand in front of Converter during charging.
- There should not be any water in the slag pot in which the slag is to bedumped.
- Persons working in the steel melting shop should use personal protective equipment (PPEs) like gloves, blue glass, fire retarding jackets.
- Blowing should not be done if there is any water leakage in the lance/hood/skirt.
- In case of excessive water logging below the converter blowing should be stopped immediately till the water is cleared.
- In case of charging and tapping of converter lot of care has to be taken to avoid any metal splashes.

Quality Requirements: Now a day as the quality norms are quite stringent and customers specification are becoming very strict so at all stages quality has to be monitored. In BOF the slag decides the quality of steel. A good slag leads to good steel. Slag carry over to the steel ladles while tapping should be minimum. Slag arrestors are used to minimize slag carry over.

Waste and environment management:

In BOF during the steel making process, lot of wastes are generated. Some of them are as follows:

- During the blowing process lot of waste gases are generated along with dust. CO gas evolved during blowing process is collected in a gas holder and it is further used as a fuel in different units. The dust collected from GCP as slurry is required to be disposed properly or re-used / recycled as input feed for BF or Sinter Plant.
- Slag generated during the steel making operation is also recycled. It is dumped and cooled then it is used by Blast Furnaces, sintering plant and Steel Melting Shop.
- The slag that is disposed off can be used for making pellets / briquettes for consumption in Sinter Plant.
- Effective dog-house must be installed to capture the fugitive emissions from the Converter.

Tapping practices to be performed in convertor:

- ***Deslagging after blow finish***
- ***Sample and temperature***
- ***Reblow if required***
- ***97% straight blow practice***
- ***Tapping of steel in steel ladle***
- ***Average cast slab wt-273t***
- ***Deoxidation by aluminium and silicon***
- ***Tapping temperature-1660 to 1680 deg centigrade***
- ***Tapping time >6 mins***
- ***Tap hole life >110 heats***

Practices to be followed for convertor nurturing:

- Splashing of retained slag for 3 mins by nitrogen blow through lance
- Addition of coke for better splashing
- Coating of converter
- Slag dumping in slag pot after splashing and coating before next charging

5.4 Secondary Steel Making

Objective:

Achieving the required properties of steel often requires a high degree of control over carbon, phosphorus, sulphur, nitrogen, hydrogen and oxygen contents. Individually or in combination, these elements mainly determine material properties such as formability, strength, toughness, weldability, and corrosion behaviour.

There are limits to the metallurgical treatments that can be given to molten metal in high performance melting units, such as converters or electric arc furnaces. The nitrogen and phosphorus content can be reduced to low levels in the converter but for further reducing carbon, sulphur, oxygen and hydrogen contents (< 2 ppm) to very levels it can only be obtained by subsequent ladle treatment. To ensure appropriate conditioning of steel before the casting process, the alloying of steel to target analysis and special refining treatments are carried out at the ladle metallurgy stand.

The objectives of secondary steelmaking can be summarized as follows:

- Refining and deoxidation
- Removal of deoxidation products (Mn0, SiO_2, Al_2O_3)
- Desulphurization to very low levels (< 0,008%)
- Homogenization of steel composition
- Temperature adjustment for casting, if necessary by reheating (ladle furnace)
- Hydrogen removal to very low levels by vacuum treatment.

The high oxygen content of the converter steel would result in large blow-hole formation during solidification. Removal of the excess oxygen ("killing") is therefore vital before subsequent casting of the steel. Steels treated in this way are described as killed steels. All secondary steelmaking processes allow deoxidising agents to be added to the ladle

Deoxidation can be performed by the following elements classified by increasing deoxidation capacity; carbon - manganese - silicon - aluminium .The most popular are silicon and aluminium.

After addition, time must be allowed for the reaction to occur and for homogeneity to be achieved before determination of the final oxygen content using EMF probes (electro-chemical probe for soluble oxygen content).

Secondary Refining

Secondary steel making units can be categorized as:

a) Stirring Systems
b) Ladle Heating Systems
c) Vacuum Degassing Systems and
d) Addition Systems (RH Process and Tank degassing unit)

a. Stirring systems

These systems involve in stirring the molten steel bath for obtaining homogenous temperature, composition, floatation of inclusions and promotion of slag-metal refining reaction.As most of deoxidation agents form insoluble oxides, which would result in detrimental inclusions in the solid steel, they have to be removed by one of the following processes during the subsequent refining stage:

Argon stirring and/or injection of reactants (CaSi, and/or lime based fluxes) achieves:

- Homogeneous steel composition and temperature
- Removal of deoxidation products
- Desulphurisation of aluminium-killed steel grades
- Sulphide inclusion shape control.

Argon stirring can be done by refractory lined lance (Top lance) or by means of porous plug made by high alumina material (bottom purging).

b. Ladle heating systems

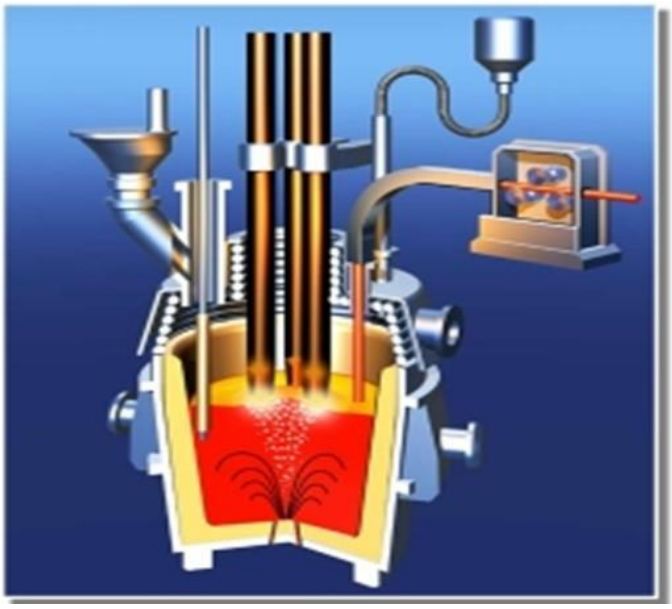
These furnaces, act as buffer between the primary melting unit and the continuous casting unit giving precise temperature and compositional control. This provides an option to the primary melting unit to tap at low temperatures leading to saving in time and energy and also the cost of Ferro-Alloys / De-oxidisers apart from increasing the refractory life of BOF. Through appropriate slag composition control, de-oxidation practice and argon stirring, it is possible to produce clean steels through Ladle furnace.

Stirring of the melt by argon or by an inductive stirring equipment and arc heating of the melt (low electric power, typical 200 KVA/t) allows:

- long treatment times
- high ferro-alloy additions
- high degree of removal of deoxidation products due to long treatment under optimized conditions
- homogeneous steel composition and temperature

- desulphurisation, if vigorous stirring by argon.

In ladle furnace the produced exhaust waste gases are cleaned by means of bag filters/ESP.



- Since 1970s, Ladle Furnace has become increasingly popular for enhancement of shop productivity
- Deoxidation and alloying additions are carried out at the LF station
- LF route is equipped with 3 electrodes, an alloying chute, a wire feeder and a powder blowing device as well as facilities for sampling and temperature and dissolved oxygen measurement.

c. Vacuum Degassing Systems

The concept of degassing started primarily to control the hydrogen content in steels but sooner it served many purposes for production of clean steels. The degassing systems can be further classified as Circulation Degassers, Tank Degassers.

Vacuum-Treatment: RH process (Ruhrstahl-Heraeus)

In the RH process the steel is sucked from the ladle by gas injection into one leg of the vacuum chamber and the treated steel flows back to the ladle through the second leg.

Tank degassing unit

In the tank degasser process, the steel ladle is placed in a vacuum tank and the steel melt is vigorously stirred by argon injected through porous plugs in the bottom of the ladle.
Millibar is term used for measurement of vacuum. Steam is used for creating vacuum.

Vacuum treatment achieves:

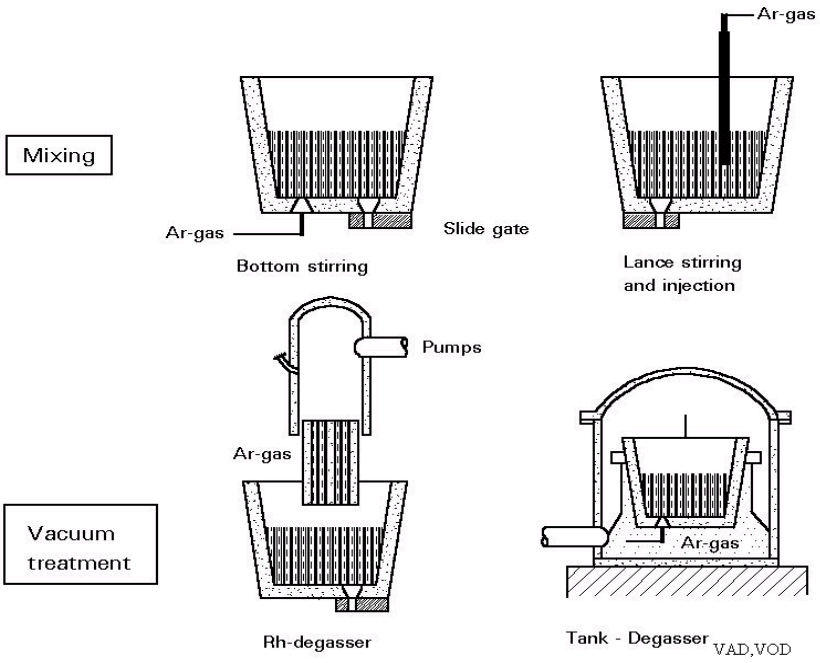
- reduction of the hydrogen content to less than 2 ppm
- considerable decarburisation of steel to less than 30 ppm when oxygen is blown by a lance (RH - OB)
  alloy addition under vacuum
- homogeneous steel composition, high degree of cleanliness from deoxidation products

High temperature losses (50 - 100°C) are a disadvantage; therefore high superheat of the melt prior to this process is essential.

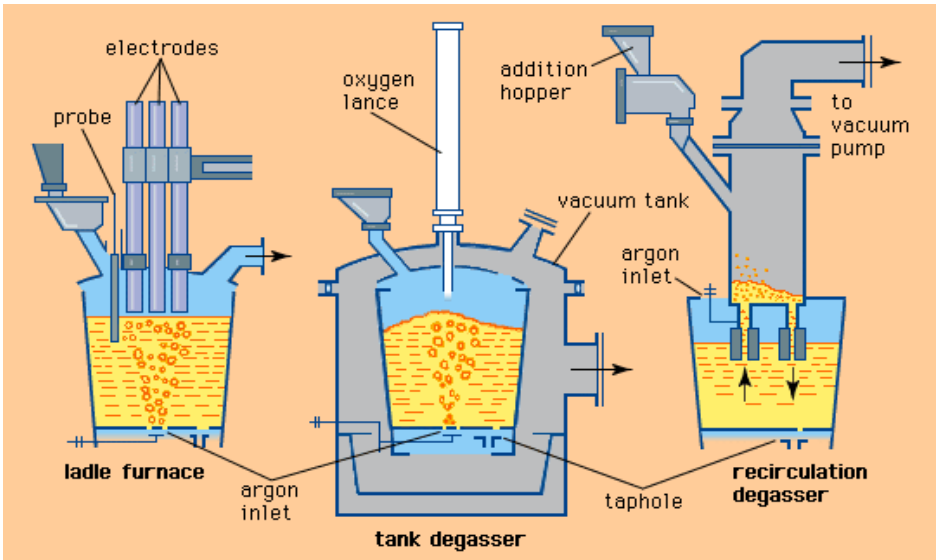
Ferro alloy addition facility for trimming addition

These contain bunkers for storage of ferro alloys, weighing hoppers, conveyor belt, skip; addition hoppers etc. Addition during vacuum is also possible.

For most secondary steelmaking techniques it is either desirable or essential to stir the liquid steel. Gentle stirring is sufficient for inclusion removal; non-metallic inclusions are brought into contact with liquid slag on top of the melt where they can be fixed. For degassing and desulphurisation however, violent stirring is necessary to increase the surface of steel exposed to vacuum (H_2-removal) or to mix the steel and slag for good desulphurisation efficiency.



Other Steel Refining Units



( ) means in slag. [ ] means in steel.

Deoxidation

As steel making process is an oxidation refining process, tap steel from primary furnace contains significant amount of oxygen(400-1000 ppm).The solubility of O_2 in liquid steel is 0.16% but in solid steel it is only 0.003%.Excess oxygen causes defects like blow holes and non-metallic inclusions. Oxygen is lowered by deoxidisers like Mn, Si, Al etc. Through vacuum treatment oxygen is removed as CO.

Decarburisation

Reaction of 'C' and 'O' removal is given by

$[C] + [O] = CO$

$[C] + 1/2O_2 = CO$

$[C] + (FeO) = CO + Fe$

'C' removal is controlled by vacuum level, Argon flow rate, initial level of 'C', bath Oxygen content, Amount of Oxygen injected

Control is required during tapping , LF & VAD operation to avoid recarburisation.

Some other sources of recarburisation are ferro-alloys, graphite electrodes during arcing.

Desulphuristion

Removal of sulphur depends on

i) High sulphidecarryingcapacity of slag - high basicity
ii) High (S)/[S] - sulphur partition
iii) Fluid slag - addition of spar or synthetic slag
iv) High stirring intensity - increased slag-metal reaction.
v) Low O potential in slag and metal- low Feo+Mno< 5%

Removal of H_2& N_2

Hydrogen removal

Reaction is $2[H] = H_2$

$[H] = k*\sqrt{H_2}$

i) H content varies with $\sqrt{p}\ H_2$
ii) To get very low H , vacuum level must be low and improved stirring.

So H removal is controlled by vacuum level, Ar flow rate, initial level of H.

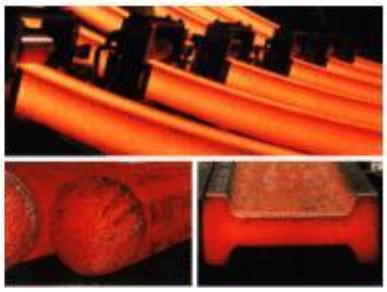
Nitrogen removal

Reaction is $2[N] = N_2$

I. To get very low N vacuum level must be very low.
II. Compared to H , nitrogen removal rate is low due to low diffusibility

5.5 Casting

Continuous Casting of Steel: Basic Principles



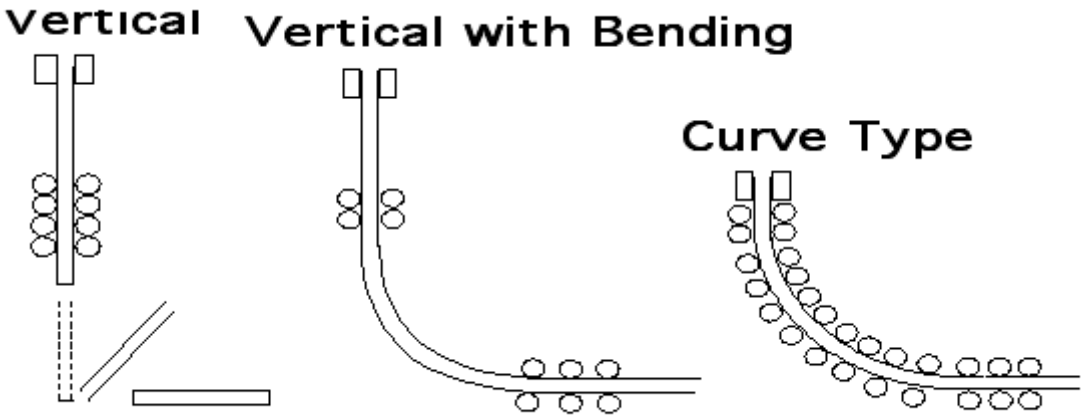
Background

Continuous Casting is the process whereby molten steel is solidified into a "semifinished" billet, bloom, or slab for subsequent rolling in the finishing mills. Prior to the introduction of Continuous Casting in the 1950s, steel was poured into stationary moulds to form "ingots". Since then, "continuous casting" has evolved to achieve improved yield, quality, productivity and cost efficiency. Figure 1 shows some examples of continuous caster configurations.

Casting of Liquid Steel

- Molten steel is continuously poured into a water cooled Cu mould that is open at the top and bottom.
- The steel gradually cools and begins to set solid in the mould. The rate at which molten steel is poured into the top is matched with the rate at which the solid steel is pulled out at bottom.
- In this way, a long continuous piece is formed. So, the process is called continuous casting. Steel formed can then be cut into length as desired.

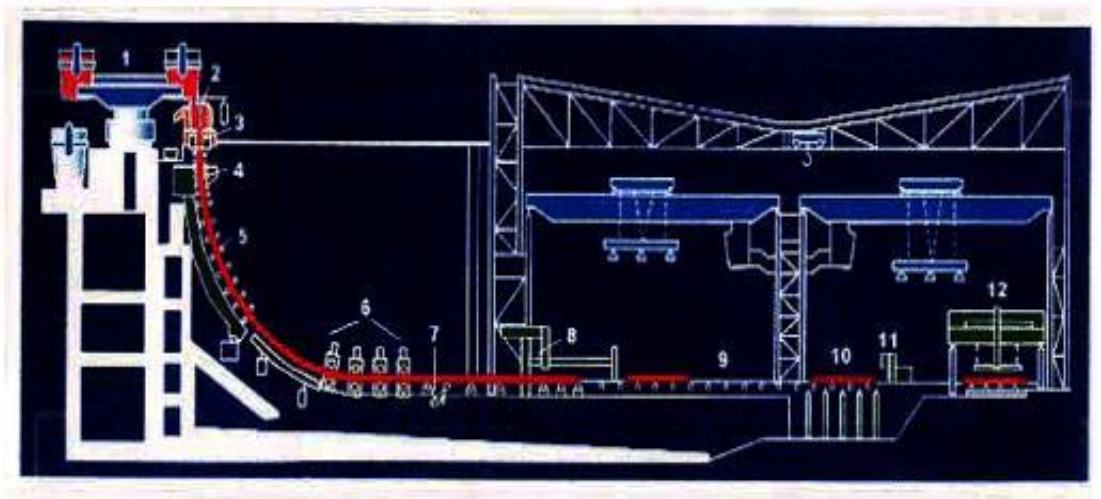
Figure 1 - Examples of Continuous Casters



Steel from the electric or basic oxygen furnace is tapped into a ladle and taken to the continuous casting machine. The ladle is raised onto a turret that rotates the ladle into the casting position above the tundish. Referring to Figure 2, liquid steel flows out of the ladle

(1) into the tundish (2), and then into a water-cooled copper mould (3). Solidification begins in the mould, and continues through the First Zone (4) and Strand Guide (5). In this configuration, the strand is straightened (6), torch-cut (8), then discharged (12) for intermediate storage or hot charged for finished rolling.

Figure 2 - General Bloom/Beam Blank Machine Configuration



1:Ladle Turret, 2:Tundish/Tundish Car, 3:Mould, 4:First Zone (Secondary Cooling), 5:Strand Guide (plus Secondary Cooling), 6:Straightener Withdrawal Units, 7:Dummy Bar Disconnect Roll, 8:Torch Cut-Off Unit, 9:Dummy Bar Storage Area, 10:Cross Transfer Table, 11:Product Identification System, 12:Product Discharge System

Figure 3 depicts a Slab Caster layout. Note the extended roller containment compared to that for a Bloom/Beam Blank (as in Figure 2), required to maintain product shape through final solidification.

Depending on the product end-use, various shapes are cast (Figure 4). In recent years, the melting/casting/rolling processes have been linked while casting a shape that substantially conforms to the finished product. The Near-Net-Shape cast section has most commonly been applied to Beams and Flat Rolled products, and results in a highly efficient operation. The complete process chain from liquid metal to finished rolling can be achieved within two hours.

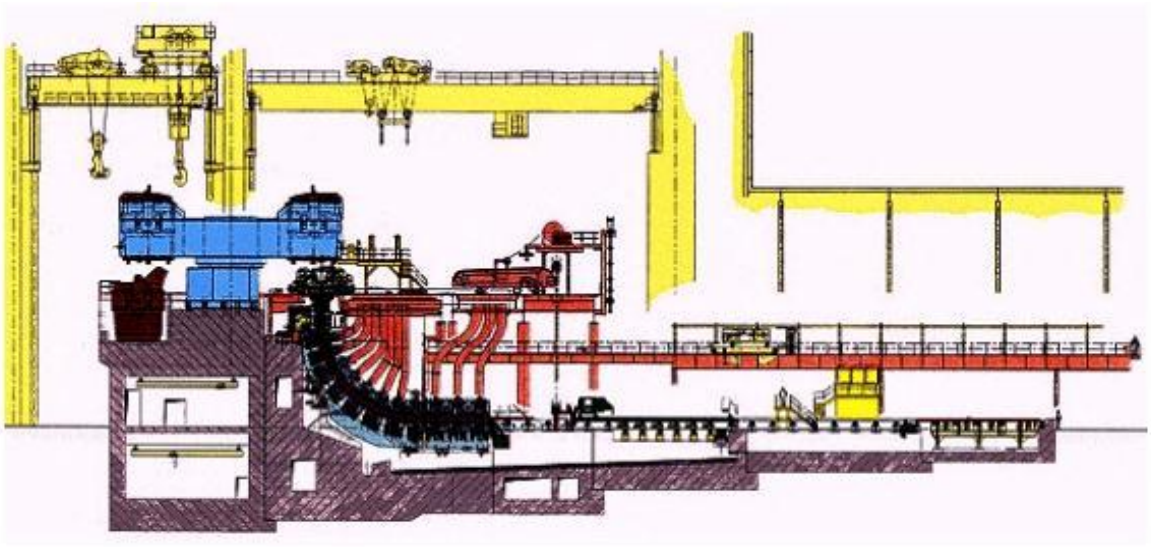


Figure 3 -Slab Caster Layout

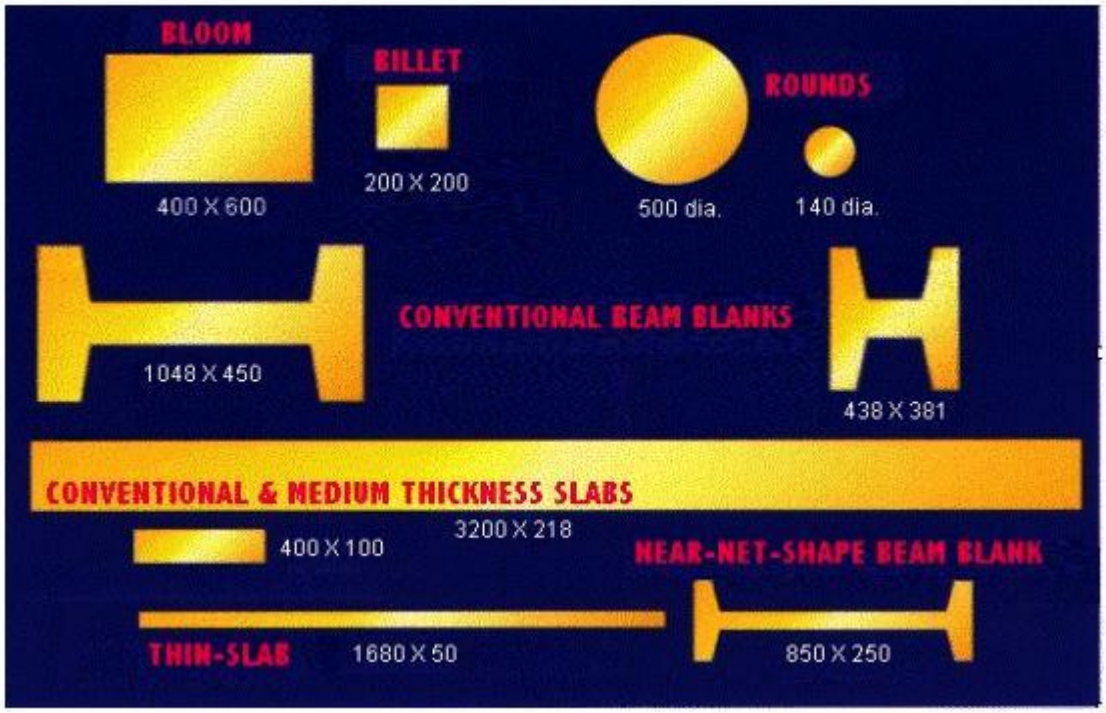


Figure 4 - Continuous Cast Shapes (sizes in millimeters)

Before going into the details of **CCM** a brief description of the caster is given below:

<BOF> => Raw/Crude Steel from converter =><SRU> => Refining crude steel i.e. killing, Homogeneous Temperature and Composition =><Caster> Turret, Ladle S/Gate, Shroud => Tundish => Mould

Liquid steel comes from the ladle into the tundish. Tundish is a device where it collects, accumulates liquid steel from the ladle and feeds to two or more moulds through SEN depending on the m/c and process

The basic design of the caster is to solidify liquid steel to its solid products uninterruptedly/continuously. For that the steel to be cast must be killed. Steel from which oxygen (dissolved in steel during steel making in BOF) is removed at SRU deoxidising elements like Al (Aluminum) Si (silicon) etc. is called KILLED STEEL. Oxygen in steel is measured using Celox Temp and expressed in ppm. Steel that is to be cast should not have high ppm of O_2 otherwise casting cannot be done because O_2 of steel will form unwanted oxides viz CaO, SiO_2 , MgO and will be deposited over the entry nozzle and thus will restrict the flow of steel into the mould.

Caster Preparation:

1. Steel that is to be cast is treated well at SRU for smooth casting.

2. Tundish through which casting will be done is to be prepared.

Tundish is a device through which continuity of the casting is maintained. There are two types of casting practices are in use namely cold tundish and hot tundish practices. Liquid steel comes from the ladle into the tundish and in turn the tundish feeds the liquid steel into the mould through different outlet at the bottom of the tundish. Tundish is made of steel and inside of which is lined with refractory bricks or castable. After that tundish boards are fixed over the refractory lined. Submerged entry nozzle (SEN) are fixed by clamping device in each of the tundish outlet.

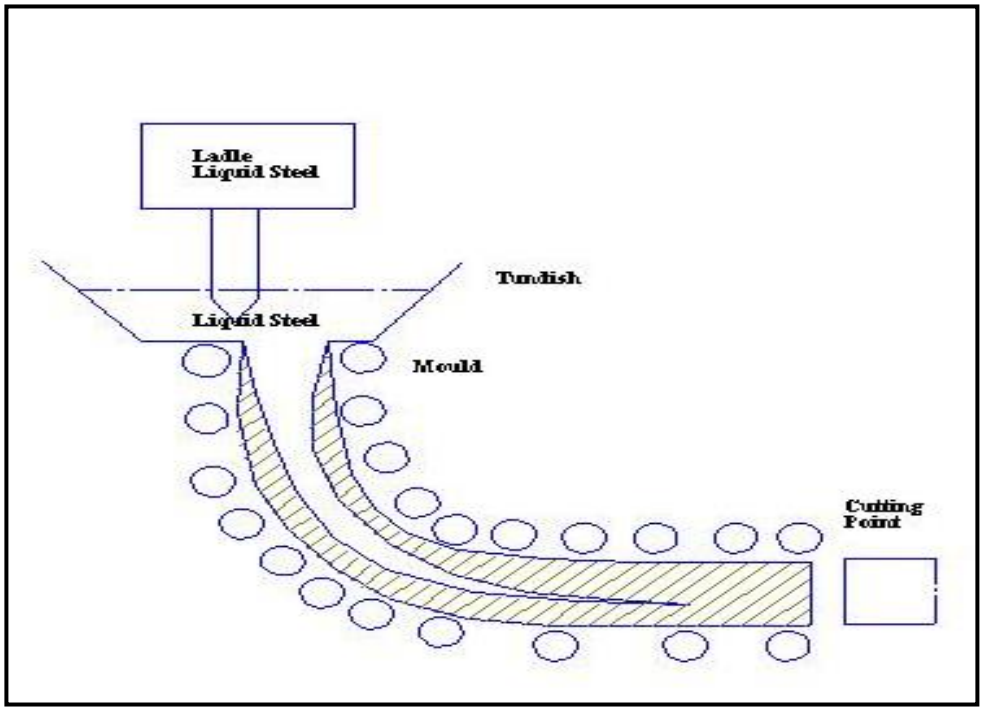
3. Mould Preparation:

Mould is the most important equipment in the caster m/c. primarily mould is prepared according to the shape and size of the product. For solidification of the initial liquid steel that enters into the mould one DUMMY BAR head is used, which is fed into the mould with a fixed rod or flexible chain. This DUMMY BAR head is packed. Mould is made purely of copper as copper has the most heat discharge capacity than any other metal economically available. All sides of this mould is made up of Cu plate and heat from liquid steel immediately discharges trough the copper plates by mould cooling system Copper plates are cooled by circulating soft water through designed tubes in the form of coils. Here the difference of MOULD COOLING WATER Outlet Temperature & Inlet Temperature is monitored continuously. It is very much hazardous part in caster m/c during casting. An alarm is provided as soon as the difference of temperature raises more. Immediate actions are to be taken and if necessary casting should be stopped without waiting for any other decision to be asked from anyone.

Casting Process

Liquid steel taken into ladle is refined at SRU is placed over the turret arm and ladle SG is fixed. Then one shroud is fixed at the bottom of the ladle collector nozzle so that no stream of liquid steel comes in contact with the atmosphere and no spillage occurs. This liquid steel gradually fills the tundish and from there liquid steel leaves tundish nozzle/TSG through SEN into the mould. Initially steel rests on the DUMMY BAR head on which some chillers are placed to get the liquid steel freeze/solidifies quickly then the m/c starts with MOM &

casting powder is to be sprayed continuously at a certain mould level. The process continues after the DUMMY BAR head is disconnected as it reaches at its particular position. Length of the slab/billet is maintained by using cutting torch/ shearing blades.



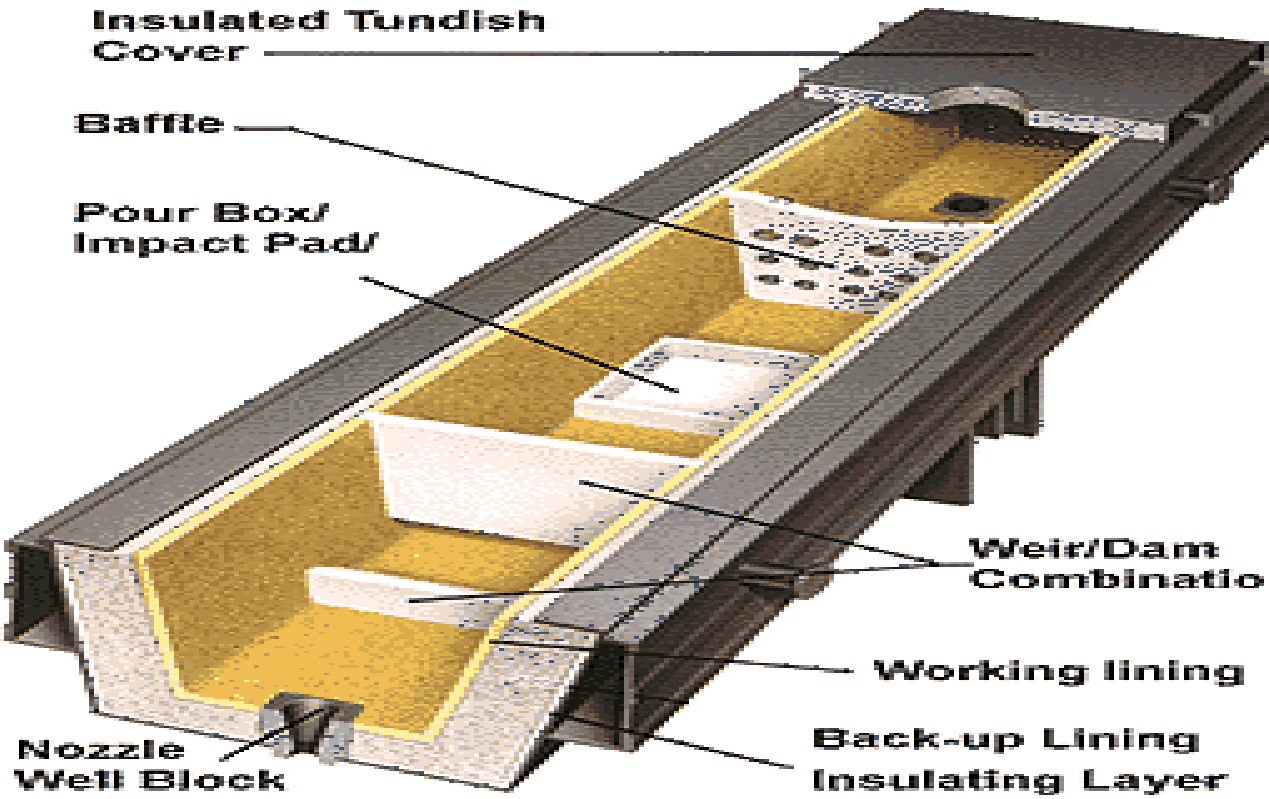
To summarize, the casting process is comprised of the following sections:

- A tundish, located above the mould to feed liquid steel to the mould at a regulated rate
- A primary cooling zone or water-cooled copper mould through which the steel is fed from the tundish, to generate a solidified outer shell sufficiently strong enough to maintain the strand shape as it passes into the secondary cooling zone
- A secondary cooling zone in association with a containment section positioned below the mould, through which the still mostly-liquid strand passes and is sprayed with water or water and air to further solidify the strand
- Except straight Vertical Casters, an Unbending & Straightening section
- A severing unit (cutting torch or mechanical shears) to cut the solidified strand into pieces for removal and further processing

Liquid Steel Transfer

There are two steps involved in transferring liquid steel from the ladle to the moulds. First, the steel must be transferred (or teemed) from the ladle to the tundish. Next, the steel is transferred from the tundish to the moulds.

Tundish



The shape of the tundish is typically rectangular, but delta and "T" shapes are also common. Nozzles are located along its bottom to distribute liquid steel to the moulds. The tundish also serves several other key functions:

- Enhances oxide inclusion separation.
- Provides a continuous flow of liquid steel to the mould during ladle exchanges.
- Maintains a steady metal height above the nozzles to the moulds, thereby keeping steel flow constant and hence casting speed constant as well.
- Provides more stable stream patterns to the mould(s).

Tundish performance largely depends on key process parameters like:

- Chemistry
- Fluid Flow
- Temperature

Clogging of SEN due to deposit formation is a major problem and leads to:

- Affects the stream flow pattern in mould.
- Reduces the pouring rate.
- May lead to premature changing of SENs and termination of casting operation.
- Steel quality may be affected.

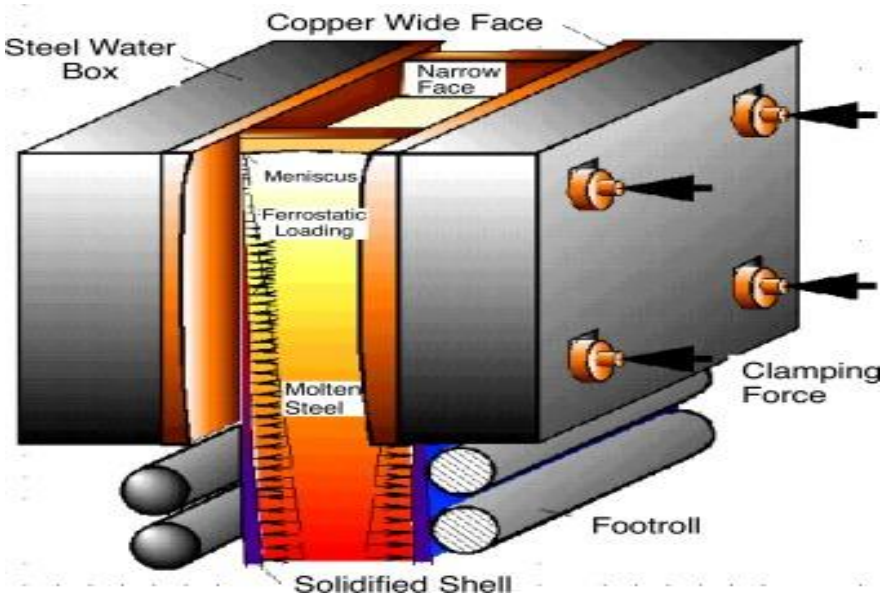
Factors affecting SEN clogging:

- Steel chemistry (alloying elements, total inclusions, etc.)

- Casting conditions (tundish depth, superheat, speed, etc.)
- SEN chemical composition, geometry & design.
- Argon injection rate
- Air aspiration into the SEN
- Oxygen provided by the refractory materials

Mould

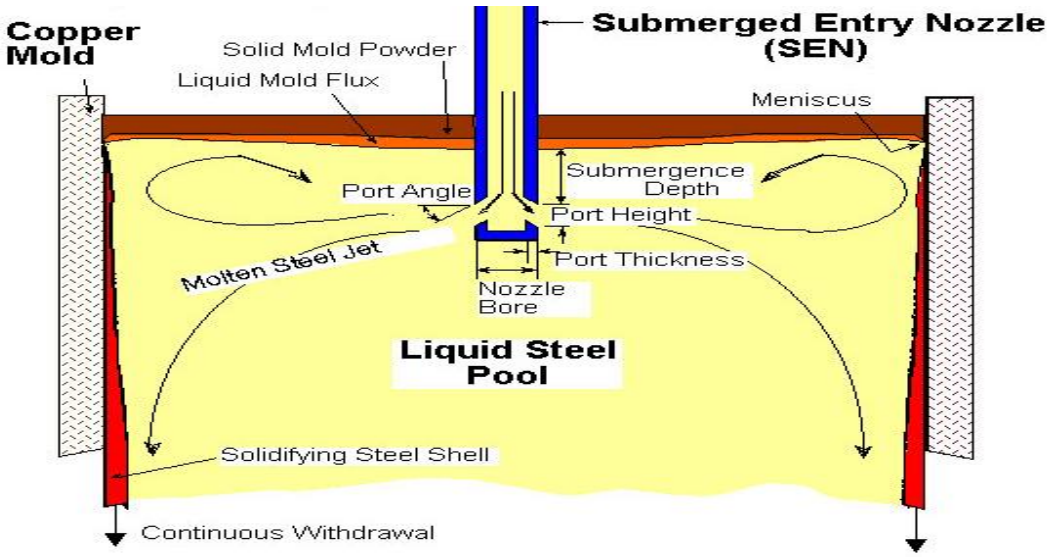
The main function of the mould is to establish a solid shell sufficient in strength to contain its liquid core upon entry into the secondary spray cooling zone.



The mould is basically an open-ended box structure, containing a water-cooled inner lining fabricated from a high purity copper alloy. Mould water transfers heat from the solidifying shell. The working surface of the copper face is often plated with chromium or nickel to provide a harder working surface, and to avoid copper pickup on the surface of the cast strand.

Mould heat transfer is both critical and complex. Mathematical and computer modeling are typically utilized in developing a greater understanding of mould thermal conditions, and to aid in proper design and operating practices. Heat transfer is generally considered as a series of thermal resistances as follows:

- Heat transfer through the solidifying shell
- Heat transfer from the steel shell surface to the copper mould outer surface
- Heat transfer through the copper mould
- Heat transfer from the copper mould inner surface to the mould cooling water



Mould Oscillation

Mould oscillation is necessary to minimize friction and sticking of the solidifying shell, and avoid shell tearing, and liquid steel breakouts, Friction between the shell and mould is reduced through the use of mould lubricants such as oils or powdered fluxes. Oscillation is achieved either hydraulically or via motor-driven cams or levers which support and reciprocate (or oscillate) the mould.

Mould oscillating cycles vary in frequency, stroke and pattern. However, a common approach is to employ what is called "negative strip", a stroke pattern in which the downward stroke of the cycle enables the mould to move down faster than the section withdrawal speed. This enables compressive stresses to develop in the shell that increase its strength by sealing surface fissures and porosity.

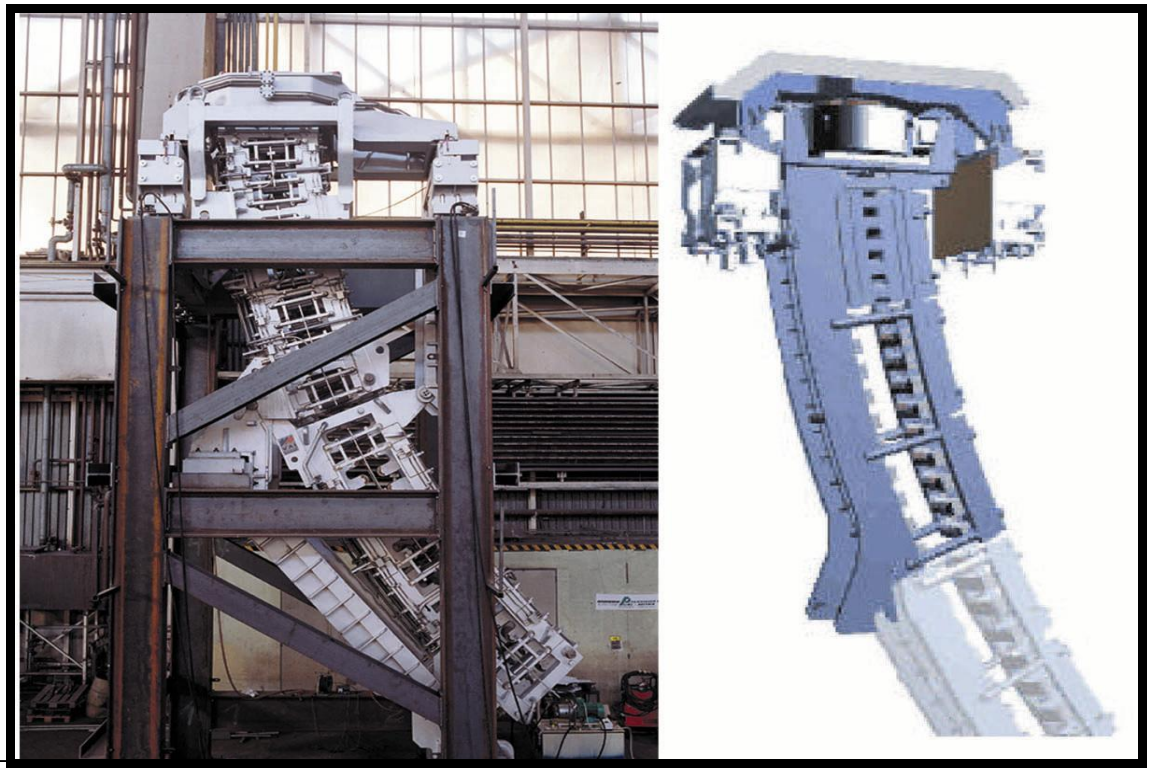
Mould Flux

- Functions of mould powder
- Provides thermal insulation to the liquid steel meniscus to prevent premature solidification
- Prevents re-oxidation of liquid steel in the mould by atmospheric air
- Absorbs inclusions
- Provides a lubricating film of molten slag between solidifying shell and mould wall

Secondary Cooling

Typically, the secondary cooling system is comprised of a series of zones, each responsible for a segment of controlled cooling of the solidifying strand as it progresses through the machine. The sprayed medium is either water or a combination of air and water.

Figure 5 - Secondary Cooling



Three (3) basic forms of heat transfer occur in this region:

- Radiation

- Conduction
  As the product passes through the rolls, heat is transferred through the shell as conduction and also through the thickness of the rolls, as a result of the associated contact.

- Convection
  This heat transfer mechanism occurs by quickly-moving sprayed water droplets or mist from the spray nozzles, penetrating the steam layer next to the steel surface, which then evaporates. Specifically,in the spray chamber (Secondary Cooling) heat transfer serves the following functions:

  i. Enhance and control the rate of solidification, and for some casters achieve full solidification in this region
  ii. Strand temperature regulation via spray-water intensity adjustment
  iii. Machine Containment Cooling

Strand Containment

The containment region is an integral part of the secondary cooling area. A series of retaining rolls contain the strand, extending across opposite strand faces. Edge roll

containment may also be required. The focus of this area is to provide strand guidance and containment until the solidifying shell is self-supporting.

Bending and Straightening

Equally important to strand containment and guidance from the vertical to horizontal plane are the unbending and straightening forces. As unbending occurs, the solid shell outer radius is under tension, while the inner radius is under compression. The resulting strain is dictated by the arc radius along with the mechanical properties of the cast steel grade. If the strain along the outer radius is excessive, cracks could occur, seriously affecting the quality of the steel. These strains are typically minimized by incorporating a multi-point unbending process, in which the radii become progressively larger in order to gradually straighten the product into the horizontal plane.

Figure 7 - Curved Section of Multi-Strand Beam Blank Caster prior to Unbending

Figure 8 - Straightener Withdrawal Units for Strand Unbending

After straightening, the strand is transferred on roller tables to a cut off machine, which cuts the product into ordered lengths. Sectioning can be achieved either via torches or mechanical shears. Then, depending on the shape or grade, the cast section will either be placed in intermediate storage, hot-charged for finished rolling or sold as a semi-finished product.

Abnormalities:

During casting some unwanted hard oxides which gets deposited over the steel into the mould and interrupts the steel flow and casting gets aborted. This phenomenon is called **Chocking**.
In some cases temperature at which liquid steel gets solidified may be reached during casting which caused solidification at SEN and restricts the steel flow, and then also casting continuity gets disturbed and casting stops. This is called **Freezing.**
Another major problem that hinders the casting process is **Break Out.**

Some Casting Defects:
Types of defects:

- Surface cracks
- Internal cracks
- Blow holes, Pin holes etc

Remedial measures:

- Control of superheat of liquid steel (appropriate temperature)
- Steel chemistry
- Casting speed

Safety Measures:

- Mould cooling temperature and its difference of temperature of Inlet water and Outlet water is to be monitored continuously.
- Tundish walls and slidegate m/c fixed on it is to be observed carefully.

5.6 Ingot Casting

A Teeming ladle is prepared for each and every heat. The liquid steel is teemed through the nozzle present at the bottom of the teeming ladle. The flow of metal into the mould through the nozzle can be controlled using slide gate system. Earlier stopper rod assembly was in use.
The ingots are stripped off from these moulds. These ingots are then sent to soaking pit. These moulds are again prepared (i.e. cooling by water, cleaning and coating) for another.
Teeming temperature is one of the most important parameters in ingot casting practice. High temperature leads to sticker formation while low temperature leads to chocking of nozzle. Care should be taken so that center pouring is done in a mould.
There are many types of defects associated with ingot casting. Surface defects such as scabs, cracks and lappiness are common. Bottom pouring of steel into fluted ingot moulds is done in DSP for special steel grades required for manufacturing Wheels and Axles for Railways.

Advantages of Continuous Casting over Ingot Casting:

- One of the main advantages of continuous casting over ingot casting is the high increase in yield from liquid steel to semi-finished cast product.
- Ingot casting yield can be as low as 80%.
- Continuous casting yield depends mainly on ladle capacity, Section sizes and sequence length.
- Yields of >95% or even higher are not uncommon.

5.7 SAFETY

LD Process or Primary Steel Making safety hazards:

- Lance / Lance tip puncture to be avoided and taken care of to avoid any water leakage inside the convertor
- During blowing CO gas monitor to be always used for multilevel activities above the convertor area

Secondary steel unit pose certain safety hazards to personnel working like:

- During argon purging metal splashes can cause burn injury.
- In ladle furnace, there is danger of metal splashes and electrocution due to very high current of electrode.
- In VAD, VOD & RH vacuum present inside treatment area can pose serious danger of suction. Body parts may get sucked inside if isolating plate collapse. Also fumes coming out may cause suffocation.
- Danger of carbon monoxide is also there in vacuum treatment stations

Do & Don't:

- Avoid going near high current line & high current cables in running ladle furnace and in VAD
- If red spot is observed in ladle, STOP arcing. It may lead to ladle through.
- People must always be aware of the safety hazards of their areas.

Steel Making MCQs:

1 The following gas used for slag splashing in Converter

a. Oxygen **b. Nitrogen** c. CO_2 d. Air

2 Lime is used in Converter as a

a. Flux b. Slag c. Gangue d. Alloying element

3 Converter vessels are usually line with

a. High alumina bricks b. Silica bricks **c. Magnesia carbon bricks** d. Fire clay brick

4 The fuel gas recovered from BOF process comprises of

a. Methane b. C.N.G **c. CO** d. CO_2

5 Argon is used for Ladle stirring because

a. It is very cheap b. It is abundant in atmosphere **c. It improves the steel quality** d. All of the above

6 Slag basicity in Converter process refers to the following ration

a. $(Cao+MgO)/SiO_2$ b. $(Cao+MnO)/SiO_2$ c. SiO_2/CaO **d. CaO/SiO_2**

7 Lance tip of a Converter is made of

a. Steel b. Refractory **c. Copper** d. brass

8 No liquid slag is left in the Converter before charging because

a. It damages the Converter lining b. It disturbs the refining process **c. It is unsafe to charge on liquid slag** d. It causes slag inclusion in steel

9 In VAD, the vacuum chamber is evacuated with the help of

a. **Steam ejector** b. Vacuum pump c. Air compressor d. None

10 Dissolved Oxygen in steel is not desirable because

a) It reduces the strength of steel. b) It causes scale formation during **c) It causes defects like blow holes** d) It makes the steel brittle

rolling

11 Inert gas is rinsed in liquid steel during secondary steel making for

a) De-oxidation b) Carburization **c) Homogenization** d) Solidification

12 The full form of VAD

a) Vacuum Argon Degassing b) Vacuum Argon Decarburizing **c) Vacuum Arc Degassing** d) Variable Arc Degassing

13 A RH De-gasser has

a) No snorkel b) One snorkel **c) Two Snorkel** d) Three snorkel

14 In Secondary refining, desulphurization is favored with

a) Basic oxidizing slag **b) Basic reducing slag** c) Acidic oxidizing slag d) Acidic reducing slag

15 Petroleum coke is added in liquid steel for

a) De-oxidation b) Re-carburization c) Slag formation **d) a and b**

16 In killed steel dissolved oxygen is

a) High **b) Low** c) Medium d) Not present at all

17 Continuous casting has replaced ingot casting because, it is

a) Cost effective b) Better quality controlled c) Safer practice **d) All of the above**

18 Hydrogen in steel is controlled through

a) Vacuum treatment b) Arcing c) Fe-alloy addition d) Synthetic slag

19 During continuous casting the metal stream from ladle falls in to a vessel called

a) Mould b) Nozzle **c) Tundish** d) none

20 Which among the following process of steel making is the oldest

a) Open hearth Furnace **b) Bessemer process** c) LD process d) EAF process

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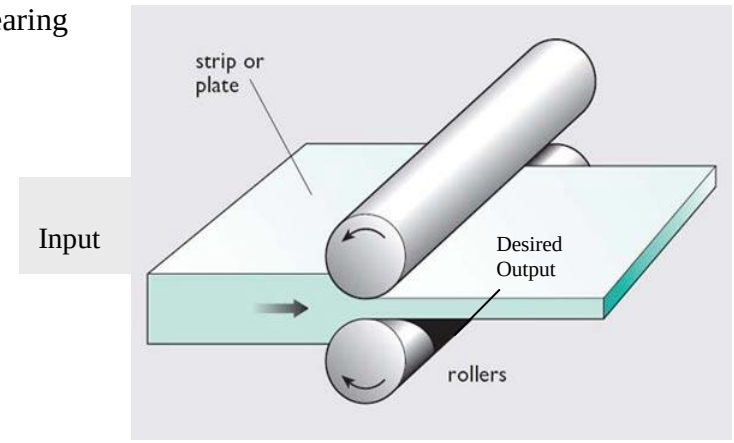
Chapter – 6

ROLLING MILLS

6.1 Basics of Rolling

Processes of metal forming are

1. Rolling
2. Forging
3. Extrusion
4. Wire drawing
5. Deep Drawing
6. Sheet metal forming
7. Stretch Forming
8. Foundry
9. Bending
10. Shearing



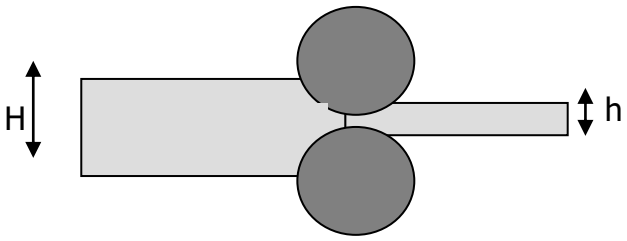
Basic Definitions

Rolling

Rolling is plastic deformation of the Metal by passing between rolls to give it the desired shape.

Draft

Difference in height or thickness of the material before rolling (**H**) and height or thickness after rolling (**h**) is called draft (**H-h**). It indicates how much the metal has been pressed during rolling.



Spread

Difference in width of material after rolling (**b**) and width before rolling (**B**) is called spread (**b-B**). It indicates how much the metal has spread during rolling.

Elongation

Difference in length material after rolling (**l**) and length before rolling (**L**) is called elongation (**l-L**). It indicates the increase in length during rolling

Reduction

Difference in area before rolling (**A**) and area after rolling (**a**) is reduction (**A-a**). It indicates how much the cross section area has been reduced during rolling.

Coefficient of Reduction

Ratio of area before rolling (**A**) and area after rolling (**a**) is called coefficient of reduction (**A/a**). It indicates how many times the area has been reduced during rolling.

Rolling Constant principle

It states the volume of material will remain same before and after rolling. It is useful in finding input and output sizes.

Basic terminology used for measuring mill efficiency

Mill Availability

It indicates the availability of the mill for rolling. In this the planned shutdown and capital repairs are subtracted from the total calendar hours.

$$\text{Mill Availability} = \frac{\text{Calendar Hours- (Capital Repairs+shutdown)}}{\text{Calendar Hours}} \times 100$$

Calendar hours in a year means 24 x 365 days(or 366 in case of leap year)

Mill Availability is expressed in percentage

Mill Utilization

It indicates the utilisation of available mill for rolling. In this the planned delays subtracted from the available hours.

$$\text{Mill Utilization} = \frac{\text{Calendar Hours- (Planned Repair + Total Delays)}}{\text{Available Hour}} \times 100$$

Available hours= Calendar Hours - (Planned Shutdown + Capital Repairs)

Mill utilization is expressed in percentage

It is a measure of effective utilization of time available

Hot Hours

Hours during a day or month or year during which rolling actually took place. Its unit is hours.

Yield

It is the ratio of useful output to input expressed as percentage Yield= $\frac{\text{Output}}{\text{Input}} \times 100$

It is a measure of efficient utilization of input and is expressed in percentage.

Rolling Rate

It is tonnage rolled in an hour. It is a measure of speed of rolling and its unit is tons/hour.

Hot and Cold Rolling

Hot Rolling: The rolling process in which rolling is done above recrystallisation temperature it is called hot rolling.

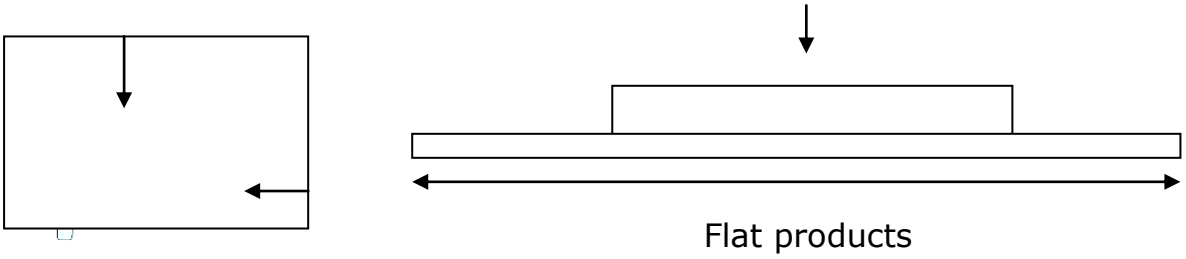
Cold Rolling: The rolling process in which rolling is done below recrystallisation temperature is called cold rolling.

Recrystallization temperature is the temperature on rolling above which we get strain free grains and minimum residual stresses in rolled metal. It is normally 0.5 to 0.7 times of melting point of the metal.

All SAIL integrated plants have hot rolling mills whereas only Bokaro, Rourkela and Salem have cold rolling mills.

Long and Flat Products

During rolling when the input is pressed from both directions perpendicularly (from top-bottom and also from both sides) the length increases to keep the volume of the metal constant. This is called **long product rolling**. If the metal is pressed from top - bottom the spreads takes place also on the sides, it is called **flat product rolling**.



Long products

Examples of long products are angles, beams, channels, rails, blooms, billets, etc. Examples of flat products are plates, sheets, strips, etc. In SAIL, integrated steel plants Bokaro and Rourkela produce flat products, while Burnpur is a long product plant. Bhilai and Durgapur produce both long and flat products.

6.2 Products of Rolling Mills of SAIL

Bhilai Steel Plant

- Semis (Blooms, Billets, Slabs and Narrow width slabs)
- Rails
- Heavy Structurals (Beams, Channels, Angles, Crossing Sleepers)
- Merchant Products (Angles, Channels, Rounds and TMT Bars)
- Wire Rods (TMT, Plain and Ribbed)
- Plates

Bokaro Steel Plant

- HR coils, sheets, plates
- CR coils, sheets
- Galvanized plain and corrugated sheets

Durgapur Steel Plant

- Semis (Blooms, Billets, Rounds)
- Merchant Products (TMT Bars, Rebars)
- Medium Structurals (Beam, Joists, Channels, Angles)
- Wheel and axle

Rourkela Steel Plant

- Semis(slabs)
- Plate Mill Plates, Special plates
- HR Plates, Coils
- CR Coils and Sheets
- Galvanized plain and corrugated sheets
- Silicon Steel Sheet & coils
- HFW Pipes(ERW) & SW Pipes

IISCO Steel Plant, Burnpur

- Structurals(Beam, Channels, Angles)
- TMT Bars, Wire Rod Coils Products

Alloy Steel Plant, Durgapur

- Alloy and Stainless steel Slabs, Blooms, Billets, Bars, Plates
- Stainless and Hadfield Manganese steel plates

Salem Steel Plant

- Hot rolled carbon and Stainless steel flat products
- Cold rolled stainless steel sheets and coils

Visvesvaraya Iron and Steel Plant, Bhadrawati

- Semis, Bars

6.3 Applications of Rolled Products of SAIL

Hot Rolled Coils, Sheets

Used for construction of tanks, railway cars, bicycle frames, ships, engineering, military equipment, LPG cylinder, automobile and truck wheels, frames, and body parts. HR coils are also used as feedstock for pipe plants and cold rolling mills where they undergo further processing. Hot Rolled Chequered coils and plates are being produced for using in floor as anti-skidding.

Plates

Steel plates are used mainly for the manufacture of bridges, dams & windmills, steel structures, ships, large diameter pipes, storage tanks, boilers, railway wagons, and pressure vessels. SAIL also produces weather-proof steel plates for the construction of railcars. SAIL is one of the major producers of wide and heavy plate products in India.

Cold Rolled Products

The products of the cold rolling mills include cold rolled sheets and coils, which are used primarily for precision tubes, containers, bicycles, furniture ,whitegoods industry and for use by the automobile industry to produce car body panels. Cold rolled products are also used for further processing, including for color coating, galvanizing and tinning. Galvanized Sheets are used in roofing, paneling, industrial sheeting; air condition ducting and structural applications. Electrolytic Tin Plates are used in containers for packaging of various products including edible oils, Cola, Fruit Juices, Pickles and confectionary items.

Railway Products

Rails are one of the main rolled products by SAIL. It is used primarily to upgrade and expand railway networks.

Structurals
I-beams, channels, and angle steel are used in mining, construction of tunnels, factory structures, transmission towers, bridges, ships, railways, and other infrastructure projects.

Bars and Rods
Reinforcement steel and wire rods are primarily used by the construction industry.

Semi-Finished Products
Semi-finished products (blooms, billets and slabs) are converted into finished products in SAIL's processing plant and, to a lesser extent, sold to Re-rollers for conversion to finished products.

Alloy and Stainless Products
Alloy and special steel products with alloyed elements including chromium, nickel, vanadium and molybdenum are primarily used for sophisticated applications, including in the automobile, railway, aerospace, power, nuclear,submarines and defence industries.Special alloy steel bittets and bars made for defence are used in shell making. Jackal and spade plates are critically applied for armour and ammunition vehicle application only. Corrosion resistance cold rolled stainless steel coils and sheets are used for diverse applications including household utensils, automobile trims, elevators, fuel, chemical, fertiliser, LPG tanks, atomic power, boilers, heavy engineering, dairy and food processing equipment, coin blanks, building and interior decoration, and pharmaceutical equipment.

Speciality Products
Speciality products include electrical sheets, tin plates, and pipes. Electrical sheets are cold rolled products of silicon steel for electrical machinery. Pipes are longitudinally or spirally welded from hot rolled coils for transporting water, oil,slurry and gas.

6.4 Hot Rolling

The rolling process which is done above recrystallization temperature is called hot rolling. More reductions are achieved in hot rolling as compared to cold rolling.

6.5 Reheating Furnaces

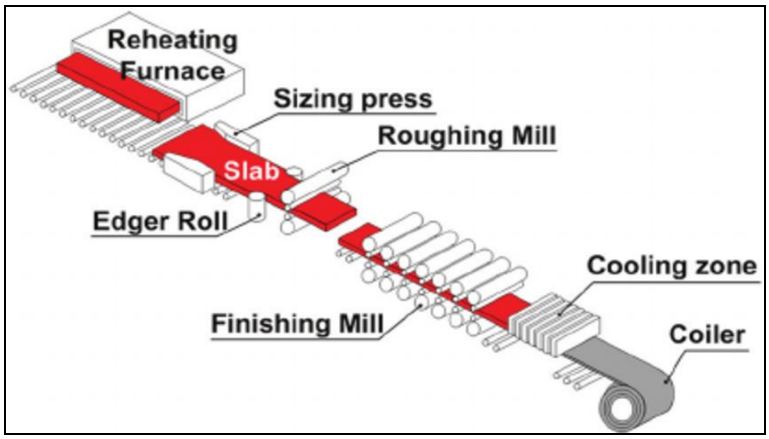
In the reheating furnaces the Input materials are heated to a specified temperature and soaked for given time depending upon size of input slab and their metallurgical requirements for which it is planned to be rolled. Ideally, it is aimed to equalize the surface and the core temperatures of the slab. Well-soaked slabs are discharged from the furnace at dropout temperature of 1100-1300^{o}C. The furnace discharge temperature is also to compensate heat losses in downstream operation and thereby it depends on it.

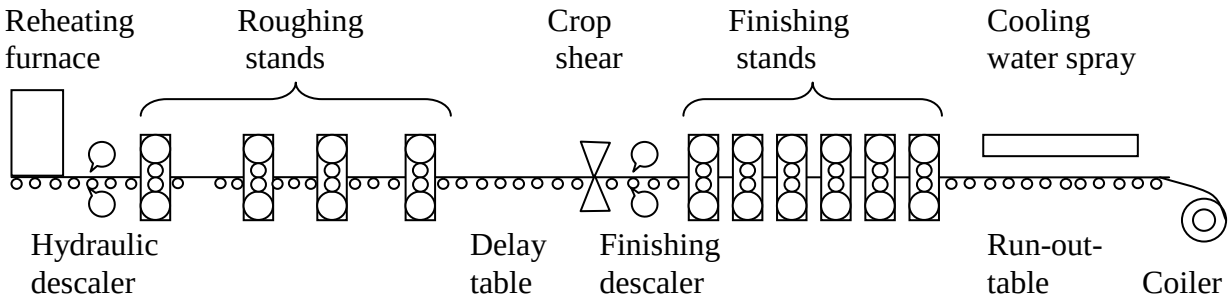
Types of Reheating Furnaces:

In Primary mills Soaking pits are used which are primarily batch type furnaces and at present not in operation . In secondary (finishing) Mills, continuous reheating furnaces are used. Continuous reheating furnaces are mainly of two type's pusher type and walking Beam type. These furnaces mainly have firing system with mixed gas (mixture of coke oven gas and blast furnace gas) which are readily available in Integrated Steel plants.

6.6 Rolling of Flat Products

Layout of a typical Hot Strip mill is shown in figure below:





Process installations shown in the figure above and operations performed are briefly described below:

PROCESS:

Reheating

Walking Beam Reheating Furnaces are having 6 zones (Preheating zone top & bottom, Heating zone top & bottom and Soaking zone top & bottom). Preheating,heating and soaking zones have firing system with mixed gas , Slabs are heated, soaked to have uniform temperature across the cross section of the slabs and discharged at 1100-1300^{o}C based on the grade of the steel and the planned dimension**.**

Descaling:

Layers of scales (oxides of iron) are formed on the surface of the slab during its heating inside the furnaces. The scales are removed by using high pressure water jet. The descaling unit consists of headers fitted with nozzles for spraying water both at top and bottom surface. Descaling is a very important precondition for rolling for defect free products.

Roughing:

The major reduction to the input material is given at Roughing mill group to get the desired thickness for Finishing Mill group. Main reduction in thickness is achieved at Roughing mills and comparatively smaller draft is given at Finishing mills. . For example, if strip of 2 mm thickness is to be produced from 220 mm thick slab, typically, thickness will be reduced from 220 mm to 26-40 mm at Roughing stands (continuous or reversible) based on the strip width .Final drafts are given at Finishing mill to get the planned dimensions.

Finishing:

Final required dimensions of the end products are achieved in finishing process. Finishing temperature of the strip(which is temperature at the last finishing stand) is a critical parameter, is maintained and not being allowed to decrease below a specified temperature for particular grades of steel . This is done to achieve the metallurgical properties.

Cooling

Before the hot rolled strips are coiled in the coiler, they are cooled at specified cooling rate on the run-out-table to achieve the desired coiling temperature. It is very much important for getting the desired metallurgical properties of the strip. The number of the water banks to be operated is decided by the targeted cooling rate of the strip to achieve the required coiling temperature.

Coiling:

The Strip moves over ROT and gets coiled in coilers. The coils are taken out of the coilers, strapped on the body and marked for identification.

Coil Finishing & Dispatch

Coils are sent for further processing or directly sold as hot rolled products. Weighment of the coils, inspection and sampling for both chemical and physical testing is done before processing and dispatch.

Equipments:

Reheating Furnace:

Re-heating furnaces of hot Strip mill are mainly of two types- pusher type or walking beam type. The walking beams are hydraulically operated and the movement of slabs inside the furnace is carried out by a set of moving & stationary beams. In pusher type furnaces the

movement is achieved by pushing the slabs one after another. The combustion system is mainly of recuperative type with heating from top and bottom. Facilities of skewed skid system are there in the furnace to compensate for temperature variations.

Descaler:

The surface of slab moving through water hydraulic descaler and the rolling bar/strip is impinged by high-pressure water jets. At many places, a mill stand with a pair of vertical rolls, called vertical scale breaker, may also be provided to remove the scale from edges of the slab.

Roughing stand:

Roughing mills are generally having one stand, two stands and multi-stands with 4-high configuration. These stands can be reversing, non-reversing or combination types. Universal type roughing stands are equipped with vertical edgers for controlling spread of material in lateral direction. Rolls of roughing stands are cylindrical and are cooled simply by water.

Finishing Stands:

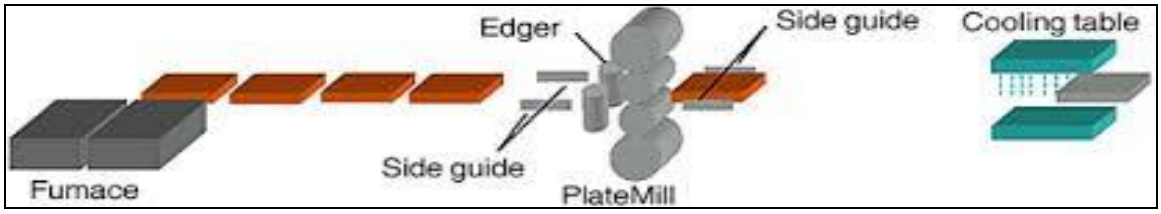
Finishing Stands of Hot strip mill normally have 5-7 stands in 4-high construction (combination of work rolls and back up rolls). These stands are in tandem and strip passes through them on continuous basis. Roll force, roll gap can be controlled through different mechanisms such as roll bending, pair crossing, roll shifting and varying crown of rolls. Cooling of the rolls is achieved by spraying water/water oil mixture over backup and work rolls.

Coilers:

The coilers are used for coiling the strips mainly with the help of Pinch rolls, wrapper rolls and mandrel.

Plate Mill

The modern plate mill of both RSP and BSP rolls out heavy and medium plate as well as those for pipe manufacturers from the reheated slabs.



MAJOR Parameters and factors affecting rolled products and their control:

The following major factors affect the quality of rolled products

a) Temperature:

The desired temperature at various stages of rolling needs to be maintained for attaining product within dimensional tolerances and properties.

b) Roll conditions:

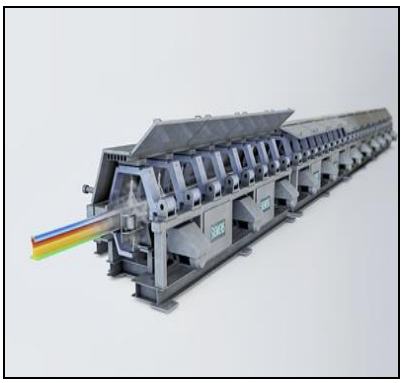
Roll change schedule has to be strictly adhered to and roll cooling conditions need to be monitored continuously. Shape and dimensional tolerances also depend on the above mentioned conditions.

6.7 Rolling Of Long Products

Long products have to be hot rolled only, to facilitate the large reduction to be made in passes. The mills can be basically classified into primary mills and secondary mills. Primary long product mills manufacture semis mainly blooms and billets. The long product mills which produce finished products like beams, angles, channels, bars, wires and rods, TMT bars and rails, are called finishing mills

Rail Mills

Rails are produced either using the two-high rolling method on two-high reversing mills or on three-high mills or, increasingly today, using the universal rolling method. The universal rolling method has proved superior to the conventional methods due to the following advantages: Closer rail tolerances, better surface quality and less roll wear.



Rail mill

Structural Rolling Mill

Rolling mills having facilities for rolling the billets, blooms, slabs and beam blanks. Input materials are heated in reheating furnaces (Walking Beam or Pusher Type) to desired temperature (1100 to 1300^{o}C). The Rolling is done through Rolling Stands (Reversing or Continuous) to achieve the desired shape and dimensions. Brand marking on finished product is done at final stands.

Wire Rod Mill

The objective of a **wire rod mill** (WRM) is to roll steel billets into **wire rods**. The production volume of **wire rods** in WRM is subject to the size of product to be rolled and **mill** availability. High productivity is achieved in case of thicker size rolling.

PROCESS

The processes of rolling of long products can be basically classified into following heads.

Reheating:
The reheating of inputs is done to make the material plastically deformable and pliable for rolling to give the desired shape and size.

Roughing:
Roughing is done to give the input a rough shape. The maximum reduction in cross section is given in roughing mills.

Intermediate Rolling:
Intermediate rolling constitutes taking the roughing mill output as its input. Output of intermediate rolling is sent to finishing mills.

Pre-Finishing & Finishing rolling:

In Pre-finishing & Finishing mills the finished profile shape is made. Pre-finishing Mills It takes metal from intermediate stands as its input. The reduction given in these stands is lesser as compared to roughing and intermediate mill. Finished shape is achieved in finishing mills. Finishing rolling mills is critical as the final output shape is made in these stands. In case of TMT bars thermo-mechanical treatment of bars is done after finishing mills area.

Cutting and stamping:

The finished bar is cut to desired lengths as per customer requirement.
In secondary mills stamping of cast number and other details are done on the rolled products in hot condition. These are required for identification and traceability of product and correlation with test results of destructive tests.

Finishing:

The finishing is done after the bar has been cooled to ambient temperature. Finishing activities at different mills may involve all or few of the following steps:

- Straightening either by roller straightening machines or by pulling the ends
- End finishing either by milling or cold cutting
- Online non-destructive testing of defects
- Heat treatment

Inspection:

Inspection is carried out by the producer and/or by customer deputed agency and/or by third party to inspect the products and ensure no defective products are sent to customer. Depending on the specifications, customer requirement the inspection may be for all or few of the parameters like Dimension, Straightness, Squareness, Surface Quality, Branding, colour coding and stamping are done.

Dispatch:

The products are sent to required destinations primarily by rail and in some cases by road. The activities involve documentation (preparation of dispatch advice (DA), test certificate (TC) and clearance by train examiner (TXR) in case of rail dispatches. In some cases packeting is done prior to dispatch.

Equipments

Reheating furnaces:

The heating of inputs is done in reheating furnaces.

Primary long product mills use batch type furnaces (Soaking pits) for reheating of ingots. Finishing mills use continuous furnaces (either pusher type or walking beam type) for reheating of inputs.

Stands:

Equipments in which rolling is done are called stands. They may consist of all or few of the following components – Rolls, housings, bearings, chocks, couplings with drives, manipulators, tilters, screw down mechanisms. The stand may have horizontal rolls or vertical rolls or combination of both types of rolls.

Accessories of stands:

Accessories of stands consist of mainly roll cooling arrangements, guards, guides, tackles and grease systems etc.

Automation:

Most of the rolling mills have Level-II automation and controlled with PLC for achieving best output and reduction in down time.

Drives:

In most of the mills reversible electrical drives of high ratings are required to drive the rolls. In certain cases the drives give their output directly to rolls through spindles.

Shears / Cutting Saws:

Shears are used to cut sections (Blooms/Billets) in primary mills. Cutting saws are used to cut products of finishing mill to desired lengths, cut crops and samples.

Straightening machines:

Two types of straightening machines are in use in finishing mills. Roller type in which the products are straightened by alternately bending the products in opposite directions between rotating rollers. In case of lighter profiles the straightening is done by pulling from both the ends.

End finishing equipments:

Ends with square cut and good surface finish required in some finished products is achieved by milling or cold cutting with carbide saws.

Online testing equipment:

In some finished products online non-destructive testing is done by ultrasonic testing machine (for inside defects) ,X- ray for subsurface defects and eddy current testing machine (for surface defects)

Auxiliaries:

Auxiliaries such as cranes, roll tables, material handling equipments etc. are very important for integrated functioning of mill.

Defects of hot rolled long products

Defects due to which hot rolled long products are rejected may be broadly classified as:

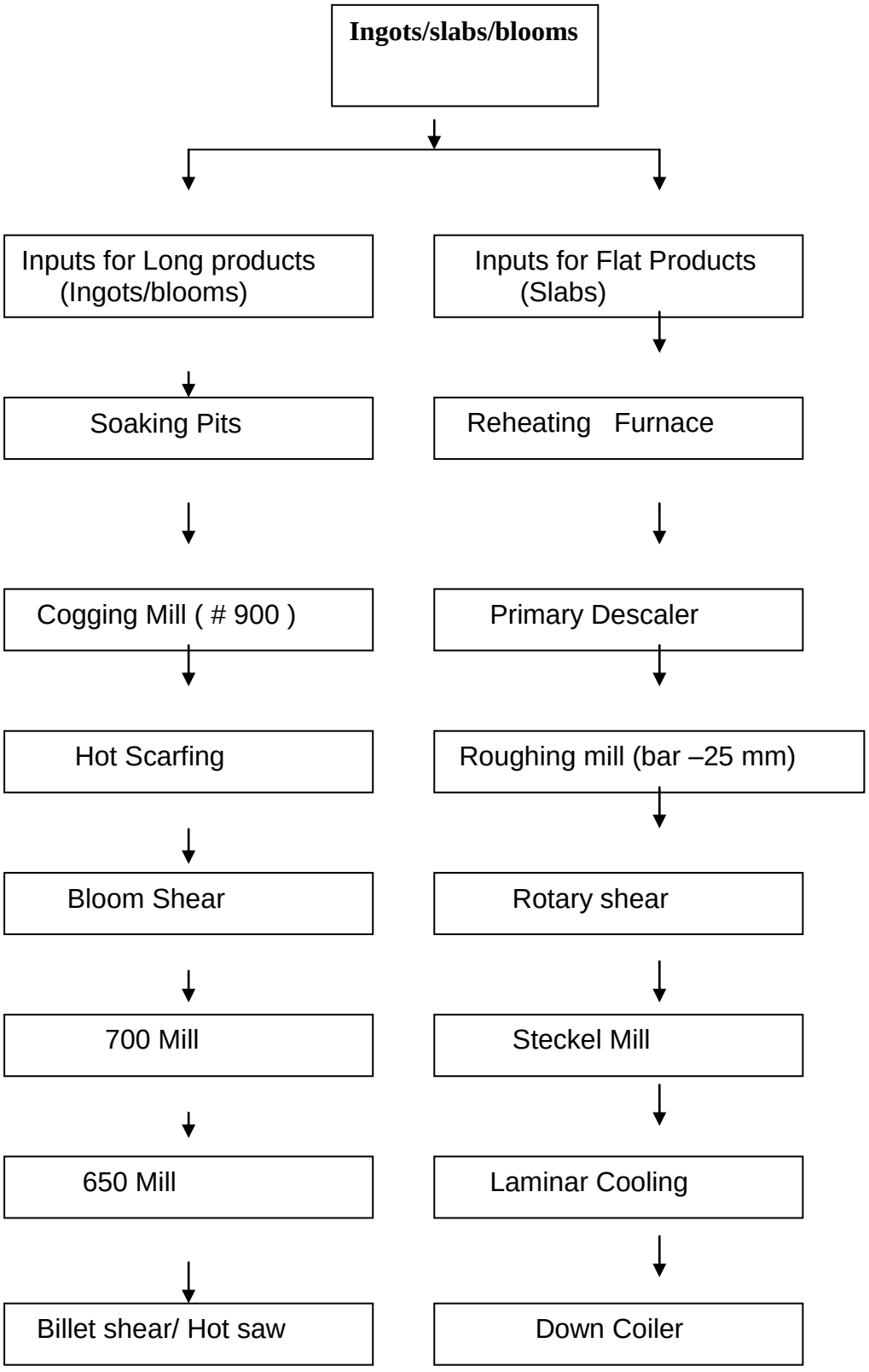
a) **Rolling defects:** Defects induced during the rolling process are classified as rolling defects.
b) **Steel defects:** Defects resulting from steel making practices and getting carried forward during the process of rolling to the end product may be classified as steel defects.

Rolling defects:

Some defects of hot rolling are:

Fins and overfills, underfills, Slivers, Laps, Fire cracks and roll marks, Rolled-in scale, Buckle and kink, Camber, Twist, Shear distortion, Out of square, Burnt edges, ridge-buckle ,wedge.

Rolling of Special Steels\ Process Flow



Special steels including Alloy and Stainless have both continuous cast and Ingot teeming products. Grades having high carbon and high alloy are hot transferred. All ingots and continuous cast slab or blooms are charged into soaking pit furnaces.

The soaked material is transferred from soaking pit to cogging mill by cranes. The scarfed bloom is taken to bloom shear for discarding hot top and bottom end. The sheared bloom is ready for finishing rolling either round or square sections.

The rolled bloom or billet is cut to length by shear or hot saw depending on the final requirements. The dis positioning depends on the grades and final property requirement.

The stainless steel slabs received from Alloy Steel Plant, are heated in a walking beam furnace in Salem Steel Plant. After this the slabs are transferred to steckel mill for hot rolling.

Slabs are rolled in 4 high roughing mills to get required T-Bar thickness and coiled in the down coiler.

Inspection

Rolled bars, Billets and Blooms are visually inspected in conditioning shops after exposing the surface either by grinding (zig-zag or ring), pickling or shot blasting. After exposing the surface, defects are removed by grinding to the allowable depth. Defective portions are discarded by gas or saw cutting. Ultrasonic flaw detectors are used for inspection of Rail & pipes.

Surface inspection and dimensional check of hot rolled coils are done before coiling and disposition.

Testing

Samples are collected from rolled products for testing for both physical and chemical. Different tests are carried out for checking internal defects, Grain size, Micro Structure, Inclusion ,Hardness, upsetting ,toughness etc.

Input hot rolled coils testing is done as they are taken up for cold rolling.

Heat treatment for Long Products

This is done at the finished stage of processing depending on mechanical property

requirement.

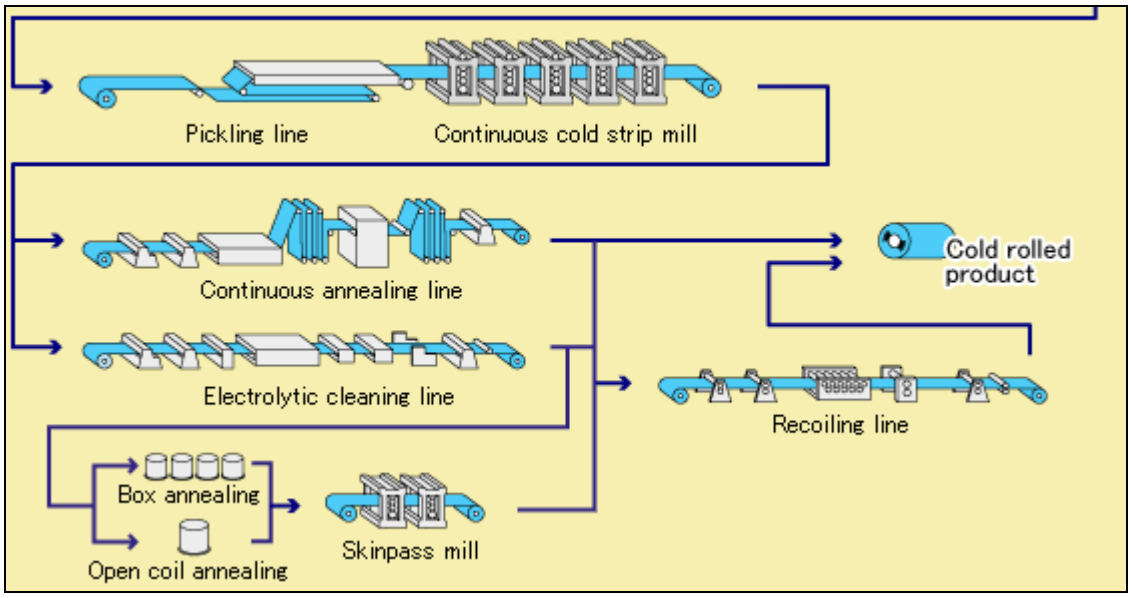
SPECIAL PLATE PLANT (SPP)

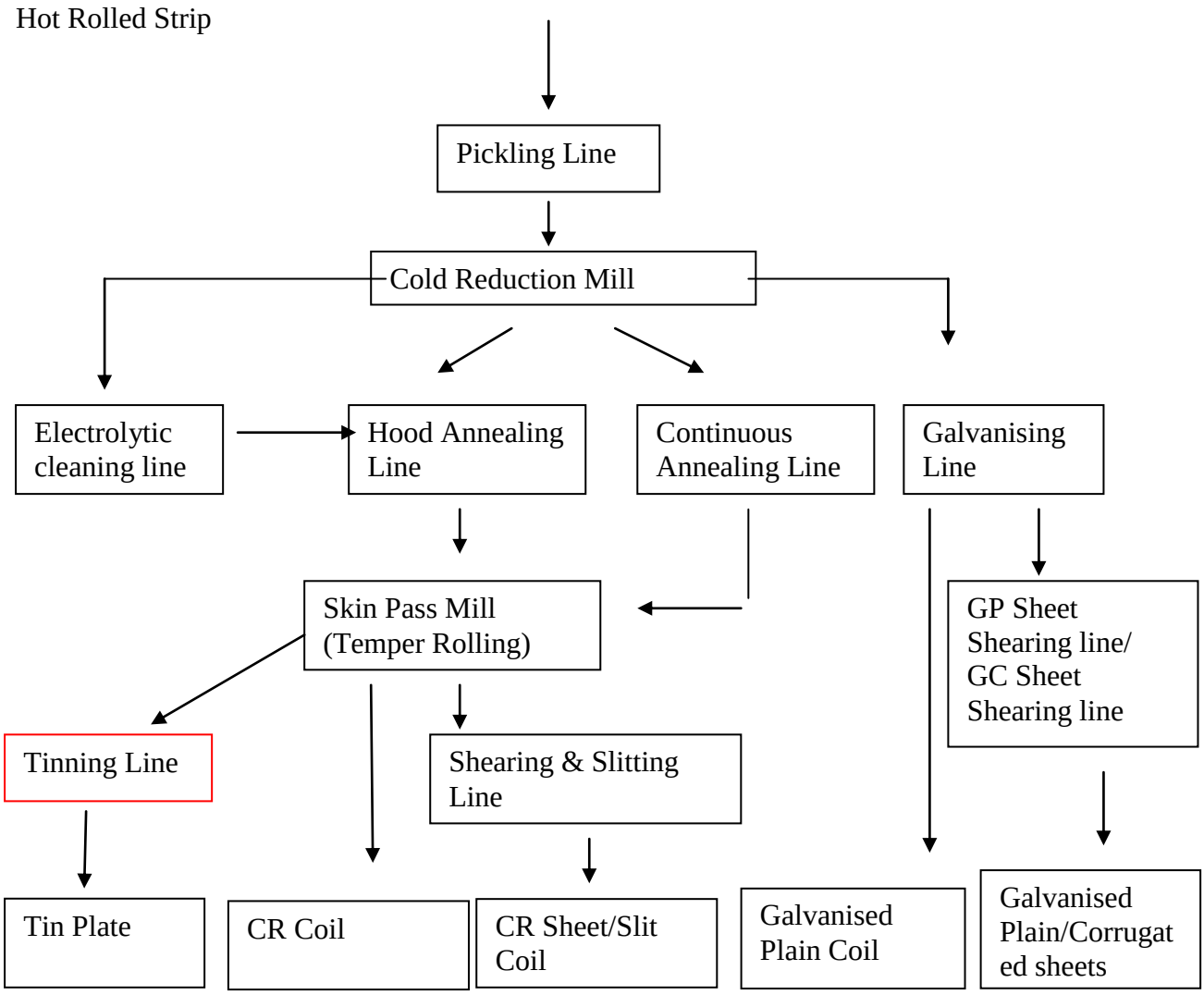
Special Plate Plant (SPP) of Rourkela Steel Plant caters to the needs of Defence & Space requirements. Special Plate Plants is **the only unit in India** producing various grades of quenched and tempered special steel plates, Armour Plates & Components for Defence in larger dimensions. All these steels are weldable.

6.8 Cold Rolling

COLD ROLLING MILL (CRM)

Purpose of cold reduction is to achieve, a reduction in the thickness, a desired surface finish, desirable mechanical properties, close dimensional tolerance and producing as per customer requirements. These thickness reductions are achieved through multi-pass rolling in a reversing mill or tandem mill. Apart from such mills, a cold rolling mill complex may include other facilities for pre-and post-rolling operations. The sequence of operation and material flow in a typical cold rolling mill complex is shown in Figure 3.1.





(Fig.3.1: Typical material flow in a Cold Rolling Mill Complex)

The input to Cold Rolling Mills is the Hot Rolled Coils (HR Coils) from HSM.

N.B. –at present Tin Plate is not being produced

<u>Pickling Lines</u>:

During the hot rolling process, a layer of scale (Iron oxides) is formed on the strip surface, which must be removed prior to further processing. This removal of scale is performed by physically breaking of scales by mechanical means & then chemically treating the surface of hot rolled strip with an acid. The process, called 'Pickling', removes the remaining scale by dissolving it in acid. Hydrochloric and Sulphuric acids are most commonly used for pickling. Pickling rate with hydrochloric acid is 2.5 to 3 times higher than with sulphuric acid under equivalent bath concentration and temperature conditions.

Cold Reduction:

After pickling, the main cold rolling operation, i.e. cold reduction, is performed in cold reduction mill where pickled strip is fed between very hard rolls. Cold rolling is done

- Either in a single reversing stand, equipped with an uncoiler and a coiler, by making several passes in reversing directions;

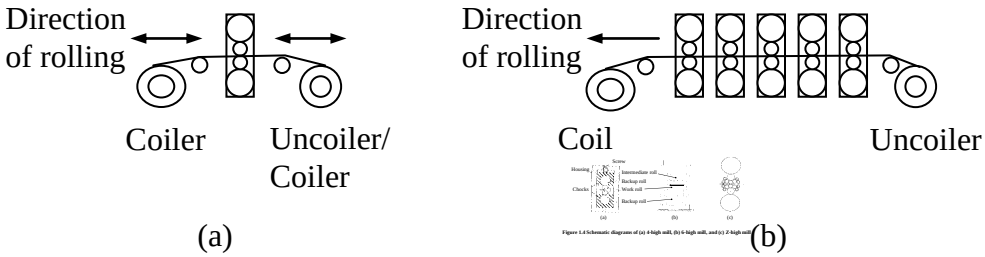
or

- In a continuous tandem mill where the strip is engaged in several stands simultaneously, enabling high-tension force to be applied.

Cold rolling in multi-stand tandem mill is widely used because of high speed of operation. The roll arrangement in each stand is 4-high, 6-high and even 20-high. The 20-high miles are used for rolling of stainless steels. Application of coolant with lubricant reduces the friction and heat generation at the roll bite and thus reduces the roll and strip temperature during rolling.

Cold Reversing Mill:

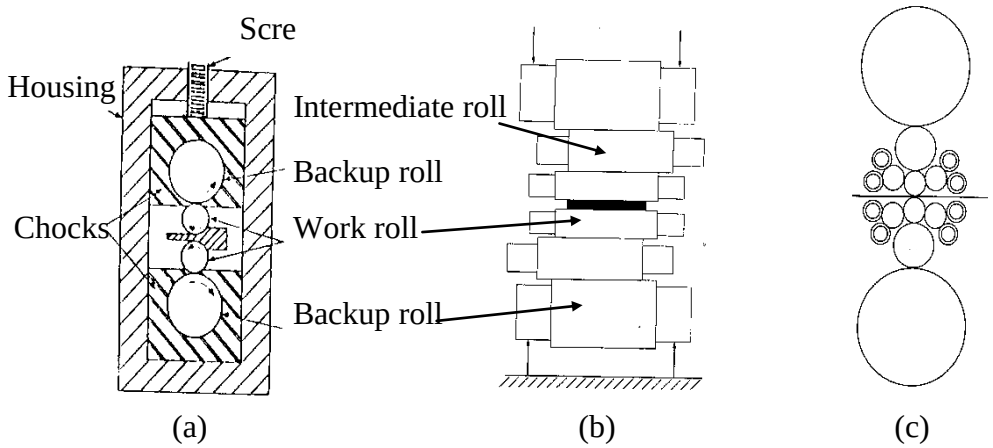
This is a 4-Hi reversing mill which makes 2-5 passes to reduce thickness. It consists of a single stand with reels located on either side of the mill. Steel strip is passed back and forth till the required thickness is obtained.



Schematic of (a) Reversing Mill and (b) Tandem Mill

Tandem Mill (TM)

In Tandem rolling, the material to be rolled undergoes reduction in all the mill stands at a time.



Schematic diagrams of 3.2(a) 4-high mill, (b) 6-high mill, and (c) Z-high mill

Each stand of tandem or reversing mills consists a set of independently driven pair of rolls, which come in direct contact with the strip and create a converging gap for imparting deformation to the strip. These rolls are called work rolls. Comparatively larger diameter backup rolls support these work rolls. When the mill is having one pair of work rolls and a pair of backup rolls it is called 4-high mill. To impart further rigidity, in some of the mills each work roll is supported by one additional roll (intermediate roll) between the work roll and backup roll. This type of the mill is called 6-high mill. A mill in which each work roll is surrounded by a cluster of backup and intermediate rolls is called Z-high mill or Sendzimir Mill. Schematic diagrams of these mills are shown in figure 3.2.

ROLL SHOP

All Integrated Steel Plants have Roll Shops/Roll Turning Shop , which does grinding/finishing of Rolls.

These depts supplies Work roll & Back up rolls to all mills i.e. Hot strip mill ,Plate Mill, New Plate Mill, Colld Rolling Mills, Silicon Mill, Pipe Plants.,URM,Wire Rod Mill.

Quality of Finished product of all Mills is dependent upon quality of finishing of Rolls.

All rolls are changed after certain Tonnage rolled which is different for all mills.

ELECTROLYTIC CLEANING LINE

Electrolytic Cleaning is required in case material rolled with high percentage of oil while reduction in mills goes for annealing in furnace.

Annealing Process:

Cold rolled strip as such is not suitable for drawing and deep drawing operations due to lack of ductility. The work hardening effects of cold reduction cause the loss.

Now these CR coils are to be annealed in protective atmosphere so as :

1. To improve the mechanical properties.
2. To increase ductility, particularly to restore the normal conditions of steel after cold working.
3. To relieve the internal stresses.
4. To remove chemical non-uniformity.
5. To change the micro-structure of steel from the distorted structure of cold worked steel to the equi-axed structure.

Annealing is done in either of the following two lines:

1. Hood (Batch or Box)Annealing Line (HAL)
2. Continuous Annealing Line (CAL)

Whichever method of annealing is used, the steel is maintained under a protective (non-oxidizing) atmosphere using **hydrogen and nitrogen** to prevent oxidation of steel while it is at high temperature. For cleaner and brighter coils sometimes Hydrogen is used as protective atmosphere though the process is costly.

Hood Annealing/Batch annealing, Box/Batch annealing is still the most common and convenient method of annealing and a major portion of cold rolled coils are annealed in Hood Annealing furnaces in spite of development of continuous and open coil annealing. The main reason for its wide use is that **wide range of annealing cycles can be adapted** to suit to Customers' requirements.

Different annealing cycles are followed for different grade & thickness of cold rolled coils.

Continuous Annealing:

Continuous annealing involves passing the steel through a high temperature furnace in the form of a continuous strip.

This is a much faster process compared to Hood annealing Process.

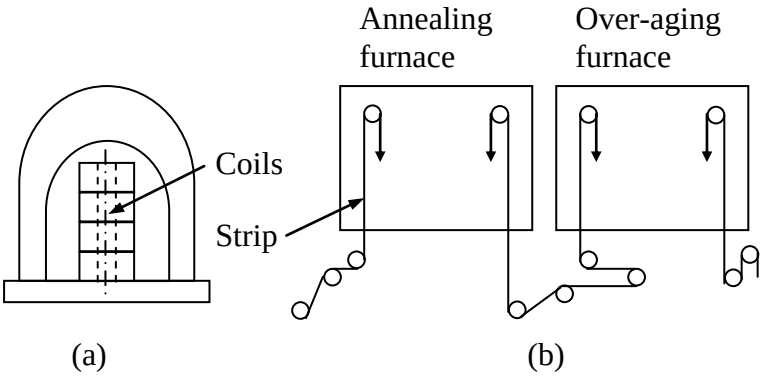


Figure: Schematics of (a) Batch Annealing and (b) Continuous Annealing

Skin Passing:

After annealing, the coils are given a further light rolling without strip lubrication. This operation is called as **Skin passing** or **tempers rolling**. It is a cold reduction method and the steel surface or skin is hardened by cold working, keeping the steel core soft & ductile. In fact, temper rolling does impart a small amount of cold reduction, typically between 0.25 and 1.0 percent.

The Skin Pass Mill where temper rolling is carried out is normally a single stand 4-high mill.

Both single and double stand Skin pass mills are present in BSL & RSP.

Following are the main advantages of Skin Passing.

a. Imparts different surface finishes to the strip required for painting, coating enamelling etc.
b. Gives a flat surface to the strip.
c. Imparts the desired mechanical properties to the strip.
d. Keeps the strip free from stretcher strains and luder bands that may develop during the forming operations.
e. The flatness is improved, and the coil is oiled with rust preventive oil.

The skin passed coils are the packed and dispatched to stock yards or Customers as CR coils**.**

Sheet Sheering Line (SSL):

Some Coils are sheared in to different lengths in Sheet Shearing lines and sent to Customers as CR sheets. SSL consists of one uncoiler & a Flying Shear to cut sheets of different lengths. On line inspection is done in most of the cases.

CR SLITTER

In slitter CR coils are slitted length-wise and also to remove side trims to obtain uniform width throughout the coil as customer requirement.

CUT TO LENGTH LINE (CTL)

In CTL slitted coils are sheared to the desired length as per customer requirement.

Coated Sheet

SAIL's family of coated steel sheet products includes both hot-dipped and electrolytically-applied coatings. The protective coatings add superior corrosion resistance to the many other desirable properties of steel.

Electrolytic Tinning Line (ETL) Complex at RSP:

Here the Coating of tin is done by employing the principles of electrolysis in a acidic medium.

The continuous Electrolytic Tinning Line produces a shining tin coated surface in a variety of coating thickness. The tin plate shearing lines are equipped with sensitive pin hole detectors and an automatic off gauge detection system.

Continuous Galvanising Lines at RSP and BSL:

Galvanizing Lines in both RSP & BSL are Sendzimer type Continuous Hot Dip Galvanizing facilities for On-line Oxidation Furnace for removing oil, grease, On-Line Reduction Furnace for annealing in protective atmosphere, Jet Coating for better control on Zinc coating thickness, Chemical Treatment to prevent atmospheric corrosion and Shearing facilities.

There are also multi-roller corrugating machines which produce corrugated sheets.

Shipping Section:

All Cold Rolled products like CR Coils/Sheets, ETP & GP/GC are packed, weighed, and despatched through Road or Rail Wagons in Shipping Section.

6.9 Major Cold Rolling Defects

Holes, Scale Pits/Scabs, Scratches, Roll Imprints / Roll Marks, Coil Breaks, Orange peel effect, Wavy edge, Centre buckle, Pinch, Bluing or Oxidation, Water stain /quench marks.

Introduction to Pipe Plants and Silicon Steel Plant

PIPE PLANTS (PPs)

Rourkela Steel Plant has two Pipe making mills

ERW PIPE PLANT(ERWPP)

The ERWPP in RSP produces IS grade as well as API grade pipes upto grade API-5L-X70of pipe outer diameter ranging from $8^{5}/_{8}$" to 18''(219.1 mm to 457.2mm) . **API 5L pipes are exclusively used** for transportation of gas and petroleum products.

Hot rolled coils (from Hot Strip Mill of RSP or from out side sources like BSL) **are the main input material** for ERW Pipe Plant. This input material is cold formed to a tubular shape by gradual deformation and then welded by the combination of heat and pressure.

SPIRAL WELDED PIPE PLANT(SWPP)

This mill meets the demand of handling bulk transportation of crude oil from shore to Refineries, slurry transportation, water supply and sewerage disposal to civil engineering pilings.. SW Pipe Plant has the capacity of producing pipes in the range of 16" to 72" (406.4 mm to 1828.6 mm) outer diameter with wall thickness of 5.6 to 14.2 mm.

SILICON STEEL MILL

This is a fully integrated Complex for production of Cold Rolled Non-Oriented electrical grade Silicon Steel of various sizes and grades in the form of Coils as well as Sheets.

Rolling of Special steels (Stainless Steel)
For rolling of Stainless slabs the following activities are carried out in sequence:
Coil Build-up Line [CBL]:
Bell Annealing Furnace [BAF]

Annealing, Shot blasting and Pickling

After annealing coils are shot blasted and pickled to remove the scale for further cold rolling. In order to remove the residual scale sticking to the surface, pickling process is carried out.

Strip Grinding

Coils which require repair grinding is processed in the line using coarse emery belt to remove the surface defects (slivers, scratches, minor scale etc) in full or in part depending on the severity and nature of the defects.

Sendzimir Mill (Z Mill)

Sendizmir Mill is used for rolling stainless steel at Salem. This mill is a 20-high mill having two work rolls supported by eighteen back-up rolls. Coolant oil is used during rolling which helps in strip cooling and also lubricating the various moving parts.

Skin Pass Mill (SPM)

Skin passing is done for stainless steel coils using Mirror polish rolls to improve the shape and have a bright surface and uniform thickness

Sheet Grinding and Polishing Line

Sheet grinding and polishing machine is used to produce special finishes and hairline finish on stainless steel sheets.

Chapter – 7

GENERAL MECHANICAL MAINTENANCE

7.1 Introduction

Maintenance can be defined as those activities which are required to keep a facility in as-built condition, so that it continues to have its original Productive Capacity. The responsibility of the Maintenance function is to ensure that production plant and equipment is available for productive use at minimum cost for the scheduled hours, operating at agreed standard.

Therefore, the function of Maintenance Engineering of SAIL are entrusted with the maintenance of plants to care of a regular and thorough supervision of the conditions and functions of all operational equipments in the right time so that effects of deterioration can be spotted early enough, before major costly breakdowns and damages occur to the equipments.

Maintenance management:

No longer does it make sense to isolate the critical activity of maintenance management from the rest of operations.

Manufacturing operations and maintenance management systems are now becoming highly collaborative as well, offering feedback loops where information and processes can be exchanged and acted upon.

It is important to have both maintenance and operations groups working closely together to optimize both operations and maintenance processes. This will be a key step in achieving the top two goals of minimizing downtime and maximizing asset utilization.

Every company wants to produce as much product as possible, at the lowest cost, with the highest return, at the best efficiency rate and, of course, without running their assets to the ground. There is also a trend in manufacturing to focus on lowering production costs without investing in people and processes. In addition, there is too much emphasis on reliability engineering and not enough on planning and scheduling. As organizations gain a better understanding for maintenance management they are beginning to realize that it is not only maintenance but total asset management that will lead them to success. As this trend continues, the concept of “maintenance management” will be replaced by “asset management”.

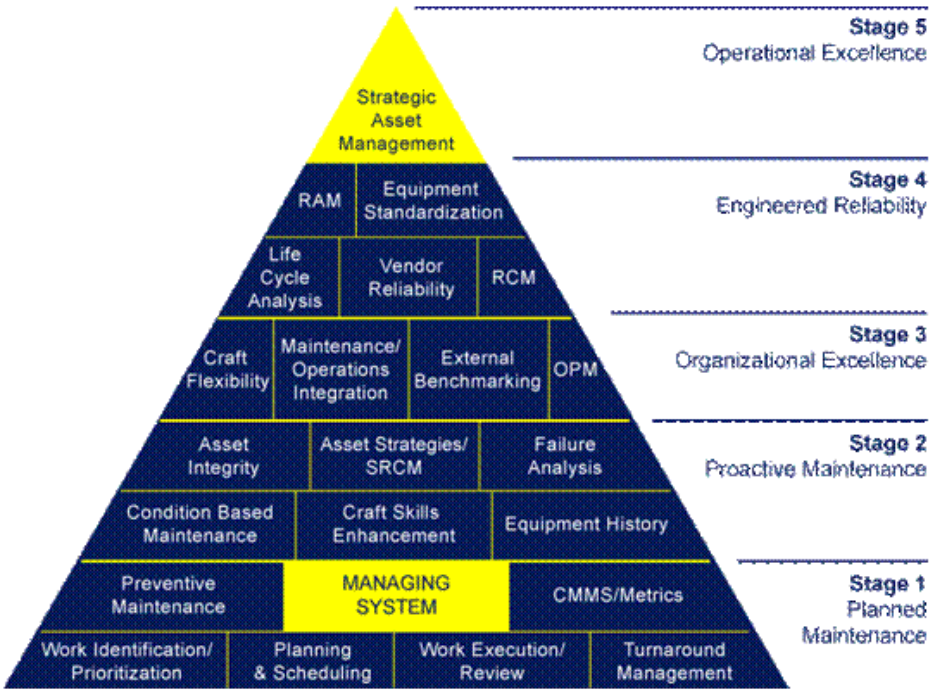


Figure 1: Asset Healthcare

DIFFERENCE BETWEEN MAINTENANCE MANAGEMENT & ASSET MANAGEMENT

We have developed a table that depicts the **Functional Excellence Model (Maintenance Management) and Asset Management Excellence Model .**By comparing the two, one can very easily see what the difference is between the models.

Functional Excellence Model	Asset Management Excellence Model
1. Operations owns production, maintenance owns equipment. 2. Maintenance excellence means efficient service (e.g. repairs) to production. A customer service model dominated by operations. Most work is inside planning time horizon. 3. Repair efficiency is the best measure of maintenance performance. No time to do it right, but hope there is time to do it over. 4. Production runs at any cost. Don't	1. Operations owns equipment and is responsible for equipment health. 2. Maintenance is a partnership with operations to identify and work ways to improve equipment health. 3. Breakdowns represent an unacceptable management system failure, and require failure analysis of equipment and process. 4. Production insists on and participates in assuring prevention and improvement activities. 5. Goals are developed top-down in a cascaded fashion. Functions share

have time to turn equipment over to maintenance as scheduled.	lagging indicator goals (e.g. monthly production), and have unique leading indictor goals that support activities (e.g. % of PMs performed to schedule).
5. Goals are set by functional managers, resulting in contradictory and self-defeating reward/recognition practices. Most measure are lagging indicators, demonstrating past results.	6. Purchasing and inventory management's highest goal is parts service level and mean time between failure for purchased parts.
6. Purchasing excellence means having the lowest cost of items available.	
7. Pressure is on individuals to do better. No gauges or tools of "better" exist.	7. Each piece of equipment has an operating performance specification, and gets the attention necessary for it.

The benefits of a successful Asset Management Strategy include:

- Accurate analysis of equipment maintenance, repair, and replacement records.
- Increased availability of production systems and equipment.
- Fewer failures of production systems and equipment, resulting in fewer unplanned outages.
- Improved product quality associated with a reduction in costs related to losing or reprocessing product.
- Lower costs for system and equipment maintenance, spare parts inventory, and capital replacement.

7.2 Maintenance Objectives

Maintenance is an integral part of an Organization in its entirety and therefore, Maintenance Objectives should be established within the framework of the whole so that overall organizational or corporate objectives and needs are adequately fulfilled.

The Maintenance Objectives are to:

a) Ensure maximum equipment availability for meeting APP targets;
b) Maintain plant equipments and facilities at an economic level of repairs at all times to conserve these and increase their life span:
c) Provide desired services to operating departments at optimum levels:
d) Ensure reliability and safety of equipments for uninterrupted production;
e) Ensure operational readiness of all stand-by equipments;
f) Eliminate hazardous environment and to ensure safety of workmens.

ASSIGNMENTS OF MAINTENANCE:

The assignments of Maintenance are likely to be categorized in two big groups, one not less important and vital than the other. These are:

a) The actual maintenance at site.

b) The theoretical and organizational assignment of Maintenance.

ACTUAL SHOP MAINTENANCE:

An outsider usually sees the shop activities of the maintenance with their obvious results of maintained and repaired equipments. These are:

i) Attending continuous running equipments such as air compressors, central lubrication or hydraulic stations.

ii) Cleaning of equipments.

iii) Short term checking and servicing of equipments.

iv) Lubrication of equipment

v) Long term inspection and maintenance.

vi) Planned repair during Shutdowns.

vii) Capital and Major repairs.

viii) Physical elimination of weak points in Design and Materials.

ix) Unplanned repairs due to Breakdowns.

x) Emergency Manufacture of small spares on shop.

ORGANISATIONAL AND ADMINISTRATIVE ASSIGNMENTS OF MAINTENANCE:

Maintenance Organization group must ensure availability of equipments and services for performance of their functions at optimum return on investments (ROI) whether this investment be in **MACHINERY, MATERIAL, MEN and MONEY.**

These are:

i) Management of Men:

This includes men power planning, selection, training, evaluation and placement. Additionally it aims at creating sufficient and capable staff groups like Design Department, Maintenance Planning Department, Consumption Cell, Hydraulic and

Pneumatic & Lubrication groups, Repair shops etc. to meet day to day maintenance to guide, control and evaluate activities of maintenance and services.

ii) Management of Machines:

Maintaining inventory of equipments, elaboration and application and development of short and long term equipment checking and servicing, planning of major and Capital Repair Plans, Breakdown and Delay Investigation and Analysis, Standardization of equipments come under this category.

iii) Management of Material:

Inventory, Spares and Consumable categorization, implementation of manufacture and repair of Spares, indenting of spares, consumables and tools etc. come under this category.

iv) Management of Money:

Management of Maintenance Budget, implementation of an accounting system for evaluating cost of manufacture and repair as well as follow up of the cost of expenditure on account of maintenance comes under this category.

7.3 Types of Maintenance Systems

Any Organization which is involved in machinery, plant, equipments and facilities must have a clear-cut maintenance policy.

Broadly the following methods are used for carrying out maintenance activities.

a) Breakdown maintenance
b) Preventive Maintenance
c) Planned Maintenance
d) Predictive Maintenance

Breakdown Maintenance:

This is event based and carried out when breakdown of equipment takes place bringing down production. This is firefighting and should be avoided at all cost. Cause of such breakdowns must be analyzed and action must be taken for non-recurrence of the same.

Preventive Maintenance:

Preventive maintenance system refers to those critical systems, which have to reduce the likely hood of failures to the absolute minimum. This is an endeavor to forestall unplanned down time of Machines. It consists of Planned & Coordinated inspection, adjustments, repair and replacements in maintaining equipments. Preventive maintenance of a machine or a running line can be carried out both during operation as well as shut down.

Purpose : To make necessary and timely repair and prevent unscheduled interruptions and deterioration of the equipments.

Result : Minimum operation down time, better overall maintenance planning , emphasizes weaknesses in equipments and accessories and reduces maintenance cost .

Planned Maintenance :

Planned maintenance is carried out with forethought, control and records to a pre-determined plan. In the planned maintenance system the emphasis is the machine needs and the expected requirements from the machine. It has to be centered around the original recommendations made and prescribed by the original equipment manufacturer (OEM). The

maintenance manager has to use all his experience and expertise to super impose refinements and improvements on manufacturers recommendations.

Essentials of Planned Maintenance**:**
It basically consists of the following activities:

1. Inspection
2. Planning & Execution
3. Reporting & Documentation
4. Feed back & Actions for improvements
5. Investigation

Inspection:
Inspection is the most important ingredient. A sound inspection system forms a strong base for a good maintenance system. It must be carried out by sincere and experienced hands so that the right problem can be detected at the right time by the right people to take timely corrective actions. One should also look for statutory violation and unsafe working conditions. The frequencies of inspection can be finalized depending upon the severity of the working condition and its importance in the production environment.

Planning and Execution:
Maintenance planning is essentially based on past experience, equipment condition and the recommendations of the OEM. There can be both Long and Short term planning for executing any repair. Men, Materials and supporting services have to be planned to carry out any planned execution of equipments

Documentation:
Details of Maintenance activities and all related requirements with reference to men, materials, services should be documented both before and after execution. This is required for future references and building up of a sound maintenance history.

Feedback:
The behavior of machines / equipments should be recorded from time to time immediately after the repair so as to note the improvements/ changes in performance if any which will go a long way in improving and fine tuning of future Maintenance practices.

Investigation:
Sudden or gradual failure of equipments, repetitive failures must be thoroughly investigated and the reasons identified. This will help in prevention of unscheduled equipment breakdowns. Methods such as Root Cause Analysis (RCA) etc. are adopted to determine the causes of failures and necessary actions are taken for non-recurrence of the same in future.

Predictive Maintenance :

This is a technique to determine the condition of in service equipments in order to predict when maintenance should be performed. This approach offers cost saving over routine or time-based Preventive maintenance because tasks are performed only when warranted. Most Predictive Maintenances are performed while the equipment is in service, there by minimizing disruption of normal system operations.

Adoption of Predictive Maintenance (PdM) in the maintenance of equipments can result in substantial cost savings and higher system reliability.

Reliability Centered Maintenance or RCM emphasizes the use of predictive maintenance (PdM) techniques in addition to traditional preventive measures.

In recent years, the trend is for implementation of predictive maintenance activities, but it is done without fully embracing and understanding its value. However as with any tool, success depends upon implementation and use of the tool.

Monitoring overall equipment effectiveness and reliability process effectiveness are no longer enough. While important, these measures are only the first step. The results to cost savings must be quantified and thereby increase in revenue capacity.

By doing so, reliability managers can quantify efforts in terms top managers understand.
Start with studying the asset to determine how it can fail and the repercussions of those failures. Though it requires more work up front, efficiencies in PdM implementation pay for the extra time quickly.

Monitoring is just part of the process. Despite all of the improvements in reliability engineering and predictive technologies, this simple concept is still poorly understood across industries. Large capital expenditures are made to support monitoring, but far less attention is paid to the analysis of the data acquired through process monitoring.

Competent individuals analyze data to convert data to information.

Companies must ensure the people performing analysis are competent, adequately resourced, and have the necessary controls within their processes to accomplish the established objectives.

Traditional PdM practices often take process for granted. Methods for acquiring data, analyzing data, reporting information and managing the information are rarely reconsidered as opportunities for improvement. However, the new economic environment is forcing everyone to reconsider conventional wisdom and accepted truths.

Technologies of Predictive Maintenance:

To evaluate equipment condition Predictive maintenance utilizes Non-destructive testing technologies, such as infrared, acoustic (partial discharge and airborne ultrasonic), Vibration analysis, Sound level measurements, Oil- analysis and other specific online tests.

Vibration analysis:

Every equipment in motion causes vibration and can be characterized by the frequency amplitude and the phase of the wave. When a machine is operating normally, the pattern of vibration is recorded as vibration signature. The deviations are registered on a vibration analyzer and this lead to corrective action.

Ultrasonic:

The technique is useful to survey wall thickness of metallic vessels, piping etc to detect cracks and to determine extent of Corrosion /Erosion at vulnerable areas.

Infrared Detection:

Use of infrared picture or thermograph is used for heated spot detection. This is particularly useful when temperature are high and conditions cannot be known of happenings inside the Furnaces, Vessels, Ladle walls and pipe lines including heat building up in Electrical cables etc. .

Eddy Current:

This is useful in the inspection of defects of non-magnetic pipe tubes of heat exchangers or other units.

Oil Analysis:

By analyzing the oil samples of the running equipments, information regarding deterioration of components can be established. It is a long term programme but can be more predictive than any other technologies. The concentration of metallic particles shows the extent of wear in the equipments and this calls for timely action before any break down takes place.

Latest techniques of maintenance adopt a proactive / precision maintenance approach.the philosophy behind this kind of technique is:" fix it once and fix it right"

Main constituents of this technique are:

1. Operating context of a particular equipment/machinery
2. Collection of historical dataof equipment'sperformance during its life time
3. Performance of special tests such as bump test, phase, lubricant,thermography etc.

Advantages and Disadvantages of proactive maintenance:

Advantages:

1. Equipment life is extended
2. Equipment reliability is improved

3. Reduction in failures
4. Downtime reduction
5. Reduced overall maintenance

Disadvantages:

1. Increased cost of instruments and services.
2. Additional skill is required for operating instruments.
3. A change in mindset and philosophy is desired.

The need of hour is to shift towards short CGT (Cleaning, Greasing & Tightening) regime from conventional PPM schedule.

Benefits:

- Adjusting maintenance needs to higher production requirement.
- Reduction in maintenance downtime.
- Optimum utilization of manpower.
- Increased frequency of cgt ensures greater reliability.

7.4 Latest Trends in Maintenance:

Computer Managed Maintenance System (CMMS) is adopted in some of our SAIL units is of immense value in terms of Equipments documentation, Maintenance planning (Schedule, Inspection and Lubrication), Costs, Material requirement, Management Information System .

The advantages are :

i) Instant communication to all levels of managements

ii) Optimisation of available resources of men and materials

iii) Improved planning and scheduling

iv) Ready accessibility to job backlogs

v) Improved inventory control due to instant access to stock data

vi) Overall improvement in system and time management for purpose of implementation.

CMMS Module consists of the following:

1. Equipment classification
2. Maintenance Planning ,Execution ,Monitoring, Evaluation and History

3. Captive Shop schedule and Manufacture of spares for optimum utilization

4. Material planning / Purchasing & Stores Control System

Condition Based Maintenance System (CBMS):

Condition Based Maintenance has been described as a process which requires technologies and people's skills that integrates all available equipment conditions, indicators (Diagnostic and performance data, Operator logged data, maintenance history and design knowledge) to make timely decisions about maintenance requirements of equipments .

The goal of Condition Based Maintenance is to optimize reliability and availability by determining the need for maintenance activities based on equipments condition. Using "Predictive techniques", technologies, condition monitoring and observations, it can be used to project forward the most probable time of failure and enhance the ability of the Plant to plan and act for prevention of the same.

Preventive maintenance jobs that are taken up are not only limited to time based frequencies but based on conditions also. While regular inspection, monitoring of parameters like pressure, temperature, current etc. detects many job requirements, maintenance organizations are adopting modern methods of Condition Monitoring as detailed under Predictive Maintenance (PdM).

7.5 Lubrication

Introduction: -

A common feature of mechanically engineered system is relative motion of one component with respect to another. Friction results in energy dissipation. The most standard approach is to use lubrication in the hydrodynamic range. The friction may then be considerably reduced.

Origin of friction is very basic in nature and extreme care is required to reduce it to a low level. It is considered as a system property with a pair of materials being specified. A few important thumb rules apply:

1. The friction force always acts in a direction opposite to that of the relative velocity of the surfaces.

2. The friction force is independent of the apparent geometric area of contact.

3. Rolling friction is always much less than the sliding friction

Wear is progressive loss of substances from the operating surface of a body as a result of relative motion at the surface. For dry metals in sliding contact it is important to note that:

- Wear rate is independent of the apparent area of contact.
- Wear varies with load applied.

BASIC OBJECTIVES OF LUBRICANTS

The basic objectives of lubrication are to reduce friction and control wear in machine elements which are in relative motion. In addition to these:

1. To remove the heat generated at the inter face (contact) area.
2. Flush out contaminants by carrying them to filter.
3. Resist formation of deposits on surfaces.
4. Inhibit aeration (air bubbles) and foaming of lubricant.
5. Dampen noise.
6. Act as a sealant.
7. Protect surfaces against corrosion.

The lubricant could be a solid, semi-solid, liquid or mist form. The use of a particular type of lubricant depends on the nature of application. Liquid lubricants find greater usage as compared to other forms of lubricants.

Greases

Grease is defined as a solid to semi fluid product of base oil & thickening agent widely used because of its unique property to adhere to the contact surface. The liquid phase may be mineral or synthetic oil or a mixture of two. The thickening agent sometime called a gelling agent may be a metallic soap, mixture of soaps. The majority of industry's needs are catered for by petroleum oil greases. The most common greases are made from metallic soaps. Among soap based greases calcium grease first appeared, followed by sodium, sodium-calcium, lithium & complex greases. Some additives are like anti-oxidants, anti-wear, anti-foam, rust inhibitor, corrosion inhibitor are added in grease to improve its performance according to application.

In selection of grease temperature is an important factor. Petroleum greases are inexpensive and adequate for temperatures between -30^0C and 100^0C. Some special greases may withstand a temperature above 100^0C non soap based greases in particular silicone grease & calcium suplphonate, poly urea based is useful. For low temperature applications, synthetic greases have proved successful.

Advantages of grease:

1. Less frequent application as it is easily retained in the system and leakage is minimum due to less flow ability.
2. Better rust prevention characteristic compare to oil.
3. Lubrication of inaccessible parts.
4. Provides better sealing action by preventing lubricant loss and ingress of contaminants.
5. Requires simplified housing design.
6. Simpler seals could also be very effective due to the physical property (flow ability) of the grease.

Disadvantages:

1. Does not perform as a proper coolant.
2. Cannot flesh away contaminants like liquids.
3. Requires high torque to its semi solid nature.
4. Heat generation is high due to high viscosity value

Grease nomenclature is according to the thickner (soap) type, additives & its consistency in NLGI scale from 000 (fluid) to 6 (very hard). NLGI-2 is the normal grease used. (NLGI-National Lubrication Grease Institute)

Lubricating Oil

Oil is a liquid which is lighter than water and insoluble in it. Liquid at normal temperature of a viscous consistence and characteristic unctuous feel, lighter than water and insoluble in it. Oils derived from vegetable sources are generally termed as fatty oils and oils from animal sources as well.

Today petroleum is the biggest economical source of lubricants known as mineral oils. The normal working range for use of mineral oil is -20^0 C to 90^0C. For every 10^0C rise over the maximum temperature limit maximum life is reduced by 50%.

Synthetic oils have high and low temperature operations and fighting fire hazards gave way to its development. Some advantages are over mineral oil

1. Wide temperature range.
2. Prolonged life
3. Less oxidation

4. Minimum loss in consumption due to low volatility.

Oil lubrication systems are widely used in rolling mill gear box, Bearings of turbine & large fans of sinter plant.

Lubrication methodologies

Every lubricating point has a specific lubricant requirement, lubricant schedule, working environment and manner of lubrication. Therefore lubrication philosophies differ accordingly as 1) Manual and 2) Automatic Lubrication systems.

Further either of the system can be categorized as 1) Single point lubrication and 2) Centralised lubrication system.

Manual Lubrication

Manual Lubrication can be done either at individual lubricating points or into a particular point from where it is centrally distributed to different points through a network of pipelines. Here, the lubricant is manually pumped from a mobile/dedicated can/tank and the flexible discharge hose is connected either directly onto the grease nipple or into a fixed point from where it gets distributed into the network. Manual lubrication is preferable in mobile systems where connecting hoses and pipelines between lubricating points and a fixed pumping station is not always possible or economical. It is also preferred where the lubrication schedule is not frequent. The main disadvantages of manual lubrication systems are that the number of lubricating points that can be lubricated from a central point are limited since the high pressure necessary will not be possible manually. Also, when it comes to lubricating individual lubricating points, given the sheer number of bearings in a large scale industry as well as some lubricating points being inaccessible, the chances of some bearings missing out on lubrication are high. Moreover, it is very difficult to adequately maintain the quantity of lubricant and the frequency of lubrication into individual lubricating points.

Automatic Lubrication

Automatic lubrication systems negate manual involvement in the lubrication process. Here, a pump driven by a motor pressurizes the lubricant stored in a reservoir into a pipeline. The pressurized lubricant with the help of various distributors and pipelines reach the respective lubricating points. The advantage of automatic lubrication systems over manual is that large number of lubricating points can be lubricated from a single pumping system due to the high pressures that can be attained. Moreover, the quantity of lubricant can be controlled.

Automatic lubrication may be of single point or centralized lubrication system.

The centralized lubrication systems are of 3 types

1. Single line system
2. Dual line system
3. Multiline system

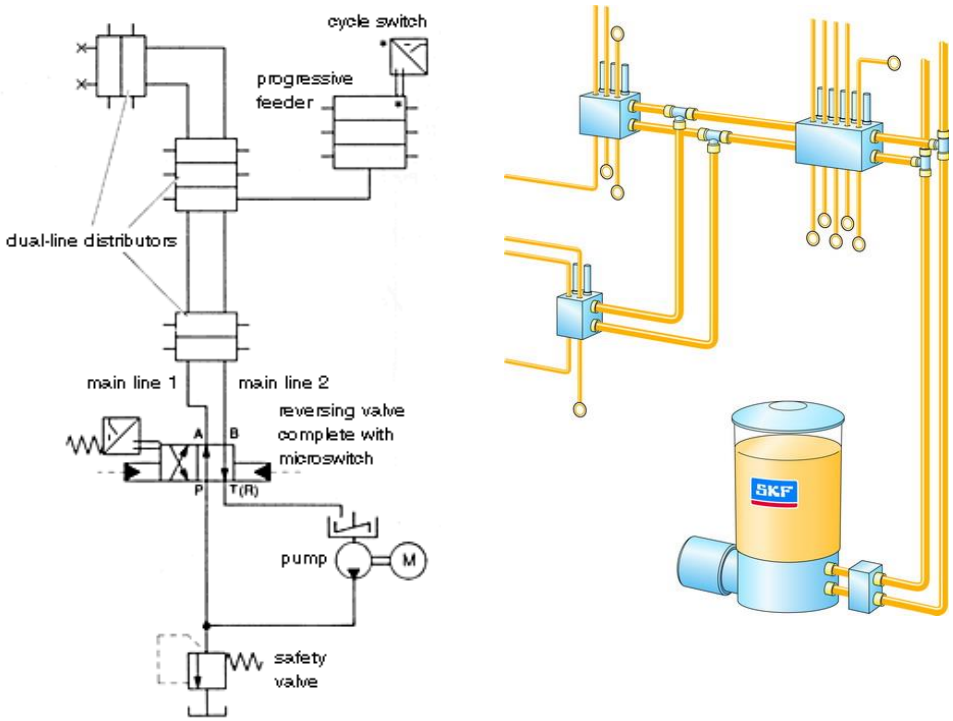
Single Line Lubrication System

Single line lubrication systems have a motor operated pump, pumping pressurized lubricant into pipelines to lubricating points through single line metering devices or distributors. From the distributors, the lubricants pass through one lubricating point to another progressively; that is only after one point is lubricated does the lubricant proceeds to the next. The disadvantage here is that if there is a clog in the piping of any lubricating point, all subsequent lubricating points remain un lubricated.

Dual Line Lubrication System

In the dual line lubrication system the pumping system is similar to single line; but here, the entire lubrication is divided into two phases or cycles. The first cycle takes care of half the number of target lubricating points and second half targets the remaining half. This changeover is done by a change over valve (COV). Here the lubrication is not progressive but parallel that is jamming of any one pipeline will not stop the lubrication of other lubricating points. Also, since a single system will take care of both the cycles individually, lubricating points of the order of 300-400 points spread over very large distances can be brought into the network. Also, the necessary lubricating quantity, pressure and frequency can be maintained based on requirements.

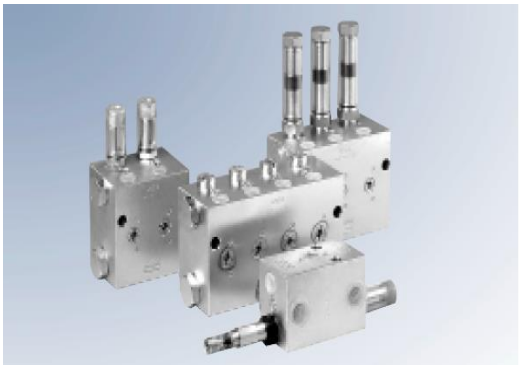
The advantage of a two-line system is that it supplies an exact metered quantity of lubricant from one pump station over large distances. The metering devices are operated by two main lines, whereby here the lubricant is simultaneously the control medium of the system. The two-line system can be combined with secondary progressive metering devices, thereby increasing the total number of lubrication points that are served by a two-line metering device.



A typical dual line system flow diagram

Parts of a Dual Line Lubrication System:

1. Reservoir
2. Pumps
3. Distributors
4. Change over valves
5. End of line pressure units
6. Refilling unit



Dual line grease lubrication system is extensible used as automatic system in steel plant.

HYDRODYANAMIC LUBRICATION:

It signifies that such a lubrication mechanism is due to motion. The shape of two surfaces being separated by the lubricant film and their relative motion is such that a pressure is generated in the lubricant film which takes up the external load. Usually in hydrodynamic lubrication thickness of lubricant film (film thickness) is significant and the pressure generated is not adequate enough to deform the surfaces locally.

HYDROSTATIC LUBRICATION:

It signifies that the lubricant is supplied at such high pressures that it separates the surfaces in relative motion, simultaneously taking up the external load and hydrodynamic action may or may not be present.

OIL MIST LIBRICATION:

It consists of a mixture of oil and atomized oil being supplied to the bearing housing under suitable pressure. Oil mist is formed in an atomizer.

7.6 Bearings & Bearing Housings

Bearings are machine element and are designed to overcome friction to provide ease of rotation & transmit the load. Generally bearings are made of Gunmetal. One way to reduce friction is by adding lubricant and other way is to utilize rolling elements. Friction is reduced as things roll easier than they slide. Bearings are designed to support shafts and allow free rotation on applied loads. There are three basic type of loads. Radial loads are applied perpendicular to the shaft. Axial loads are applied parallel to the axis of rotation.

Combination load is encountered when the bearing simultaneously subjected to radial and axial load.

Bearings can be categorized as:

i. **Plain bearings**:

Many applications require oscillating, linear movements and require accommodating misalignment. Spherical plain bearings, rod ends and bushings in various designs and with different sliding contact surface combinations are suitable. Bushings are also referred to as journal or sleeve bearing. The plain bearing is cylindrical in shape and designed to fit tightly in the housing and on the shaft. The advantages of plain bearings include:

1) Smaller outside diameter (as compared to rolling element bearings)
2) Quiet operation and absorption of shock loads.
3) Repetitive back and forth motion and low cost
4) Can take more misalignment compared to rolling element bearing

Bronze, Babbitt, PTFE are various low coefficient materials used in plain bearing construction. Some plain bearings are maintenance free (lubrication not required).

RADIAL SPHERICAL PLAIN & ROD END BEARING

These bearings find applications in hydraulic cylinder clevis, large size valve. These are available in maintenance free & requiring maintenance types.

ii. **Rolling element bearings:** These are also called as anti-frication bearings & more complex than plain bearings. Its major components are: inner race, outer race, rolling elements & cage.

Inner/Outer race and rolling elements carry the bearing load, the type, size, and numbers of the rolling elements directly influence the bearing's overall load capacities.

The cage is added to maintain even spacing between each rolling element and to ensure equal distribution of load. Steel & brass cage is common. Some cases plastic is also used.

Seals and shields keep lubricants in and keep contaminants out. While increasing the size and quantity of rolling elements increases the overall load carrying capacity. Bearing seals are mostly found on single and double row ball bearings. Bearing shields are made up of steel and are affixed to the bearing's outer ring, but unlike the seal, the shield does not make contact with the inner ring.

DIFFERENT BEARING TYPES

There are many types of bearings, each used for different application either singularly or in combinations. These include ball bearings, roller bearings (spherical, cylindrical, taper roller & needle roller) & thrust bearings (ball or roller).

BALL BEARINGS

Ball bearing is a common bearing found in electric motor & centrifugal pump. These bearings are capable of taking both radial and axial loads and are usually found in applications where the load is light to medium and is constant in nature (ie not shock loading). Deep groove & angular contact type are two variety of ball bearing designated as 6XXX & 7XXX.

ROLLER BEARINGS

SPHERICAL ROLLER

Roller bearings like the one shown are normally used in heavy duty applications such as conveyer belt pulleys, gear boxes, industrial fans where they must hold heavy radial loads. In these bearings the roller is a cylinder, so the contact between the inner and outer race is not a point (like the ball bearing above) but a line. This spreads the load out over a larger area, allowing the roller bearing to handle much greater loads than a ball bearing. However, this type of bearing cannot handle thrust loads to any significant degree. Spherical roller designated as 2XXXX.

Spherical roller bearing comes with plain or taper bore. Taper bore bearing is used with adapter or withdrawal sleeve for easy mounting & dismounting. Adapter sleeve are designated as H-XXX.

Double row spherical roller of diameter above 500 mm is used in converter trunion bearing in single piece of split type.

CYLINDRICAL ROLLER BEARING

Cylindrical roller bearings generally are single row bearings with a cage. High-capacity bearings, double row bearings, multi-row bearings, single, double and multi-row full complement bearings (without a cage) and split bearings are other varieties. Bearings with a cage can accommodate heavy radial loads, rapid accelerations and high speeds. Full

complement bearings incorporate a maximum number of rollers and are therefore suitable for very heavy radial loads at moderate speeds.

Four row cylindrical roller bearings are generally used as roll neck bearing in rolling mills.

NEEDLE ROLLER BEARING

A variation of roller bearing design is called the needle bearing. The needle roller bearing uses cylindrical rollers like those above but with a very small diameter. This allows the bearing to fit into tight places such as gear boxes, cardan shafts that rotate at higher speeds & also has a more load carrying capacity.

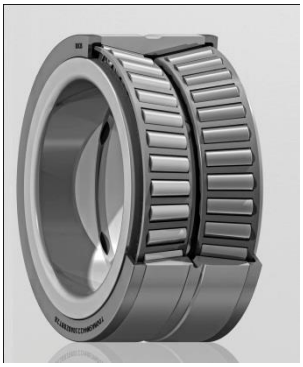
THRUST BALL BEARINGS

Ball thrust bearings like the one shown are mostly used for low-speed non precision applications. They cannot take much radial load and are usually found in low precision farm equipment. Thrust ball bearing designated as 5XXX.

ROLLER THRUST BEARING

Roller thrust bearings like the one illustrated can support very large thrust loads. They are often found in gear sets like car transmissions between gear sprockets, and between the housing and the rotating shafts. The helical gears used in most transmissions have angled teeth, this can causes a high thrust load that must be supported by this type of bearing. Roller thrust bearing designated as 8XXX

TAPER ROLLER BEARING



Tapered roller bearings are designed to support large radial and large thrust loads. These loads can take the form of constant loads or shock loads. Tapered roller bearings are used in many gear boxes, where they are usually mounted in pairs facing opposite directions. This gives them the ability to take thrust loads in both directions. Taper roller designated as 3XXX in metric size & in inch size 9XX/9XX.

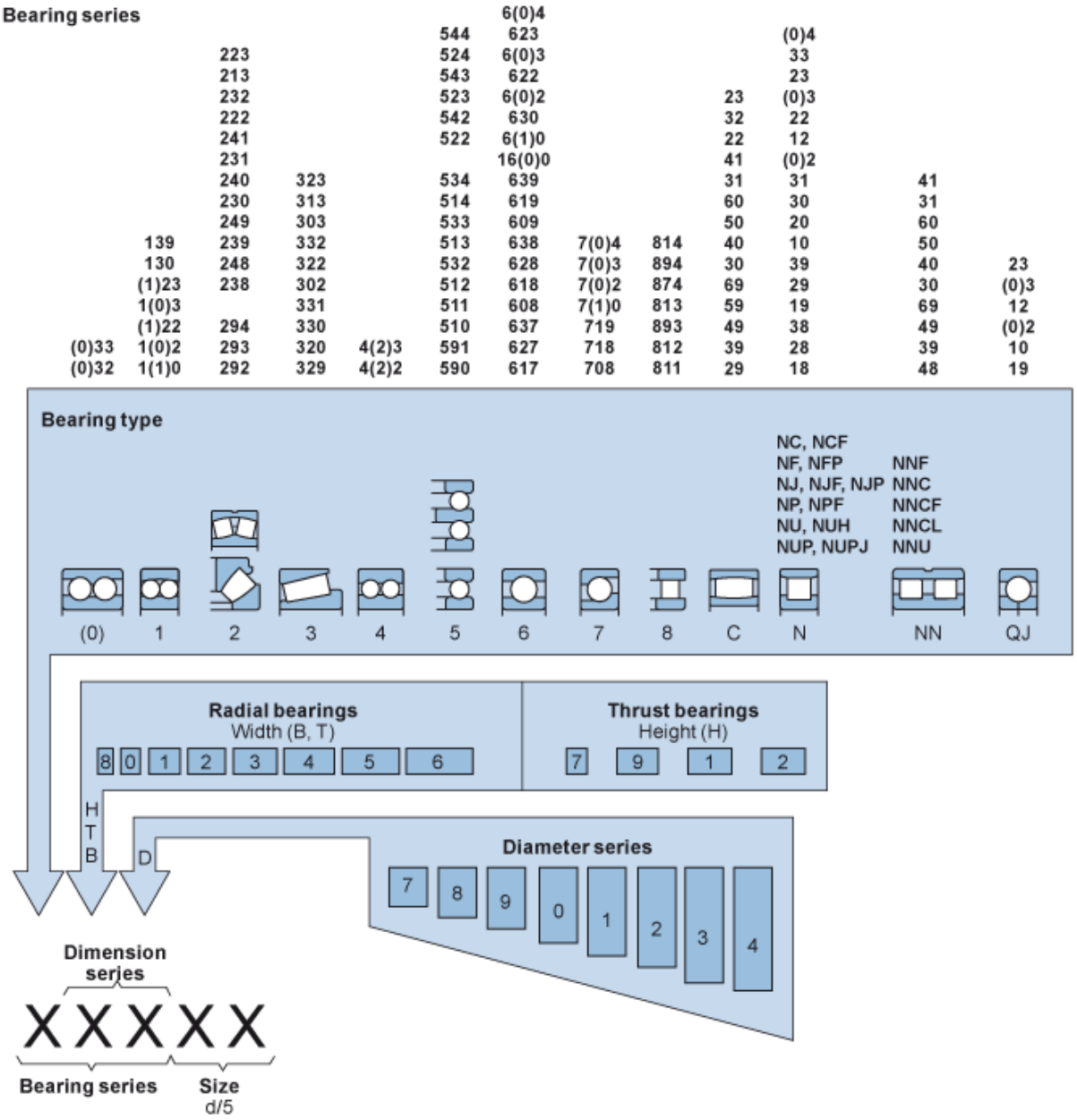
Four row taper roller bearings are used in rolling mills rolls.

BEARING DESIGNATION SYSTEM

The designations of most rolling bearings follow a system that may consist of a basic designation with or without one or more prefixes and/or suffixes

Common Suffixes-

C- Plain bore
E- Internal design
K- Taper bore
W33- Oil groove with hole
Z- Metal seal on one side
ZZ/2Z- Metal seal on both side
2RS- Soft seal
MB- Machined Brass cage
Internal Clearance: C2-less than normal, C3- greater than normal, C4-greater than C3 & C5-greater than C4



SPECIAL BEARING TYPES.

The above bearing types are some of the most common. Essentially further types of bearings usually take all or some of the characteristics of the above bearings and blend them into one design. Some of the special bearings used in steel plants are slew bearing, CARB bearing,

This bearing can take radial, axial & tilting loads. Slewing bearings are generally manufactured in very large diameters & fixed by bolting. These are found application in blast furnace clay gun & tap hole drill machine, Caster ladle turret & heavy cranes. Plain & gear (internal & external) are two varieties.

CARB Bearing

It is a single row spherical roller bearing which can take axial movement. This bearing finds application in beam blank & slab casters.

Mounting and dismounting of Bearings: -

Bearing is an extremely accurate component parts which fit together with very close clearances. The bore and the outside diameter are manufactured within close tolerance. To fit with respective supporting members – the shaft and the housing manufacturer tolerances limit must be followed.

Three basic mounting methods are used, the choice depending on factors such as the number of mountings, bearing type and size, magnitude of interferences and the possible available tools.

1) Cold mounting/dismounting: -

Mounting of a bearing without heating it first is the most basic and direct mounting method. Force of sufficient magnitude is applied against the face of the ring having the interference fit. This method is most suitable for cylindrical bore bearings up to about 70 mm bore and for tapered bore bearings up to about 240 mm bore.

For dismounting of plain bore bearings mechanical/hydraulic bearing pullers & press should be used. Direct hammering should be avoided as it may damage the bearing.

For mounting/dismounting of taper bore bearings adapter sleeve nut to be tightened/loosen by C spanner.

2) Temperature mounting: -

Temperature mounting is the technique of obtaining an interference fit by first introducing a temperature differential between the parts to be fitted. The necessary temperature differential can be obtained in one of the three ways: -

a) Heating one part (most common)

b) Cooling one part

c) Simultaneously heating one part and cooling the other.

Heat mounting is suitable for all medium and large size straight bore bearings with cylindrical seating arrangements. Normally a bearing temperature of 65^0C above shaft temperature (not to exceed 120^0C) provides sufficient expansion for mounting. As the bearing cools, it contracts and tightly grips the shaft. It is important to heat the bearing uniformly and to regulate heat accurately, since excess heat destroys a bearing's metallurgical properties (softens the bearings). Never heat a bearing using an open flame such as a blow torch. Heat mounting reduces the risk of bearing or shaft damage during installation because the bearing can be slide easily on to the shaft. Appropriate electric heat-bearing mounting devices include induction heater, ovens, hot plates and heating cones. Of these, induction heaters and ovens are the most convenient and induction heaters are the fastest devices to use.

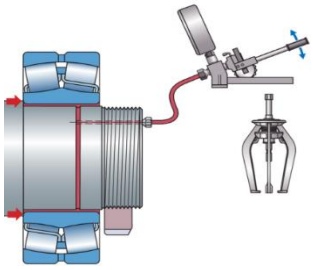
Hot oil baths have traditionally been used to heat bearings, but are no longer recommended except when unavoidable. In addition to health and safety considerations, the environmental issues about oil disposal are also involved.

In case of hot oil bath**,** both the oil and the container must be absolutely clean. Oil previously used for some other purpose should be thoroughly filtered. An insufficient quantity heats and cools too rapidly. Thus introducing the risk of inadequately or unevenly heating the bearing. It is also difficult in such a case to determine when the bearing has reached the same temperature as the oil.

Sufficient time should be allowed for the entire bearing to reach the correct temperature. The bath should cover the bearing.

3) Oil injection mounting/dismounting: -

Oil injection method allows bearings and other components with an interference fit to be fitted in a safe, controllable and rapid manner. It is based on injection of oil between interfering surfaces. The mating surfaces are separated by a thin film of oil injected under high pressure, thereby virtually eliminating the friction between them. When dismounting bearings mounted on cylindrical bore, the injected oil can reduce the required pulling forces by up to 90%. Subsequently, the physical effort required when using a puller to remove the bearing from its seating is significantly reduced. Oil Injection Method to dismount bearings mounted on tapered bore, the interference fit is completely overcome by the injected oil. The bearing is then ejected from the seating with great force, making the use of a puller unnecessary.



This method can’t be used unless provided for in the design of mounting. Special oil injection tool is required.

After mounting of bearings the axial float of the bearing should be as per OEM recommendation.

Storage and handling:

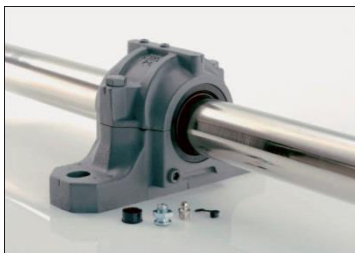
Keep bearings in their original unopened packages until immediately prior to mounting to prevent the ingress of contaminants and corrosion. Bearings are coated with a rust-inhibiting compound and suitably packaged before distribution. For open bearings, the preservative provides protection against corrosion for approximately three years. The conditions under which bearings and seals are stored can have an adverse effect on their performance. Inventory control can also play an important role in performance, particularly if seals are involved. Therefore a "first in, first out" inventory policy is recommended.

Sealed bearings, the lubrication properties of the grease with which they are filled may deteriorate with time. Lubricant deteriorates over time as a result of ageing, condensation, and separation of the oil and thickener. Therefore, sealed bearings should not be stored for more than three years

Large rolling bearings should only be stored lying down, preferably with the support for the whole extent of the side faces of the rings. If kept in a standing position, the weight of the rings and the rolling elements can give rise to permanent deformation because the rings are relatively thin walled. For the same reason, if large and heavy bearings are moved or held in a position using lifting tackle, they should not be suspended at a single point; rather a sling or other suitable aid should be used. A spring between the hook of the lifting tackle and the sling facilitates positioning the bearing when it is pushed onto a shaft.

For ease of lifting, large bearings often have threaded hole in the ring faces into which the eye bolts can be screwed. As the hole size is limited by the ring thickness, it is only permissible to lift the bearing itself or the individual ring by the bolts. When mounting a large housing over a bearing that is already in position on a shaft, it is advisable to provide three point suspensions for the housing and for the length of one sling to be adjustable. This enables the housing bore to be exactly aligned with the bearing.

BEARING HOUSING




Bearing accommodate the bearing within it & also contain the lubricant within it. Also to restrict the axial movement locating rings are mounted within it. For oil lubricated bearing

housing is different than the grease lubricated bearing housings. Bearings housings have different types of seal according to the application like felt, rubber, labyrinth etc. Bearing housing generally split type. Single piece type housing is also used in some application. Take up type bearing housings are used for adjusting the equipment. Flanged housings are find application.

Common grease lubricated bearing housings designated as SN/SNA/SNL-XXX. Oil lubricated housings are designated as SOFN/LOE-XXX.

Bearing housings are usually made of grey cast iron. Cast steel housings are used in special applications.

Some ball/roller bearings which are greased & sealed with housing ready to mount are called bearing units.

7.7 Power Transmission and Power Drives

POWER is transmitted from the prime mover to a machine, from one machine to another, or from one member of the machine to another, **by means of intermediate mechanisms called drives.** These intermediate mechanisms are necessary instead of directly coupling the machine to the prime mover, due to the **following reasons**:

1. The **optimal speeds** of the prime mover or that of the standard motors may be different from the velocities required to operate the machines. The prime mover s usually have higher angular velocities, while the operating members frequently require a large torque with relatively low velocities.

2. The **velocity of the driven machine** may have to be frequently changed or regulated, whereas the speed of the prime mover should be kept constant for its use to the full advantage.

3. In some cases, several machines may have to be operated from only one prime mover.

4. Sometimes the machines are not coupled directly to the prime mover shaft due

   to the considerations of safety, convenience and maintenance.

MECHANICAL DRIVES:

1**) by mode of power transmission:**
Transmission by

a) friction and by b) mesh

a) Transmission by **friction** may be further classified as:

- With direct contact, e.g. friction drive
- With a flexible connection, e.g. belt drives

b) Transmission by **mesh** may further be classified as:

- With direct contact, e.g. toothed and worm gears
- With a flexible connection, e.g. chain drives

The velocity ratio in toothed wheel gearing is limited only by size of the drive and in belt drive, by the minimum allowable arc of contact on the smaller pulley.

From straight shot conveying systems to heavy-duty power transmission— **belt and chain drives are integral to their reliable operation.**

"In today's world there are many factors that influence the decision on whether to use belts vs. chain drives. Many of these factors were not as important or not even considered just a few years ago. Speeds, accuracy, safety, environmental and even noise factors now take a high prominence in the modern decision-making process — along with the age-old factors such as power, direction of rotation, how many axes are to be powered by the drive device, etc. Belts have improved a lot in recent years; so have chains and their method of lubrication, we notice that belts are the preferred method in most modern applications for precision drives.

Belts are friction and can handle high speeds smoothly.

Speeds of 3,600 RPM are better suited for belts. Also, the fact that belts are a friction technology means that in the event of an overload, belts will slip and avoid system damage.

For applications in conveyor transmissions or to develop torque, chains make better sense. **"Conveyors are much slower—under 350 RPM on the driver. Chains can be used with a wide selection of sprocket ratios to achieve the desired speed.** The demand for torque gives chains an advantage due to mechanical ratios and the need for a positive drive."

Chains are excellent for a range of speeds and loads, plus chain length is easy to adjust by specifying the number of links required.

"**The chain selection process is fairly straightforward**. Key things to know are horsepower, RPM, intensity of shock load, temperature and exposure to potential corrosive conditions.

Both belts and chains will produce some sort of contaminant during their operation. Chains have grease, oil, and metal particulates. Belts will shed material over time as well.

The primary differentiation between the two is in **maintenance**. Chains require routine lubrication and more frequent replacement. In wash-down environments, the potential for spread of grease and oil contamination is elevated and the maintenance requirements skyrocket.

KEYS AND COUPLINGS:

Keys: The most common function of a key is to prevent relative rotation of a shaft and the member to which it is connected, such as the hub of a gear, pulley, disc, or crank.

An extensive use of keys is largely due to their simple and dependable design, convenience of assembly and disassembly, low cost etc. In a design of key, shaft and pulley, key is made weaker so that when excess load appears key fails and it keep shaft & pulley safe.

The major disadvantages are:
Keyways not only make the effective cross-section of the part smaller but also involve considerable stress concentration. Failures of shafts and axles are very often caused by high local stresses arising in the area of keyway. One key cannot transmit large torques. **The greater accuracy required and complicated load conditions made the development of SPLINES made integral with shaft.**
Because: they can transmit greater loads at varying speeds and impact loads. But they have uneven load distribution between the splines and they need special cutting and measuring tools.
Couplings:
They are necessary to connect one shaft to another or to couple a drive shaft to a driven shaft. Shaft couplings are used in machinery for several purposes:
Beyond the basic purpose of holding together two shafts, couplings accomplish the following:

- **Reduction of shock loads** between shafts.
- **Defense from overload.** If a system is running too hot or too fast, a major mechanical catastrophe could occur. Some couplings help prevent the need for costly repairs by disconnecting or slipping when a certain level of torque is surpassed.
- **Shifting vibration of turning parts.** Vibration is key in industrial machinery; it is like a heartbeat for the entire mechanical system. Some couplings can alter the vibration output, thereby reducing the amount of repair required.
- **Mechanical flexibility and allowance for misalignment**. Couplings can facilitate operations even when shaft misalignment and movement are present.

G couplings, also known as gear couplings, are a specific type of coupling that is often used in high-torque, high-horsepower situations. A G coupling does not typically include a grid, which is a kind of net that is sometimes located within a coupling system. Compared to universal joints, gear couplings can typically withstand more torque, while universal joints cause lower vibrations. The basic structure of a G coupling is two hubs with external and internal teeth and a one- or two-piece sleeve

Rigid couplings. These are perfect when misalignment is not an issue and when thrust loads are high.

Floating shaft assemblies. These allow shaft connections across long distances. For instance, if you have an engine that needs to operate a fan located 15 feet away and there's no place to mount supports for the connecting shaft, a floating shaft assembly is a good solution.

Slide couplings. These are used in circumstances where some axial movement is needed and thermal shaft expansion must also be accounted for.

Shear pin couplings. These are ideal in systems that tend to overload or become jammed. When the pin inside the coupling breaks, the equipment can no longer run. This prevents damage by stopping the system as soon as loads become dangerously high.

Disconnect couplings. These are similar to shear pin couplings in that they can disconnect quickly according to the situation at hand. Disconnect couplings may be used in both low- and high-speed applications.

These are only a few of the varieties of G couplings available today. One thing holds true for all of these coupling systems: They will last much longer with proper maintenance.

UNIVERSAL JOINTS

A universal joint is a positive, mechanical connection between rotating shafts, which are usually not parallel, but intersecting. They are used to transmIt motion, power, or both.

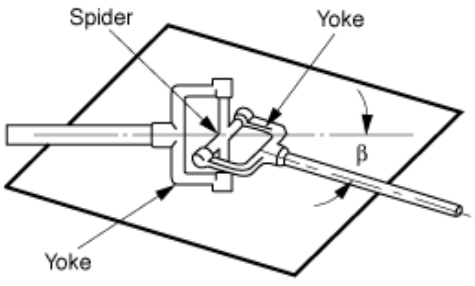


Figure 1 - Single Universal Joint

The simplest and most common type is called the Cardan joint or Hooke joint. It is shown in *Figure 1*. It consists of two yokes, one on each shaft, connected by a cross-shaped intermediate member called the spider. The angle between the two shafts is called the operating angle

A basic characteristic of the Cardan joint is the nonuniformity of motion transmission through the joint. The angular-velocity ratio between input and out put shafts varies cyclically at two cycles per revolution of the input shaft.

Oldham Coupling

Oldham couplings consist of three members. A floating member is trapped by 90 displaced grooves between the two outer members which connect to the drive shafts as shown.

Oldham couplings can accommodate lateral shaft misalignments up to 10% of nominal shaft diameters and up to 3 angular misalignments.

Lubrication is a problem but can in most applications be overcome by choosing a coupling that uses a wear resistant plastic or an elastomer in place of steel or bronze floating members.

Oldham couplings have the following advantages:

a. No velocity variation as with universal joints
b. High lateral misalignments possible
c. High torque capacity
d. Ease of dismantling

Disadvantages:
a. Limited angular displacement of shafts
b. Need for periodic lubrication due to relative sliding motion
c. Possible loss of loose members during disassembly

7.8 Technology of Repair of Steel Plant Equipments

All industrial equipments are subjected to wear and tear, stress, corrosion, ageing including mishandling and mal-operation. Systematic care and attention is required not only to keep

equipments in good working order but various technological methods are also adopted to increase the service life of equipments.

Engineering technologies such as Machining, Welding, Fabrication, Fitting & Assembly, Forging, Casting, Heat treatment, Balancing etc. are adopted for both manufacturing and repair of spares and equipments. In order to cater to these needs, Captive Engineering Shops have been established with all these facilities in our integrated steel plants.

The various facilities available with the engineering shops are :

Machine Shop :

Machining is an important method of shaping metal parts and especially of finishing them to close dimensions. Machine Shop consists of light and heavy Machining Sections equipped with lathes, planers, Horizontal and Vertical Boring machines, Gear cutting machines, Slotting machines and Grinders for manufacturing and repair of equipment spares like Shafts, Liners, Gears, rolls etc.

Simple lathe tools and operations are schematically shown below:

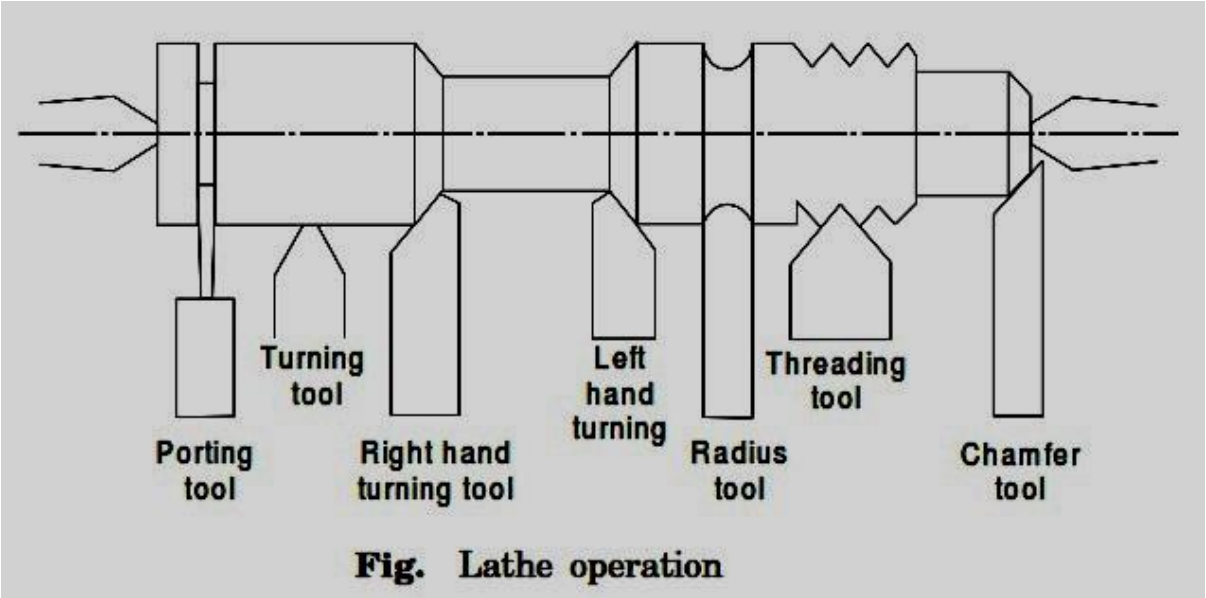
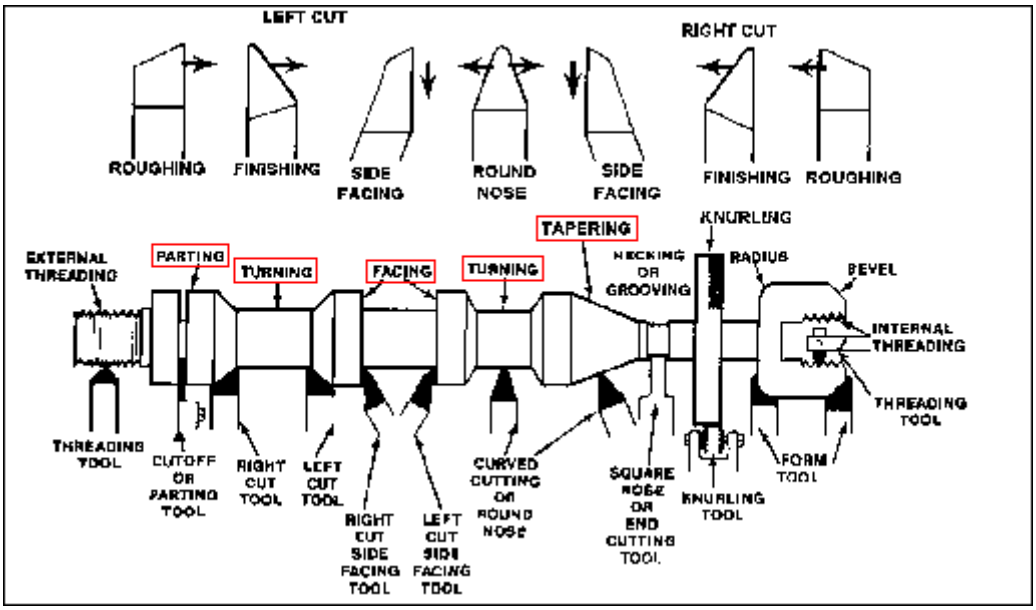


Fig. Lathe operation



Balancing

Unbalance in a rotor is the result of an uneven distribution of mass, which causes the rotor to vibrate. The vibration is produced by the interaction of an unbalanced mass component with the radial acceleration due to rotation, which together generate a centrifugal force. Since the mass component rotates, the force also rotates and tries to move the rotor along the line of action of the force. The vibration will be transmitted to the rotor's bearings, and any point on the bearing will experience this force once per revolution.

Balancing is the process of attempting to improve the mass distribution of a rotor, so that it rotates in its bearings without uncompensated centrifugal forces. This is usually done by adding compensating masses to the rotor at prescribed locations. It can be also be done by removing fixed quantities of material, for example by drilling.

Forging Shop :

Forging is a manufacturing process of shaping metal through hammering, pressing or rolling. Forging can be categorized according to temperature at which it is performed. Basically there are two types of forging:

a) Cold forging b) hot forging.

Welding / Fabrication Shop :

Welding is a materials joining process by using high heat that melts the parts together and allow them to cool causing fusion. A filler material is added to the joint to form a pool of molten material that cools to form a joint. This is a highly versatile process used for day to day and regular repair of plant equipments. The main Welding processes are :

a) Oxyfuel Gas welding – Use the heat produced by a gas flame for melting the base metal and if used, the filler metal. Pressure may or may not be applied.

b) Arc Welding – A fusion welding process wherein union of work piece is produced by melting the surfaces to be joined with the heat energy obtained from an A.C. or D.C source.

c) Resistance Welding – A group welding process, which produces union of metals with heat obtained from resistance offered by the work to the flow of electrical current through the parts being joined.

TYPES OF WELD JOINTS

There are five basic types of joints for bringing two parts together for joining. The five joint types are not limited to welding; they apply to other joining and fastening techniques as well.

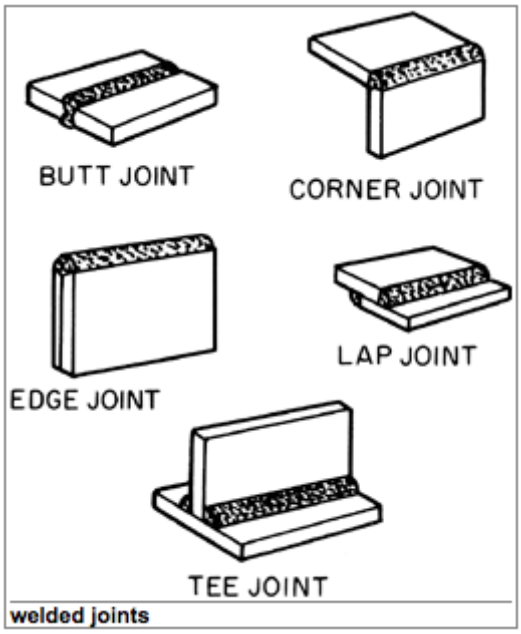
(a) **Butt joint**. In this joint type, the parts lie in the same plane and are joined at their edges.

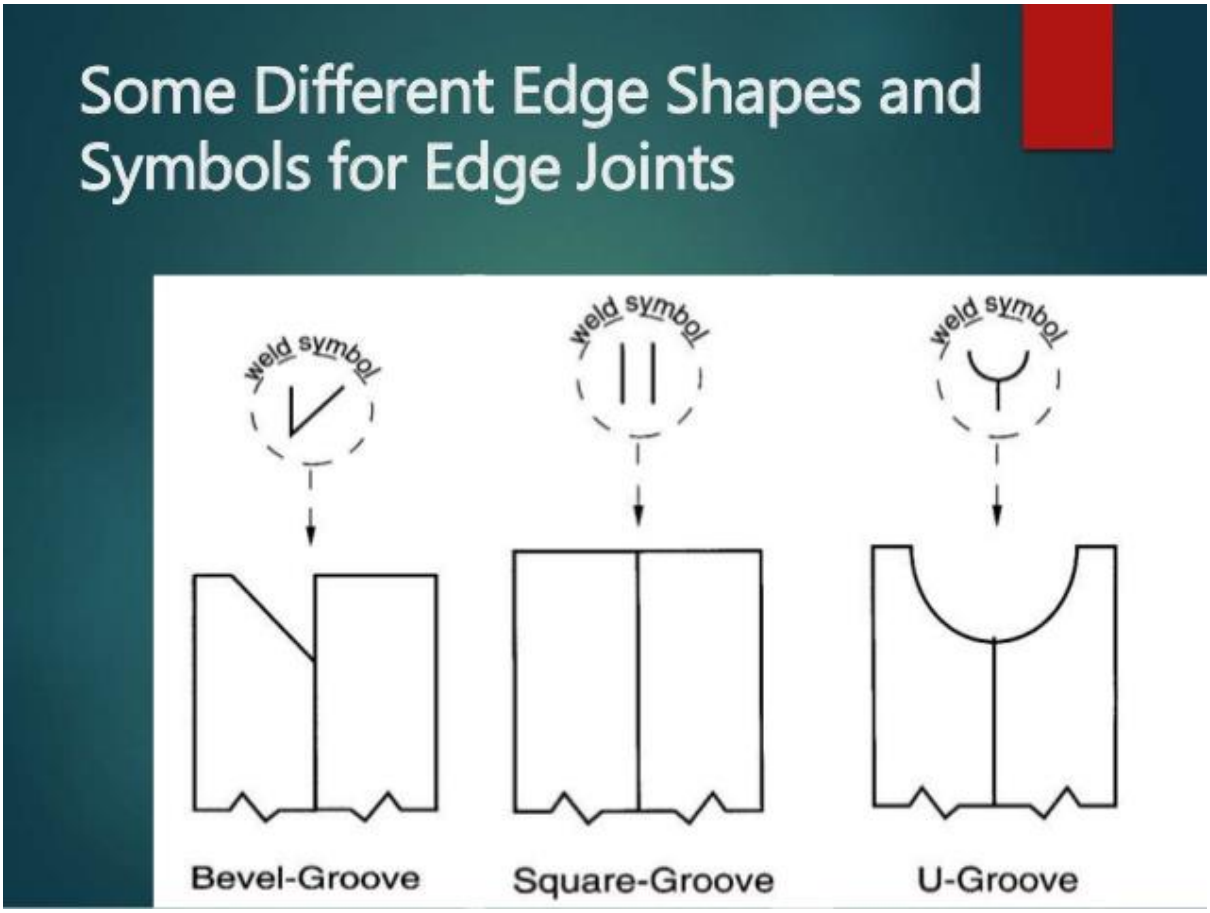
(b**) Corner joint**. The parts in a corner joint form a right angle and are joined at the corner of the angle.

(c) **Lap joint**. This joint consists of two overlapping parts.

(d) **Tee joint**. In a tee joint, one part is perpendicular to the other in the approximate shape of the letter ‘‘T.’’

(e) **Edge joint**. The parts in an edge joint are parallel with at least one of their edges in common, and the joint is made at the common edge(s).





Fabrication Shop

Welding, forming and fitting are the three basic processes used mainly for fabrication of metal structures / equipments. This is very important for repair /manufacture of steel plant equipments and structures. Fabrication Shop is generally equipped with Profile cutting machines, Plate Bending machines, Shears, Welding machines of different types, Hydraulic presses, facilities for heating & Material handling etc.

Fitting & Assembly Shop Fitting & Assembly is an important ingredient of a Repair shop activity. Small and big equipments need overhauling and repair after rendering long service.

Huge repair shops under different units of SAIL cater to such needs which are equipped with material handling facilities, Hydraulic Press, Heating arrangement, Portable machines, besides necessary tools and tackles and trained manpower.

Besides the above facilities, **Heat Treatment** section, **Hydraulics and Pneumatics** section, **Gears and gearbox repair** section, **Tool room** facility, **Instrument Section**, **Inspection**, **Chains and Sling Testing** sections, etc. have their importance in the Engineering shops of our steel plants.

Inspection & Measuring Instruments :

Inspection is an important wing of Engg. Shops where Measuring Instruments play vital role in determining dimensional accuracy of spare parts repaired / manufactured not only in these units but also in all maintenance units across the steel plant.

Some of the commonly used measuring instruments are :

- Measuring tapes of different lengths,
- Scales,
- Callipers (for inside & outside sizes),
- Slide/Vernier callipers for measuring length, inside & outside diameter, depth),
- Micrometers (for measuring outside & inside diameters),
- Dial gauges (for outside & inside diameters),
- Gear tooth verniers for measuring gear tooth vital dimensions,

etc.

Foundry & Pattern Shop :

The Shop produces ingot moulds and bottom plates vitally required for Steel Melting Shops. They also produce Iron castings, Steel castings and Non-ferrous castings to meet regular requirements of spares for steel plant.

In addition to Engineering Shops, departments like Crane Maintenance**,** Heavy Maintenance Engineering, Design, Field Machinery Maintenance, Loco Repair Shop**,** Electrical Repair Shop **come within the ambit of Maintenance Organisation.**

TECHNOECONOMICS

Maintenance costs:

Production unit of any magnitude cannot afford undesirable downtime. The concept of maintenance costs deals with two aspects:

1 Costs actually related with maintenance activities.

2 Costs related with downtime of production units.

In maintenance activities, consumable products used in carrying out maintenance have direct impact on costs. Labor costs involved in carrying out maintenance related works viz repair; reclaimations, erection, testing, inspection etc. have a direct or indirect impact on maintenance costs. The aim of maintenance crew is to:

- Control maintenance cost by salvaging, generating in house spares, proper assembly & in house repairs and reduction of downtime of equipments.
- To ensure implementation of preventive maintenance, planned maintenance, shut down maintenance, modification & design maintenance to achieve maximum equipment availability.
- Daily planning of maintenance jobs, prioritizing & execution.
- Periodic maintenance of routine, preventive maintenance activities including condition based maintenance.

7.9 Availability and Reliability of Equipments

Availability is a key performance indicator, which indicates the effectiveness of maintenance in a work. Availability can be defined as the ratio of "**NET OPERATING TIME**" to "**NET AVAILABILITY TIME**".

- Net operating time= net available time- unplanned downtime
- Net available time= total time- planned downtime

Few other important aspects to take care are:
Mean time between failures **(MTBF)**
Mean down time **(MDT)**
IN THIS WAY WE DEFINE AVAILABILITY AS RATIO OF
MTBF to **MTBF+MDT**
The **down time** in a plant comprises of:
Reporting time, inspection time, tool and man power arrangement, troubleshooting time, logistics time, actual repair time, spares procurement time, test run time, handing over time etc. So, **DOWNTIME** SOLELY DOESNOT DEPEND UPON SKILL OF WORKERS OR SEVERITY OF DEFECTS.

RELIABILITY stands for trust.
Reliability is the probability, that a machine when operated under a given condition, will produce the desired output for given period of time.
A high reliable machine may have less availability; again a highly available machine may have less reliability and high maintainability. **MAINTAINABILITY** is basically "the degree of ease in maintenance".

Total Quality Management (TQM) in Maintenance Organization:

Total quality management (TQM) is the continual process of detecting and reducing or eliminating errors in manufacturing, streamlining supply chain management, improving the customer experience, and ensuring that employees are up to speed with training. Total quality management aims to hold all parties involved in the production process accountable for the overall quality of the final product or service. Doing business in today's Global market calls for reduction in production cost with improvement on quality. Quality means "Fitness for use" or "Conformation to standards", which is the totality of features and characteristics of a product or service. With the ongoing competition in the global scenario it has become imperative to produce quality. Quality of Maintenance, like the quality of product must be designed and built into the system, process or methods of maintenance. Total quality of maintenance depends upon well-designed plans, systems and procedures, use of proper tools and test equipment, adoption of correct technical practices and the creation of conducive environment for good maintenance.
Achievement of consistent quality output over a period of time should be the main objective of the Maintenance function. Keeping this in mind, many of SAIL steel plants have adopted **ISO-9001:2000,** the Quality Hallmark of International scenario into their maintenance organizations.

7.10 Do's And Don'ts & Safety

DOS

1) Monitor oil contamination level regularly.
2) Oil tank temperature should be kept within specified limit to maintain desired viscosity and prevent damage of oil seals.
3) Be careful while opening pumps or valves, cylinders containing compressed spring.
4) Keep fire extinguishers, sand, water nearby place of cutting-welding hydraulic pipes.
5) Before starting hydraulic pumps ensure opening of suction line valve.
6) Periodically clean water filters provided in inlet line of heat exchangers.
7) Keep away from repaired pipe line flanged joints at the time of testing.
8) Always Depressurize a pressure line in steam/water/hydraulic/gas system before opening.
9) Use gas mask/ other safety appliances while working on coke oven gas pipe line/valves.
10) Always take electrical shutdown of electrically operated equipments before start of maintenance job.

DON'TS

1. Never take up maintenance work in running equipments.
2. Never open hydraulic pipe connections without depressurizing the pipeline or component to be removed.
3. Never fill oxygen in place of Nitrogen in pressure vessels such as hydro gas accumulators.
4. Never touch pump coupling without proper electrical shut down.
5. Never use cotton waste in hydraulic component or pipe line repair job.
6. Never plug drain line of pump or valve.
7. Never allow welder to do welding job with wet hand or with wet hand gloves
8. Never apply sand paper to clean spool of hydraulic valves. Lapping paste can be used to clean rusts in spools.
9. Never go alone in gas prone area/conveyor belt area./ tunnels .

SAFETY

Whenever system trouble-shooting/maintenance is carried out; safety should be the foremost consideration. So, it is better to have a systematic shutdown procedure like one given below-

1. Take proper shutdown of equipments.
2. Lower or mechanically secure suspended load.
3. Depressurize the pressure line.
4. Where ever necessary stop valves should be closed.

5. Isolate the electrical control system.
6. Drain out accumulator unit.
7. Discharge both ends of intensifier.
8. Always check and record condition of rope ladder before use.
9. Always use tested tools and tackles.
10. Always balance load on either side of rope during rope changing in cranes.
11. Use CO monitor in gas areas.
12. Use safety belts while working in height.

Chapter - 8

HYDRAULICS

8.1 Introduction

Since ancient times, hydraulics (water wheel, wind mills, Archimedes screw) were in wide use. But in those days due to lack of sealing materials, precision machining facilities, efficient working medium, the progress was zero. Nowadays it is widely used in machine tools, mobile cranes, earth moving equipments, industrial equipments, special purpose machines, hospital equipment, marine, space, aviation, robotics etc. In one word one cannot think of new equipment without the use of hydraulics.

The principles of operation of pneumatics, and hydraulics are almost same. Pneumatics can do same job with less efficiency, less accuracy, less reliability due to compressibility, water condensation, noise and dust pollution. Load capacities are also less due to low pressures involved. Hence hydraulics is slowly replacing pneumatics.

Fluid is one of the most versatile means of transmitting power and modifying motions.

BASICS OF HYDRAULICS

The science which deals with flow of fluids (under pressure) is called Hydraulics. This is divided into (a) Hydrodynamics study of fluids in motion (b)Hydrostatics study of fluids at rest .Hydrodynamic machines converts the Kinetic Energy of the fluid into mechanical energy like in water wheel , water turbine etc. In Hydrostatics (generally called as hydraulics is a misnomer) machine converts the pressure energy of the fluid into mechanical energy (Flow velocities are negligible)

NEW ERA DEFINITION:- Transmission & control of forces & movements by means of fluids is called hydraulics.

Fluids under pressure can be used for Power Transmission. Fluids means gases (air) and liquids (oil or water etc). The system which uses air as working medium is called pneumatics and which uses oil/water is called Hydraulic system. Fluid Power/ Oil Hydraulics/ Industrial Hydraulics/ Hydraulic Power Transmission are all same subjects.

Velocity of the fluid is the average speed of its fluid particles past a given point, measured in meters/second. Velocity is an important consideration in sizing the hydraulic lines that carry the fluid between components. Low velocities are desirable to reduce frictional losses and turbulence.

Laminar Flow: If fluid particles are moving parallel to the flow path, then it is called laminar flow. It is always desirable to have laminar flow, so that energy losses are minimum.

Turbulent flow:- If the path of fluid particles is haphazard and not parallel to the flow path then it is called as turbulent flow. This is not desirable and to be avoided at the design stage. Lot of energy will be wasted as heat in this type of flow.

Flow rate is the measure of volume of liquid passing through a given point in unit time. Generally measured in lpm or gpm. Flow rate determines the speed of the actuator and therefore is important for consideration of power.

Pressure: Force is the effort required to do the work. Pressure means force exerted per unit area, generally measured in psi, or kg/sq cm, or bars*.

Atmospheric Pressure

At sea level the whole column of atmospheric air exerts a weight or force of 14.7 pounds for every square inch i.e. a pressure of 14.7psi or 1.03kg/sqcm. This is called atmospheric pressure.

1 Atmospheric Pressure = 1.03 Kg/sqcm =14.7 psi = I Bar

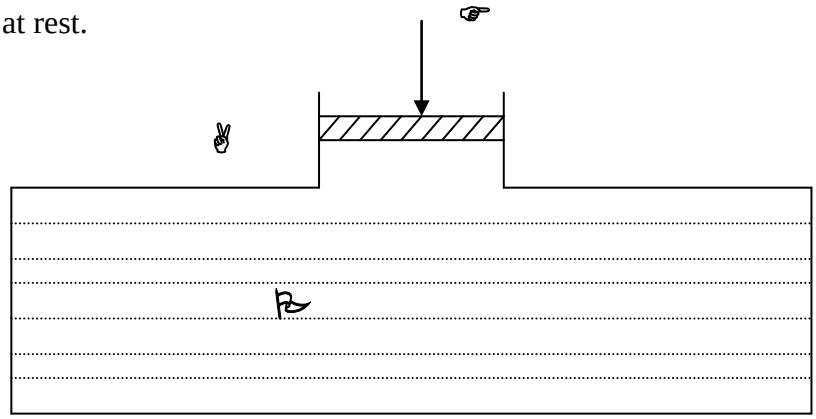
Flow & Pressure are inter-related. Flow is responsible for causing the motion of piston in a cylinder. It is the movement of hydraulic fluid caused by a difference in pressure at two points. When we open the kitchen tap the pressure difference (between the water tank at height and tap) pushes the water out, or causes the water to flow. In a hydraulic system flow is usually produced by the action of the hydraulic pump. If the pressure is not sufficient to take the load on the cylinder, it will not move.

GENERAL POINTS

1. Oil is most commonly used hydraulic fluid, because it acts as lubricant for all moving parts of hydraulic system.
2. Generally the weight of hyd. Oil is around 55-58 pounds/cubic feet. One foot of oil causes a pressure of 0.4 psi. A 10 m column of water causes a pressure of 1 kg/sq cm.
3. There must be a pressure drop across an orifice/restriction to cause flow. If there is no flow, there is no pressure drop and vice versa.
4. Force exerted by a cylinder is dependent on pressure of oil supplied & piston area
5. Speed of the cylinder is dependent on piston area and the rate of fluid flow into it.
6. Fluid velocity through a pipe varies inversely to the square of inside diameter.
7. Friction in pipes results in pressure drop
8. Air is compressible, where as oil is incompressible practically.
9. Pump only transfers the fluid. It is the resistance to flow which develops pressure.
10. It is the atmospheric pressure which is responsible for pushing of oil from tank to the suction chamber of the pump.

Pascal's Law

PRESSURE APPLIED ON A CONFINED FLUID IS TRANSMITTED UNDIMINISHED IN ALL DIRECTIONS AND ACTS WITH EQUAL FORCE ON EQUAL AREAS AND AT RIGHT ANGLES TO THEM (If a force F is applied on a piston of area A, (over a confined fluid) then it gives a pressure P = F/A. This pressure will be uniform in the entire confined fluid at rest.



ADVANTAGES OF HYDRAULIC SYTEMS

Due to limitations of other power transmission system such as electrical, electro-mechanical and pneumatic etc. hydraulic power transmission is preferred. Large forces can be transmitted to long distances with high pressure stability and quick response. There are multiple application possibilities which is suitable for use where large forces with infinitely variable speeds are to be applied in given directions. Hydraulic equipments give smooth operation for longer period with very less maintenance cost. Normally oil contamination control and leakage control may give long life to hydraulic components.

Other advantages of hydraulic system are:

1. **Highly compact**- Power to weight ratio is very high. A hydraulic motor weighs about 1/7 th of an electric motor of same power
2. **Precise control**- depending on different requirements we can get exact speed, force and position of user,
3. **Over load protection**- in case there is over load in pipe line or by the user, there is provision of relief valve set at a certain maximum pressure to take care of it,
4. **Suspension of load for long period**- by providing a pilot operated non-return valve in pipeline, load may be suspended for a longer period,
5. **Flexibility in design**- As per needs of production, scheme of hydraulic circuit may be changed easily only with addition of a few components,
6. **Easy maintenance**- its maintenance is easy. Only oil contamination control will fulfill major portion of maintenance work. For this monitoring of set parameters and inspections of pipe lines, religiously is necessary

7. **Variable Speed Controls**: - We can get infinitely variable speeds and positions as per need of users.
8. **Stalling of loads**:- The loads can be stalled to zero speed without any damage to the equipments

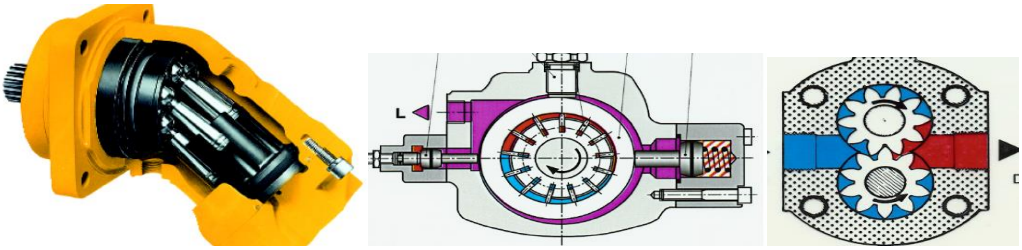
8.2 Components of Hydraulic System and their Functions

RESERVOIR: The tank which stores the working medium (oil) and supplies to pump and also takes back the return and drains oil in a hydraulic system and protects the medium from external contamination is called Reservoir. It also allows the oil to cool through its walls and allows contaminants to settle and air to separate. Generally in many cases it houses cooler, return filters, air breather(a device which allows air to move in and out of a container to maintain atmospheric pressure), level indicator, level switches (float switches). It is also provided with drain plugs to drain oil, manhole (for maintenance and cleaning purpose), baffle plates which allow the return oil to settle and cool before entering the pump through suction line.

SUCTION LINE: The pipe line connecting tank to pump generally with a shut off valve in between is called suction line. Without opening this valve, pump should not be started. Generally a hose or rubber bellows is provided in this line to isolate the vibrations of the pump.

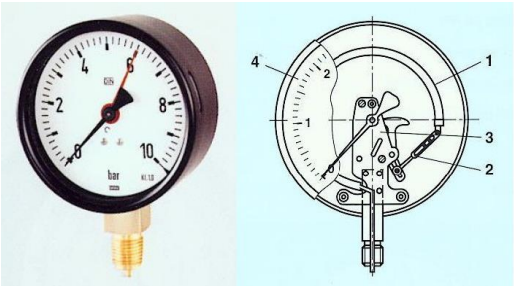
PUMP: The element which transfers oil/fluid from one point to another point or which gives flow is called pump. Pump only gives flow, but the resistance to flow develops pressure. In hydraulics only positive displacement pumps are used. In these pumps there is positive sealing between suction and delivery. For every revolution of pump, a fixed amount of oil is transferred from suction to delivery irrespective of load conditions. Practically there will be minor internal leakages which are negligible. This fixed amount of oil transferred is called Displacement of pump. The displacement when multiplied by speed of the electric motor driving the pump, gives Discharge of the pump (flow of the pump)

Centrifugal pumps (non positive displacement type) are not used in hydraulic systems. In this if delivery is closed, pressure will not build up beyond a particular limit. Safety valve is not required. Most commonly used positive displacement pumps used in hydraulics are Gear, piston and vane types are popular. A positive displacement pump should never be started without opening the suction valve. There should be sufficient oil level in tank so that air does not enter the pump. If air enters the pump, it will run with high noise and it will be damaged very soon. This is called aeration. Even though sufficient oil is there, aeration can occur due to any loose pipe joints in suction line. Pump is always followed by a relief valve (safety valve), pressure gauge, check valve and shut off valve (These are required for pressure setting and isolating).

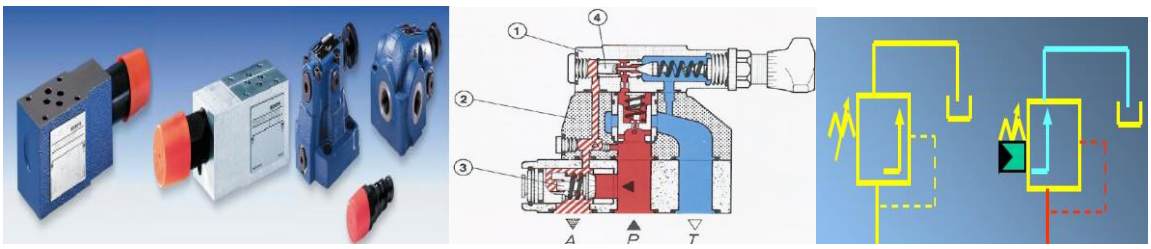


CHECK VALVE/NON-RETURN VALVE: It is a valve which allows flow in one direction only. Generally provided after the pump in most of the cases to take care of reverse rotation of pump. It is also used in many places of the circuit as a bypass etc. Check valve and non-return valve are same.

PRESSURE GAUGE: It is provided to know the pressure and for setting of various valves, pressure switches.

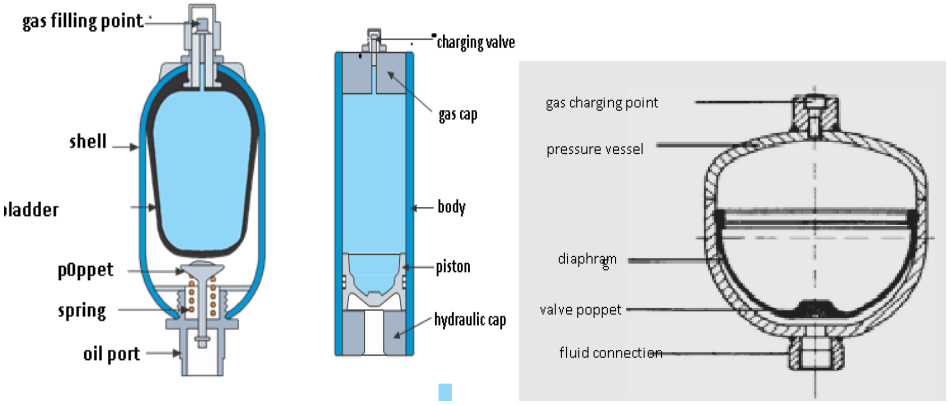


SAFETY VALVE/ RELIEF VALVE: Both are same and it is the most important component of Hydraulic system. It limits the maximum pressure in the system so that elements, hoses, cylinders, pipes etc does not burst due to high pressure. I t also protects the equipment and system from over loading. When the system pressure increases beyond the set point, the safety valve opens and relieves the excess oil to tank.



ACCUMULATOR: It is a reservoir of pressurized hydraulic fluid i.e. storage of energy by means of spring or compressed nitrogen, dead weight. It is basically a pressure vessel. No welding is allowed on this. 1. Bladder type (most commonly used) 2.Piston type 3.Dead weight type 4. Direct gas loaded type.

Nitrogen is generally used in accumulators but never use oxygen as it may result in explosion. You should never open a pressure line with accumulator in line. Always isolate/ preferably drain the accumulator before starting the job.

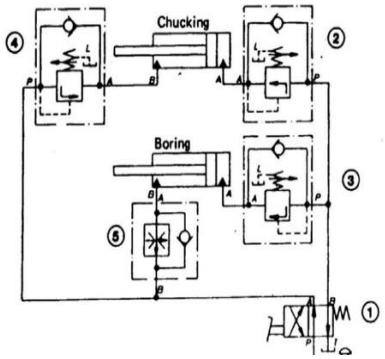


Accumulator is used (a) for smooth functioning of HS without pressure and flow fluctuations (b) as an emergency power source for essential operations in case of power failure. (c) for holding pressure for long times in a circuit (d) a big pump can be replaced by a small pump (cost & energy saving) and many other purposes.

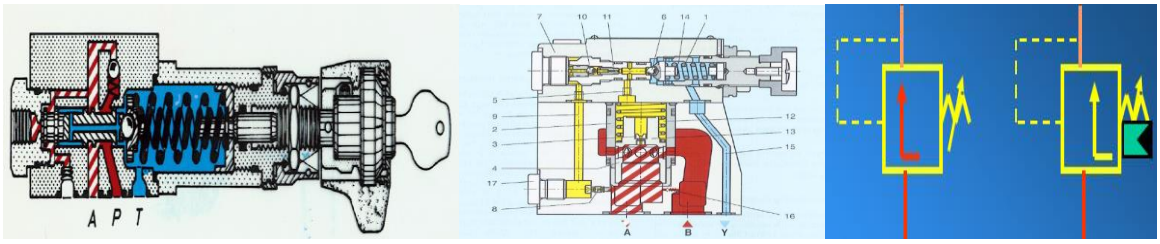
DIRECTION CONRTOL VALVES: Distributor/Master valve / DC valve are all same. If a pump supplies oil directly to a cylinder, it is not possible or convenient to control the load or to change the direction of motion. Hence a dc valve is provided in between pump and the load cylinder to stop/start /reverse the motion of the load. DC valve can be activated by a lever, cam, solenoid, pedal, pneumatic/hydraulic pressure depending on the design and requirement. Most commonly used are solenoid operated and they are having two/ three positions. If you are using a two position valve you cannot stop the cylinder in between .There are many varieties of dc valves.

FLOW CONTROL VALVES: To control the speed of the actuator /load, the amount of oil flowing into the cylinder is controlled by means of these valves. Generally these are provided before the cylinder or in branch circuits where flow is to be controlled. Simple needle/globe valve can also be used as flow control valve in some cases.

SEQUENCE VALVE: In a simple punching machine, the job is held in position by a clamping cylinder at low pressure and then a hole is punched by another cylinder at a high pressure. Now these two cylinders are always to be operated in definite sequence only. This sequence can be achieved by electrical/mechanical or by hydraulic means through a valve called sequence valve. Hydraulic sequencing is most common and versatile. A dc valve supplies oil to cylinder-1 and through a sequence valve to cylinder -2. (After cylinder -1 is operated completely, pressure will buildup and then sequence valve gets opened and oil goes to the cylinder -2 at a higher pressure. The sequence valve is tuned and set to achieve the sequence). It is almost similar to a safety valve but not same.

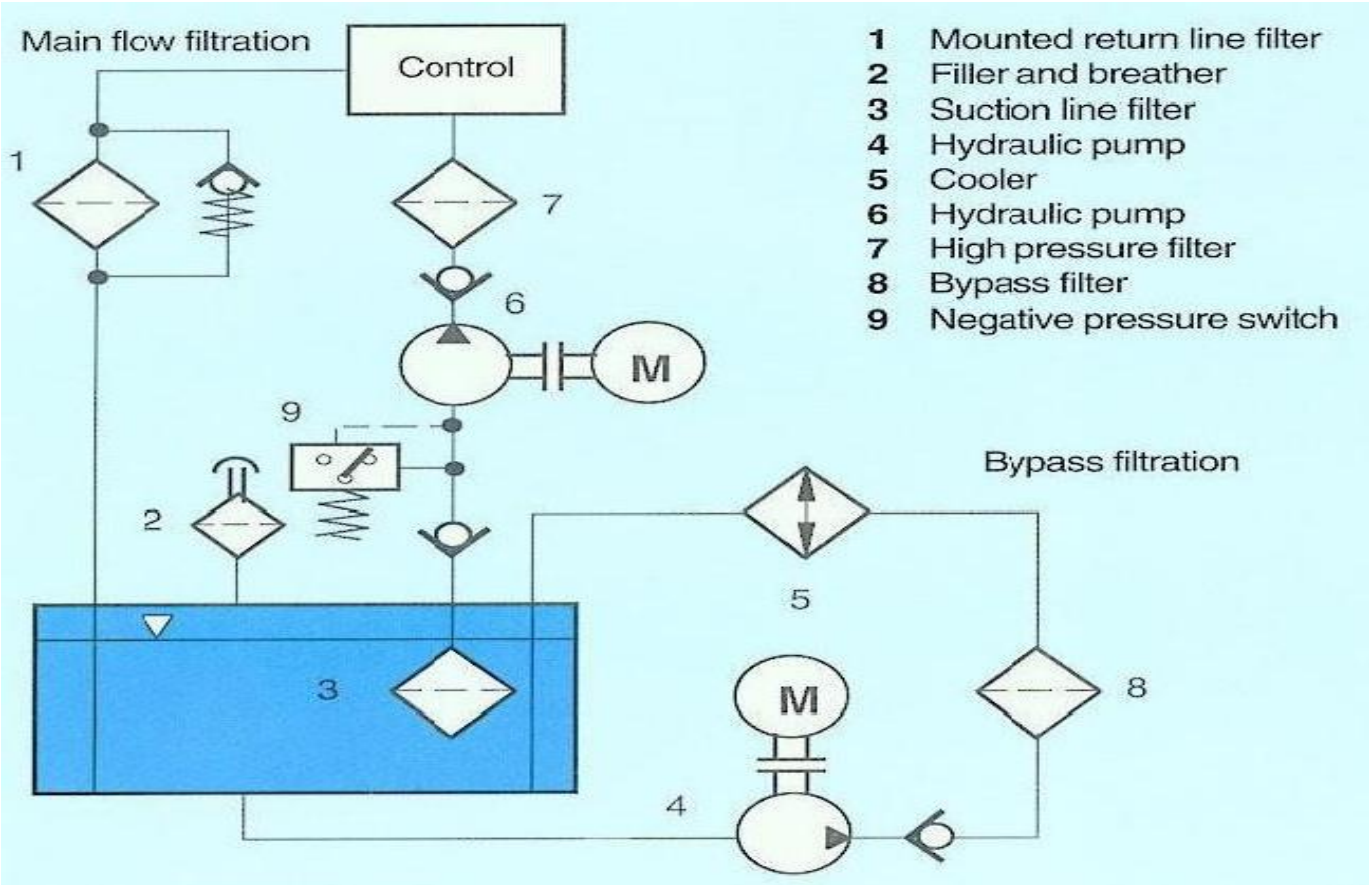


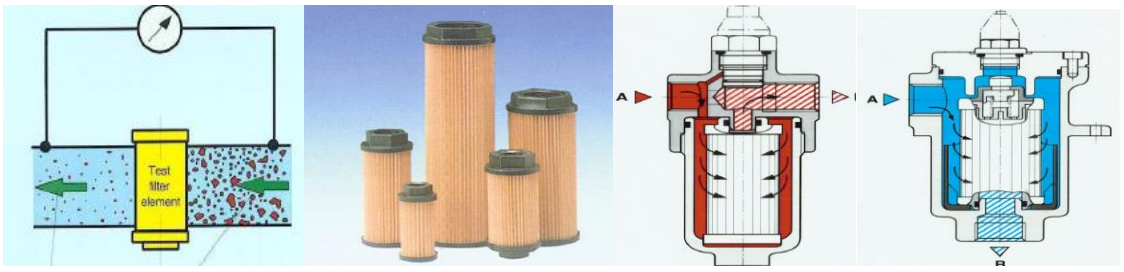
PRESSURE REDUCING VALVE: In some HS many cylinders are working at different pressures ,but a few cylinders does not require full pressure and can work at a lower pressure .Then all these selected cylinders are supplied oil at a lower pressure through a valve known as pressure reducing valve. In pressure reducing valve, the output pressure cannot go beyond a particular limit. This setting will be lower than the safety valve setting. Pressure Relief valve and Pressure Reducing valve are not same and never get confused.



FILTERS: All hydraulic elements work under close tolerances and they are precision items with mirror surface finish .Contaminants and dust are the single largest enemy of the HS as they cause malfunctioning and jamming of valves and fast wear out of elements. The contaminants are internally generated in the system and some are external to the system. Working medium is to be regularly cleaned from these contaminants. Hence oil filters are used in suction line, pressure line and return line and before an important precision valve/pump as per the need. This will improve the performance of the system. The coarse filter used in suction line of pump sometimes is called STRAINER .Hydraulic systems are most reliable, if the contamination is kept under control, and breakdowns can be minimized.

Location of filter in hydraulic system

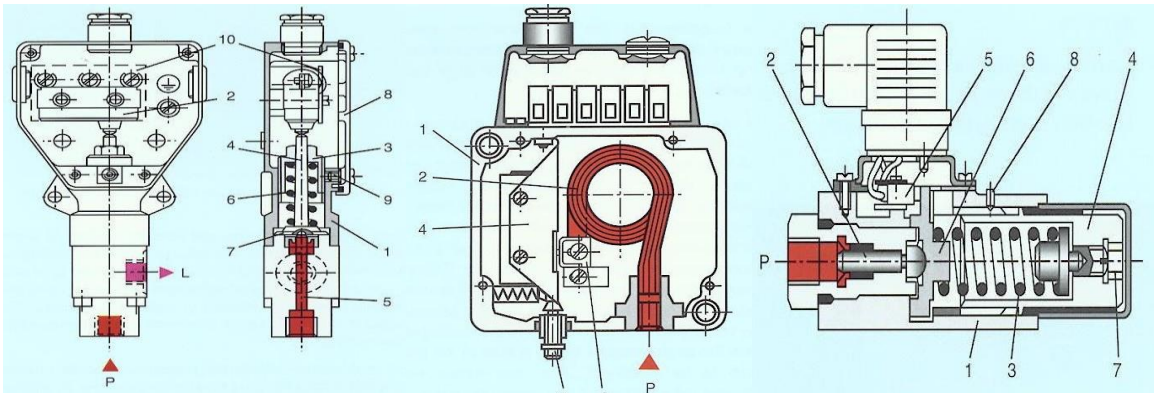




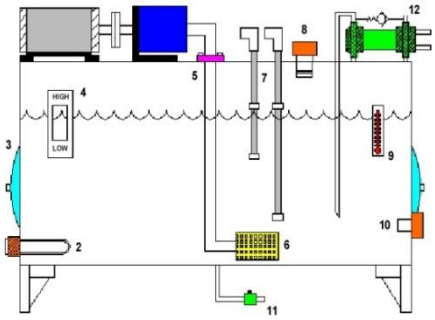
In a filter the hydraulic oil is allowed to pass through a porous medium (like clay, paper, wire mesh, synthetic fiber etc) so that the dust particles and other contaminants are retained and only clean oil goes ahead into the system.

Offline filtration (mostly portable) systems are also used for up keeping the system depending on the criticality. Electrostatic Liquid cleaners are also used nowadays. These are very simple to operate and cheap.Generally filter are provided with parallel byepass check valves to take care of clogging temporarily.

PRESSURE SWITCH: The hydraulic oil under pressure pushes a small plunger which in turn makes/breaks an electrical contact. These are provided in the system for safety and efficient operation or for achieving a particular logic sequence. Contact Manometer is a pressure gauge with electrical contacts, which does almost the same job, but they are less reliable and less robust.



LEVEL SWITCHES: Generally the reservoir is provided with low level and high level float switches, so that they give alarm of low oil level/ high level and can be used for interlocking purpose. Float switch operates due to buoyancy in oil. Generally the low level switch is interlocked with the drive of pump, so that when there is no oil due to any reason, the pump will trip or will not allow the pump to start.



FILTERING-CUM-COOLING CIRCUIT: In hydraulics, more than 80% of problems are due to contaminated fluid. Thus, it is important to keep system fluid very clean. Particulate contamination and water contamination in hydraulic fluids can have serious adverse effects on the fluids' physical and chemical properties. Oil gets heated during operation of systems. As a result, the oil needs to be cooled to retain its viscosity. Heat load for the cooler is considered as 40% (maximum) and 25% (minimum) of the kW rating of all the running main pumps. Capacity of heat exchangers are usually expressed in Kcal/hour (1kW = 860 Kcal/hour).

For the above reasons it is required to have a cooling cum filtering system which is nothing but a combination of pump, heat exchanger and the filter as a secondary system which runs parallel to the main system.Filters have already been discussed and in this part we will learn a bit about the heat exchangers

HEAT EXCHANGER: Heat exchanger is the device which takes away heat from one fluid (fluid to be cooled) and in that process heating up the cooling fluid. This can be of many types

1. **Based on working principle** a.) Recuperative Heat Exchanger
   b.) Regenerative Heat Exchanger
   c.) Evaporative Heat Exchanger

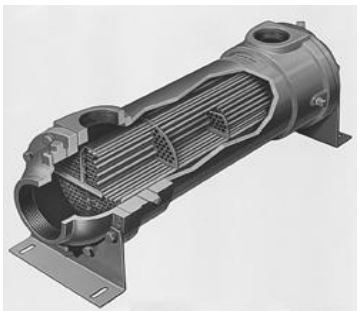
2. Based on construction

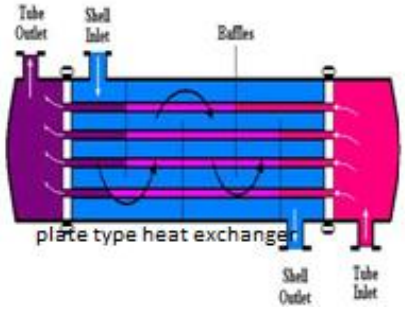
a.) Shell & tube type

b.) Plate type

i.) Brazed type

ii.) Gasketted type In general the tube in shell type heat exchangers and plate type heat exchangers are most commonly used



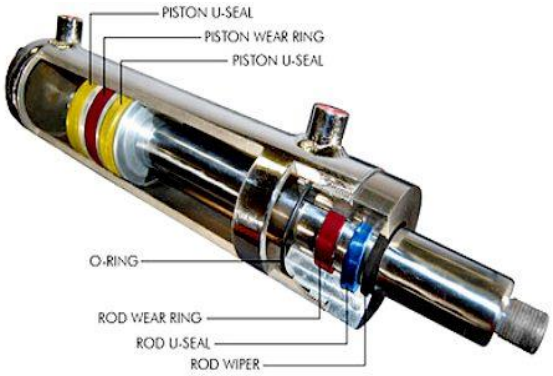


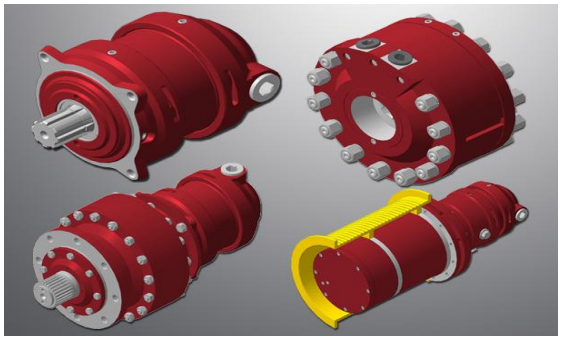
In shell and tube type heat exchangers the cooling fluid flows in the bunch of tubes placed in side the shell while the fluid to be cooled flows, in a reverse direction, in the shell, in the leftover gaps between the tubes.

In the plate type heat exchangers the two fluids flow in the opposite direction in the honecomb shaped recess between the plates which can either be seperated by brazed plates or by gasketed joints

ACTUATORS: Generally the hydraulic cylinders and hydraulic motors are called actuators. These actuators do the actual job of lifting/lowering/pushing/rotating /holding etc. Hydraulic motor replaces many applications of electric motors due to many advantages like speed control, over load protection etc. Hydraulic motors are almost similar to pumps. When these are supplied oil at pressure, they will give rotary output. Generally gear/vane /piston motors are in use.

Generally two types of Hydraulic cylinders are commonly used viz, a) Double acting cylinders, which can be used for pulling and pushing ,consists of piston , piston rod, body , covers, seals and fasteners, eye . Basically a sealed piston with rod reciprocates inside a cylindrical body under the pressure of oil. B) Single acting cylinder. These types can only push/lift a load. The single acting cylinder cannot retract due to hydraulic force. It retracts due to weight/spring/ load. Hydraulic jacks are generally single acting type.



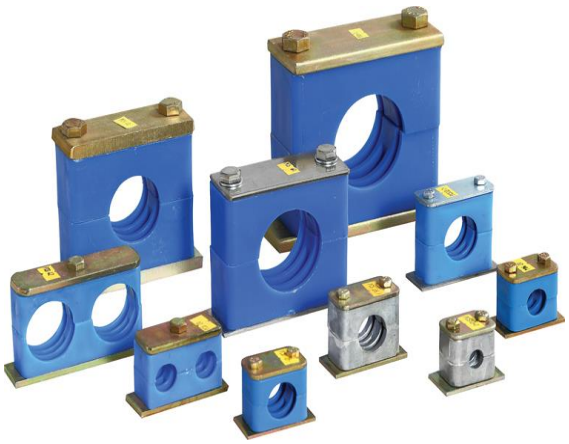


SEALS: The component which prevents the motion of the fluid in the undesired direction is called seal/packing. Can also be defined as that component that separates two fluids. The functions of the seal are a) to seal the hydraulic fluid in a closed chamber , b) Maintains pressure , c)stops dirt/water/contamination from entering the system d) separates two fluids, e) performs any combination of the above functions. In simple terms a seal stops internal or external leakages. Cost of the seal is a small fraction, but determines the efficiency of the system.

Problems associated with seals: Wastage of fluid leaked, fire hazards, slippery floor, makes equipment and products dirty, environment pollution, depleting natural resources.

Leather, cork, ropes are the oldest seals, which are widely used in the earlier days. Then natural rubbers, synthetic rubber (ELASTOMERS), PTFE, Polyurethane, POM etc are used nowadays. Seals should be handled delicately, and sharp tools should not be used.

PIPES, FITTINGS, CLAMPS: Generally pickled, flushed seamless pipes are used in hydraulic systems. For maintenance convenience and ease of laying, pipe joints are provided at suitable places. For small pipes union joints are used and in bigger pipes flange joints are used. There is large variety of pipe joints of different standards and designs are available. Care should be taken that different fittings do not get mixed up. Also while doing maintenance on fittings thread type/seat design/size etc should be matched. Otherwise lot of problems will result. Pipes should be properly clamped and supported; otherwise the joints get loosened during working due to vibrations. Pipe clamps are made of wood/ aluminium/ synthetic materials. Wooden clamps are to be avoided due to environment protection. Aluminium clamps are used where high temperatures are there. Synthetic clamps are commonly used nowadays. While laying hose pipes, the layout should be smooth, and they should not crisscross/twist/entangle and rub each other.



WORKING MEDIUM

Hydraulic power system may be operated with fluids produced from different base fluids:

1) Mineral oil. 2) Vegetable oil. 3) Synthetic oil. 4)Water

Mineral oil - Most hydraulic systems use hydraulic fluid based on mineral oil. Since base oils do not have all the characteristics which a high performance hydraulic fluid should have, different types of additives are dissolved in base oil to improve the properties

Vegetable oil - These fluids are biodegradable and so are being used more frequently in installations that are subjected to strict antipollution regulations. (food processing industry)

Synthetic oil -These fluids are most commonly used in systems where there are special demands on hydraulic fluid such as fire hazardous zones (furnace area)

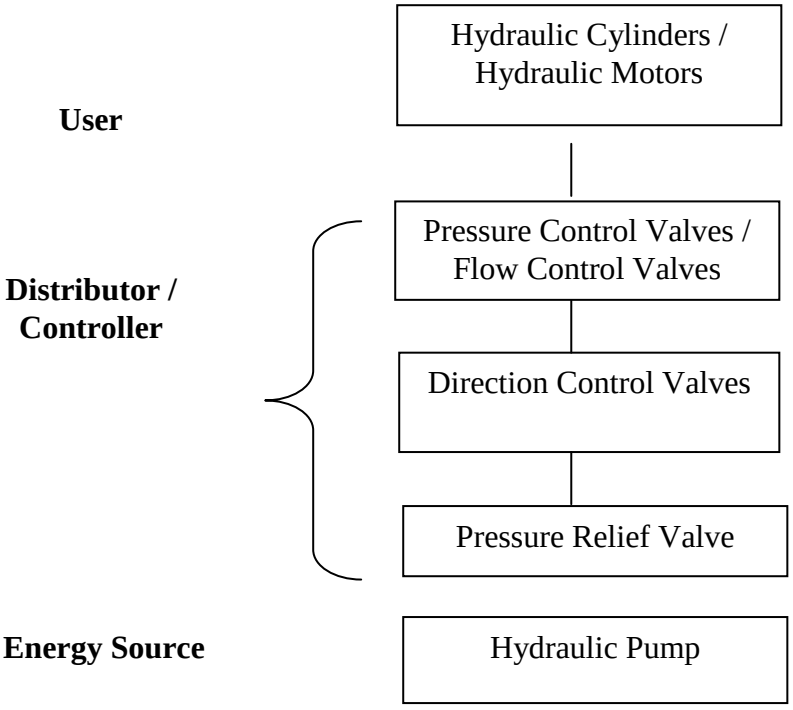
Water - Pure water is seldom used as the fluid in hydraulic system. It can be used as emulsion adding oil in it or adding water to oil.

Following are the important properties which hydraulic fluid should possess:

a) Oxidation Stability b) Protection from Corrosion c) Anti Wear d) Viscosity &Viscosity Index, (viscosity index should be high so that viscosity variation with temperature will be less) (e) Demulsibility (ability to resist formation of emulsion when mixed with water) f) Anti Foaming Characteristics, g) Thermal and high pressure stability, h) Good Lubricant, i) Compatible with Seals and Hoses, and Metals, j) High Flash Point (the minimum temperature at which oil just takes fire and do not burn continuously) & Fire points (the minimum temperature at which oil catches fire and burns continuously).

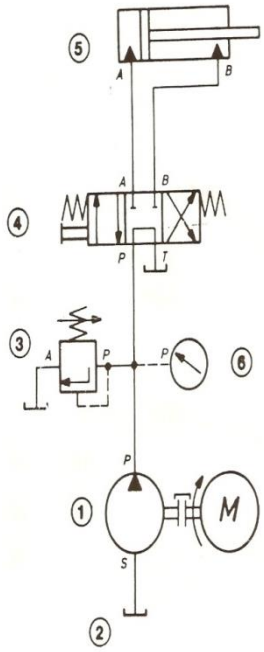
8.3 Block Diagram of Hydraulic System

Every hydraulic system can be traced back to a common basic circuit containing only the main function as under



SIMPLE HYDRAULIC CIRCUIT (OPEN CIRCUIT) (See the Fig Below)

Here we have a hydraulic system in its most simple form. A pump 1 with fixed flow sucks fluid from a tank 2 and feeds it into the system connected to it. In zero position of the manually operated direction control valve the hydraulic fluid, circulates almost without pressure from the pump to the tank 2. The dc valve is spring centered. When the dc valve 4 is operated into its left switching position, (parallel arrows) fluid reaches the piston chamber of cylinder 5. The piston rod travels outwards. The speed of the outward travel depends on the pump flow and the cylinder size (piston area). The force available at the piston rod is dependent on the piston area and the maximum system pressure. The maximum system pressure and thus the loading of the hydraulic system is set at the pressure relief valve 3. The actual pressure available, determined by the resistance to be overcome at the user, can be read at the pressure gauge 6.

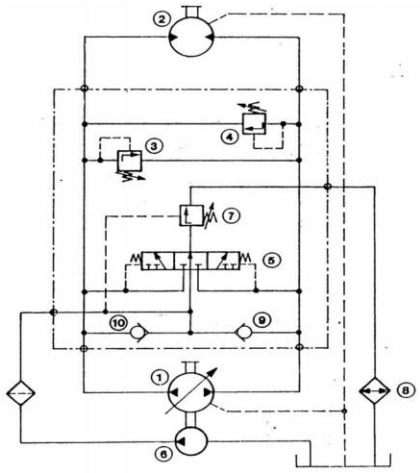


Generally pump is always followed by a Relief valve and then a NON RETURN VALVE (CHECK VALVE).

This is a typical circuit where check valve is not required. Symbol of check

SIMPLE HYDRAULIC CIRCUIT (CLOSED CIRCUIT) (See the Fig Below)

Normally the closed circuit hydraulic system is used in the places where continuous operation of the hydro motor is there



In the closed hydraulic the oil after rotating the hydro motor doesn't go to the tank back, instead it goes to the pump's suction line again. In this process the same oil is only circulating. To take care of the mixing of cool and fresh oil from the tank a booster pump is installed which is normally in tandem with the main pump. It mixes the oil from the tank to the circuit through a flushing valve.

8.4 Application of Hydraulic Systems n Steel Plants

There are various applications of Hydraulics in Steel Plants. Some of the important applications are:

1. Roll Balancing and Spindle Balancing, Hydraulic Manipulators, Slab Extractors, Walking Beam Furnaces for Heating of Slabs and Blooms, Automatic Gauge Control for controlling

thickness of plates/sheets, Rail Welding Machine, Roll Assembly Machine etc in Rolling Mills
2. Electrode Movement Control in Electric Arc Furnaces (VAD, Ladle Furnace)
3. Mobile Cranes and Earth Moving Equipment
4. Coke Oven Pusher Cars, Door Extractors and Charging Cars
5. Blast Furnace BLT Equipments, Mud gun, Drilling Machine
6. Stacker cum Reclamers in Ore Handling Plants
7. L&T Mechanism, Segments closing/ opening, Pinching Actions in CCS
8. Hydraulic Presses and Various Machine Tools etc.

8.5 Do's and Dont's, & Safety

DO'S

11) Monitor oil contamination level regularly.
1) Oil tank temperature should be kept within limit to maintain desired viscosity and prevent damage of oil seals.
2) Be careful while opening pumps or valves, cylinders containing compressed spring.
3) Keep fire extinguishers, sand, water at a nearby place of cutting-welding hydraulic pipes.
4) Before starting of any hydraulic pump first time after repairs/new installation, ensure oil is filled in pump and suction valve is also opened.(otherwise pump will be damaged)
5) Periodically clean water fillers provided in inlet line of heat exchangers.
6) Keep away from repaired pipe line flanged joints, union joints at the time of testing.

DON'TS

1. Never take up maintenance work in running equipments.
2. Never open hydraulic pipe connections without depressurizing the pipeline or component to be removed.
3. Never fill oxygen/ air in place of Nitrogen in pressure vessels such as hydraulic accumulators.
4. Never touch pump coupling without proper electrical shut down.
5. Never use cotton waste in hydraulic component or pipe line repair job.
6. Never plug drain line of pump or drain line of any valve.

SAFETY

Whenever system trouble-shooting/maintenance is carried out; safety should be the foremost consideration. So, it is better to have a systematic shutdown procedure like one given below:

a) Lower or mechanically secure suspended load.

b) Depressurize the pressure line.

c) Where ever necessary stop valves should be closed.

d) Isolate the electrical control system.

e) Drain out accumulator unit.

f) Discharge both ends of intensifier.

g) Keep fire extinguishers, sand buckets, water buckets, near the place of cutting/ welding of hydraulic pipes

h) If hydraulic oil falls into eye, thoroughly wash with water.

i) If high pressure hydraulic oil penetrates into blood through skin, it is harmfull.

Hence never expose yourself directly to high pressure jets/leakages.

Chapter – 9

Electrical and Electronics

9.1 Basic Electrical Engineering

Electric Circuits

An electrical circuit is an inter-connection of electrical elements.

Current (Alternating and Direct)

In a conductor, a large number of electrons are mobile or free electrons, moving about randomly due to thermal energy. When a conductor, e.g., a metal wire, is connected across the two terminals of a voltage source such as a battery, the source places an electric field across the conductor. The moment voltage is applied, the free electrons of the conductor are forced to drift toward the positive terminal under the influence of this field. The free electron is therefore the current carrier in a typical solid conductor.

The current **I** can be calculated with the following equation:

I = Q/t where, Q is the electric charge in coulombs (ampere seconds) and t is the time in seconds. The unit of current is Ampere (A).

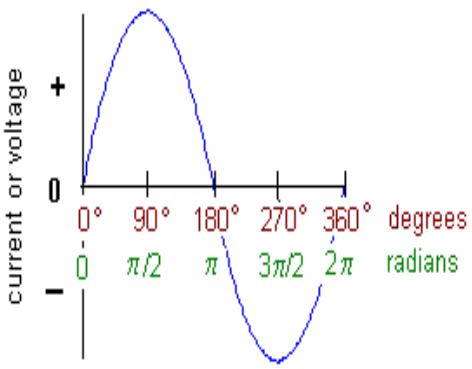
An **alternating current** (**AC**) is an electrical current whose magnitude and direction vary cyclically but in case of **direct current (DC)** the direction of the current remains constant. The AC system is widely used to supply electricicity in domestic and industrial application as it is cheaper in comparison to DC system. DC system is used for crane, hoist etc. where high starting torque is required and in control and protection system where reliability is of utmost importance, either through AC-to-DC converters (like diodes, thyristors etc.) or as a back-up source through batteries. High Voltage DC system is used for bulk transmission of power to minimize transmission loss.

The usual waveform of an AC power circuit is a sine wave. For example, the voltage in an AC circuit can be represented by the following equation:

$$\mathbf{V(t) = V_{max} \sin \omega t}$$

where, V_{max} is the amplitude or

instantaneous value, and ω is the angular frequency.



The sinusoidal waveform repeats itself after T seconds

where T is the time period of the sinusoid.

As can be seen from the above waveform,

$\omega T = 2\pi$ or $T = 2\pi / \omega$.

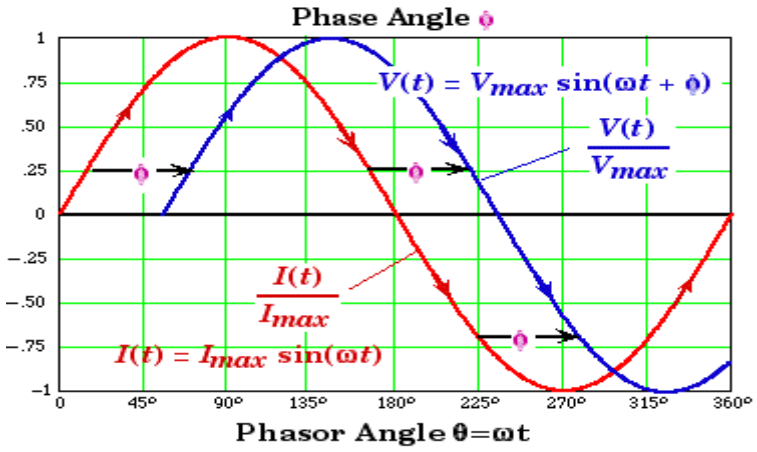
The rate of repetition of the sinusoid function is called its **frequency**, *f*, where

$$f = 1 / T \qquad \text{or, } f = \omega / 2\pi \qquad \text{or, } \omega = 2\pi f$$

Frequency is measured in Hertz (Hz), where 1 Hz = 1 cycle per second. The AC power supply frequency in India is 50 Hz. Therefore, the time period of the sinusoidal curve is T=1/f or T= 1/50 or T= 20 miliseconds.

Phase Angle

Both current and the voltage oscillate sinusoidally, with the same frequency, in an AC circuit, but they are out of phase with each other.



The angle by which the sine curve of the voltage in a circuit leads or lags the sine curve of the current in that circuit is called the phase angle Ø. If Ø is positive the voltage leads the current.

Voltage (or Potential Difference)

Voltage (or potential difference) is the difference of electrical potential between two points of an electrical or electronic circuit. The unit of voltage is volt (V).

Electrical potential difference is the ability to move electrical charge through a resistance.

Voltage is usually specified or measured with respect to a stable and unchanging point in the circuit known as ground (earth) or neutral.

Resistance is defined as the property of a conductor to oppose or restrict the flow of electricity (or electrons) through it. Metals, acid solutions and salt solutions are very good conductors of electricity. Poor conductors of electricity like Bakelite, mica, glass, rubber, paper, PVC and dry wood offer relatively greater resistance to the flow of electrons. Hence they are used as insulators or insulating materials.

Ohm's law states that *the ratio of potential difference or voltage (v) between two points on a conductor to the current (i) flowing through the points is a constant*.

this constant is the resistance (r) of the conductor. ohm's law can be stated by the following equation:

V / I = R **or,** **V = I x R.** The unit of resistance is ohm (Ω).

The resistance of a conductor is defined by following equation :

R = ρ(l/A) where, 'ρ' is the specific resistance value, 'l' is the length and 'A' is the cross section area of the conductor.

Power and Energy in electric circuits

The power (P) consumed by a circuit element (say a resistor R) through which a current I is flowing is

P = V x I The unit of electrical power is watt (W).

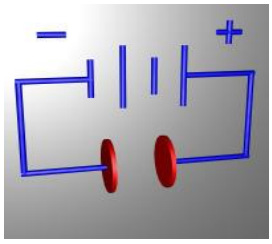
Electrical Energy consumed over a period of time t is expressed as,
E=V x I x t or **E= P x t** The unit of electrical energy is watt-hour (Wh). The common unit of consumption of electricity (i.e. energy) is kWh.

Energy is measured by energy meters which take the supply voltage (V) and line current (I) as input. In high voltage systems, voltage or potential transformer output and current transformer output are used in the energy meter to get the energy consumed.

Capacitor and Capacitance

A **capacitor** consists of two conducting surfaces, separated by a layer of an insulating medium (or dielectric). The conducting surface may in the form of either circular, rectangular, spherical, or cylindrical shape. The capacitor stores electrical energy by electrostatic stress in the dielectric. Please note that the term condenser is wrongly used for a capacitor, because it does no condense energy.

After resistors, capacitors are the most widely used component in electrical circuit. They are used in electronics and communication (e.g., tuning circuits of radio receivers), computers (as dynamic memory), and power systems (for power factor correction).



A parallel plate capacitor is shown in the adjoining figure, connected to a battery. The potential difference across the plates of the capacitor is equal to the battery voltage, thereby charging the capacitor. However due to the inherent nature of

a capacitor, it opposes the deposition of charge on it. Gradually a positive charge + Q is deposited on the positive plate of the capacitor with a negative charge – Q on its negative plate. A capacitor in an electrical circuit opposes any change in voltage magnitude in the circuit.

Capacitance

Capacitance (C) is the property of the capacitor to store electric charge. It is defined as the amount of charge required to create a unit potential difference between the plates.

$C = Q / V$

i,e., capacitance is the charge required per unit potential difference.

The unit of capacitance is Farad (F). A farad is however too large for practical purposes. Capacitance is usually expressed in smaller units like microfarad ($\mu F=10^{-6}$ F), nanofarad ($nF=10^{-9}$ F), or picofarad ($pF=10^{-12}$ F).

The capacitance, C, is an inherent characteristic of the capacitor and does not depend on Q and V. It depends on the physical dimensions of the capacitor. For the parallel plate capacitor, the capacitance is

$$\mathbf{C = \varepsilon A / d}$$

where, **ε** is the permittivity of the dielectric; **A** is the cross-sectional area; and **d** is the distance between the plates.

Like resistance in an electric circuit capacitance offers capacitive reactance (**Xc)** in ohm,

$$\mathbf{Xc = 1/ \omega c \ \ or, Xc= 1/2\pi \ } \boldsymbol{fc}$$

Types of Capacitors

Capacitors can be classified

1. depending on the type of construction as fixed or variable; or
2. depending on the dielectric material as polyester, mica, polystyrene, or electrolytic.

Inductor and Inductance

While capacitors store energy in their electric field, inductors store energy in their magnetic fields. Inductors are used in power supplies, transformers, radios, TVs, radar, and electric motors. Common applications for inductors are as coils or chokes. In power systems inductors are used in relays, delay timers, sensing devices, etc. In telecommunications, they are used as sensing heads, in telephone circuits, and loudspeakers.

An inductor consists of a coil of conducting wire. The voltage across an inductor is given by

V = L di /dt where L is the inductance.

Inductance is the property whereby an inductor exhibits opposition to the current flowing through it. Inductance is expressed in henrys (H).

The inductance depends on the physical dimension and construction of the inductor. For a solenoid

$$L = N^2 \mu A / l$$

where N = number of turns; l = length; A = cross-sectional area, and μ = permeability of the core.

Like resistance in an electric circuit inductance offers inductive reactance ($X_{L)}$ in ohm,

$$X_L = \omega L \text{ or, } X_L = 2\pi fL$$

Types of Inductors

Inductors can be classified depending on the

1. type of construction as fixed or variable; or
2. core material as iron, steel, plastic, or air.

9.2 Basic Principles of Transformer

WHAT IS A TRANSFORMER?

A **transformer** is an electrical static device that efficiently changes alternating voltages from one voltage level to another using principle of electromagnetic induction (EMI). The alternating flux produced by the primary winding links with the secondary winding and induces the alternating voltage in the secondary winding depending on the ratio of number of turns in the two windings.

Transformers are at the core of a power distribution network. They work at very high efficiencies (95 to 99 per cent). A transformer is mostly used to step-up or step-down the system voltage as required.

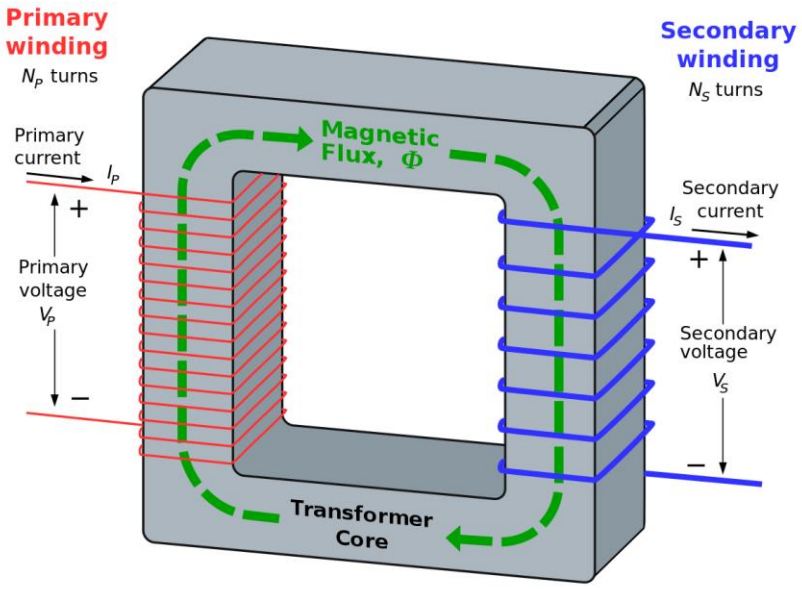


Figure-1 shows ideal single phase transformer

Basic components of an ideal transformer:

- Magnetic core of laminated iron, Generally CRGO (Cold rolled grain Oriented) grade steel.
- The core is laminated to reduce Hysteresis loss and Eddy current loss.
- Primary and the secondary windings which are placed around Core.
    - Winding that is connected to the source is known as the primary winding and the one connected to the load is the secondary winding.
    - Winding carrying High voltage is HV or HT winding and winding carrying Low voltage is called LV or LT winding.

Turns Ratio (k)

Turns Ratio (k) = Primary Voltage / Secondary Voltage

= Number of Primary Turns / Number of secondary turns

= Secondary Current / Primary Current

TAPS IN TRANSFORMER WINDING

Taps are brought out normally from Low current aka high voltage windings to the tap changing switch. The tap points are brought out from the middle of the windings to keep the magnetic balance and usually correspond to ±1.25%, ±2.5% and ±5.0%. If the primary voltage is abnormally low for most of the time, it is advisable to go for -10% tapping.

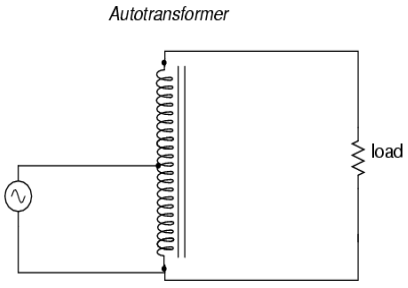
A typical OLTC is shown in Figure-1 where currently tap 2 is selected and current is going from tap-2 via diverter switch in position A to neutral terminal. When tap-3 is selected diverter switch changes position from A to B and the current path completes from tap 3 to diverter switch in position B to neutral terminal

Tap changers are mainly of 2 types OFF-LOAD type generally used in distribution transformers and ON-LOAD type generally used in power transformers where frequent tap changing is required. The former (i.e. OFF LOAD TC) is operated after switching OFF the transformer and the latter (i.e. ON LOAD TC) is changed without interruption of power supply.

OTHER TRANSFORMERS USED IN STEEL PLANTS

Other than conventional two winding power and distribution transformers there are other transformers used in steel plants which are:

They can be classified as follows:



a. **Auto Transformers:** In an autotransformer the secondary voltage is derived from the tapped primary winding. It is used for transfer of large amounts of power, where electrical isolation is not required.

b. **Power Transformers:** Used to step-down (EHV to HV) or step-up (HV to EHV) voltage for bulk

transfer of power at switchyards. They may have either one or two secondary windings. These transformers generally show high efficiency at higher loadings

c. Distribution Transformers: Used to step-down HV to LV at sub-stations near loads. These transformers show high efficiency at low loadings.

d. Thyristors (Converter / Inverter) Transformers: Used for drives which are in turn used to drive AC motors via AC-to-DC (or vice versa) conversion or in thyristorized control systems like VVVF drives. These transformers have inverter grade insulation to sustain steep switching jerks.

e. Furnace Transformers: Used in arc furnaces where HV typically of grade 33kv is stepped down to LV at around 440V to generate very high operating currents of the order 20-30kA used for arcing, mainly for "secondary steel-making". Here voltage variation is done by an On-Load Tap Changer (OLTC). This operates generally 70-80 tines in a day.

f. Instrument Transformers: CT or current transformer and PT or Potential transformer fall in this category and are used for protection and metering. These are very small in size as compared to conventional transformers and are basically used to tell the amount of current or voltage flowing in the network.

g. Isolation Transformers: Their primary and secondary voltages are of same ratio and they are used to provide electrical isolation so that a downstream fault does not affect other components of the system. Generally they are used before lighting loads so that primary circuit's system surges do not get reflected into secondary circuit where lighting load is attached thus protecting the load from getting fused.

h. Impedance Matching Transformers: Used to match the load resistance to the source resistance, for example to connect a loudspeaker to an audio power amplifier. The speaker's resistance is only a few ohms while the internal resistance of the amplifier is several thousand ohms. For impedance matching, the required number of turns of the transformer is selected.

i. Capacitance Voltage Transformer :

Wound type Voltage Transformers above 66 KV becomes too bulky & expensive. Above 66 KV Capacitor Voltage Transformers are used. The line to ground voltage is divided by use of calculated number of high voltage capacitors in series. The voltage across the ground end capacitor is applied to a small wound potential transformer with atleast two secondary windings having output $110V/\sqrt{3}$

INSULATING MEDIUM IN TRANSFORMERS

Depending on the insulating medium, transformers are also classified as

i. Mineral oil-filled
ii. Synthetic liquid-filled

iii. Dry types.

Power and furnace transformers are mineral oil-filled, which acts as an insulating medium as well as coolant.

Distribution and thyristor transformers have all three insulating media. There are two types of dry-type transformers – cast-resin and vacuum pressure impregnated. However absence of an external coolant / insulating medium limits their capacity (up to 15 MVA).

Synthetic liquid-filled transformers have excellent insulating properties and do not degrade like mineral oil. However these liquids (and their fumes) are harmful to human beings. Hence such liquids are **banned worldwide**. However, we still have a large number of liquid-filled filled transformers installed during the late 1950s to mid-1980s, which are gradually being phased out by dry-type transformers.

Dry Type Transformer

9.3 Basic Principles of Motor

WHAT IS MOTOR?

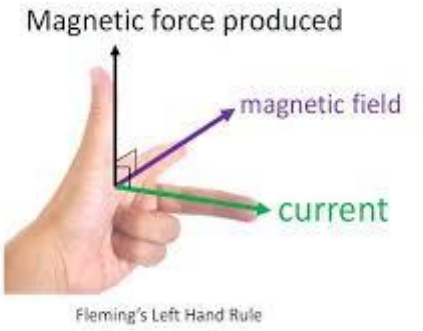
A **motor** is nothing but an electro-mechanical device that converts electrical energy to mechanical energy. In simple words we can say a device that produces rotational force is a motor.

MOTOR PRINCIPLE

The very basic principal of functioning of an **electrical motor** lies on the fact that force is experienced in the direction perpendicular to magnetic field and the current, when field and current are made to interact with each other.

Magnitude is given by

F=B x **I** x **L**



Fleming's Left Hand Rule

Where,

F is the Force exerted (Newtons)

B is the magnetic field (weber/m^2).

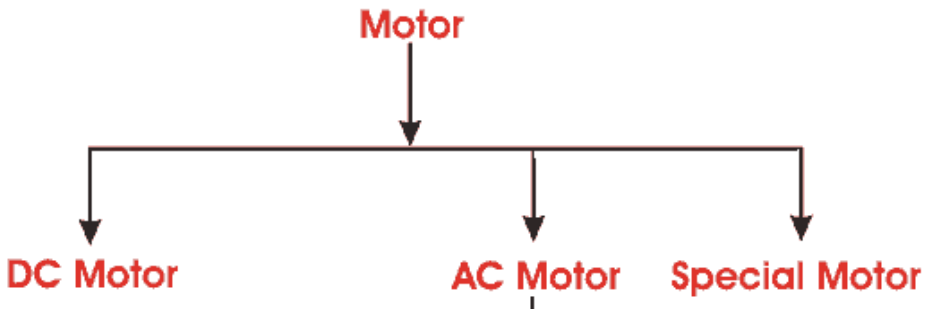
I is the current (Amperes), and

L is the length of the coil (meter).

The direction of mechanical force is determined by Fleming's Left-hand rule as shown. The force, current and the magnetic field are all in perpendicular to each other

CLASSIFICATION OF MOTORS

Motors can be classified majorly on the basis of type of supply it is using to rotate its rotor. Following diagram shows broad classification of motors.

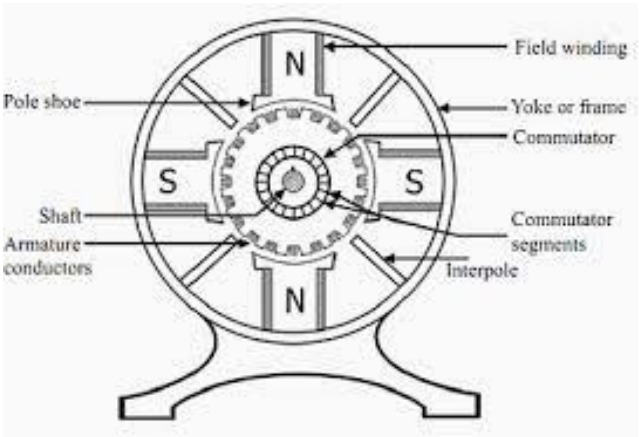


DC MOTOR

The motors, practically used in industrial applications are multi pole D.C. Motor. When its field magnets are excited and its armature conductors are supplied with current from the supply mains, they experience a force tending to rotate the armature. Because all conductors experience a force which tends to rotate the armature, the forces collectively produces a driving torque which sets the armature rotating. It has following parts:

BASIC CONSTRUCTION OF DC MOTOR

A. YOKE:



The outer frame of the motor is called yoke that serves two purposes.

1. It provides mechanical support for the poles and act as a protecting cover for the whole machine.

2. It carries the magnetic flux produced by the poles.

B. POLE CORES AND POLE SHOES (FIELD):

The field magnets consists pole cores and pole shoes. The pole shoes serve two purposes

1. They spread out the flux in the air gap and also, being of larger cross section, reduce the reluctance of the magnetic path

2. They support the exciting coils (or Field Coils).

The field coils or pole coils, which consists of copper wire or strip, are former-wound for correct dimension. When current is passed through these coils, they magnetise the poles which produce the necessary flux that is cut by revolving armature conductors.

C. ARMATURE CORE:

It houses the armature conductors or coils and causes them to rotate and hence cut the magnetic flux of field magnets. In addition to this, its most important function is to provide a path of very low reluctance to the flux through the armature from a North Pole to a South Pole.

It is cylindrical or drum-shaped and is built up usually circular sheet steel discs or laminations. The laminated core is made up of high silicon steel to reduce Hysteresis loss and laminated design reduces Eddy Current loss in the armature.

D. COMMUTATOR AND BRUSHES:

The function of commutator is to facilitate collection of current from the armature conductors. The brushes, whose function is to collect current from commutator, are usually made of carbon and are of the shape of a rectangular block. These brushes are housed in brush holders which hold down brushes on to the commutator by a spring. A flexible copper pigtail mounted at the top of the brush conveys current from the brushes to the holder.

TYPES OF DC MOTOR AND ITS CHARACTERISTICS

Based on the type of Field excitation being used motors are classified as following

The field of DC motors can be:

1. Permanent magnet (Permanent magnet stator),
2. Electromagnets connected in series (Wound stator),
3. Shunt (Wound stator), or
4. Compound (Wound stator).

1. PERMANENT MAGNET MOTORS

The permanent magnet motor uses a magnet to supply field flux**.** Permanent magnet DC motors have excellent starting torque capability with good speed regulation. A disadvantage of permanent magnet DC motors is they are limited to the amount of load they can drive.These motors can be found on low horsepower applications.

Another disadvantage is that torque is usually limited to 150% of rated torque to prevent demagnetization of the permanent magnets.

2. SERIES MOTORS

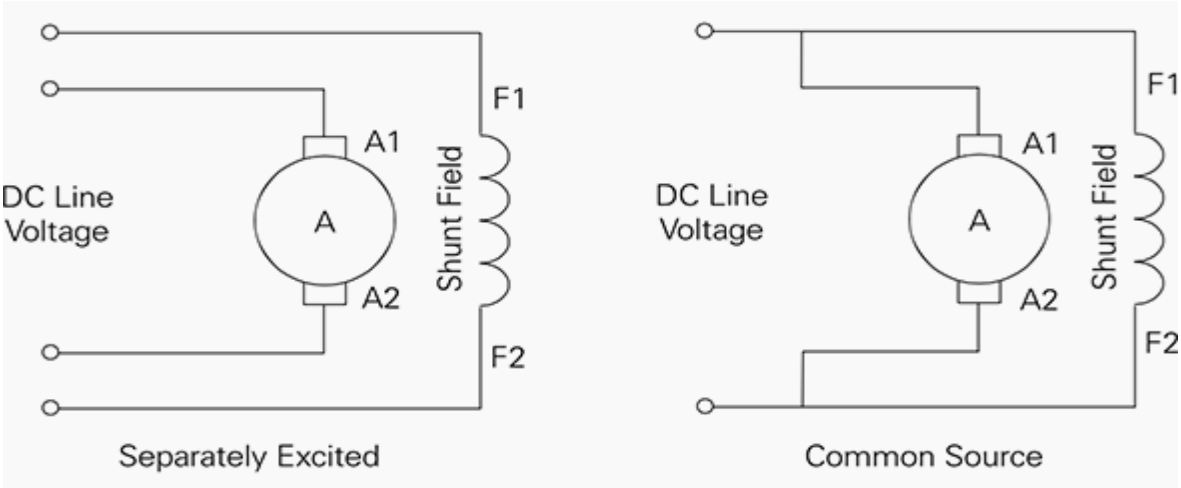
In a series DC motor the field is connected in series with the armature. The field is wound with a few turns of large wire because it must carry the full armature current.

A characteristic of series motors is the motor develops a large amount of starting torque. However, speed varies widely between no load and full load. Series motors cannot be used where a constant speed is required under varying loads.

Additionally, *the speed of a series motor with no load* increases to the point where the motor can become damaged. Some load must always be connected to a series-connected motor.

Series-connected motors generally are not suitable for use on most variable speed drive applications

3. SHUNT MOTORS



In a shunt motor the field is connected in parallel (shunt) with the armature windings. The shunt-connected motor offers good speed regulation. The field winding can be separately excited or connected to the same source as the armature

An advantage to a separately excited shunt field is the ability of a variable speed drive to provide independent control of the armature and field.

The shunt-connected motor offers simplified control for reversing. This is especially beneficial in regenerative drives

4. COMPOUND MOTORS

Compound motors have a field connected in series with the armature and a separately excited shunt field. The series field provides better starting torque and the shunt field provides better speed regulation.

However, the series field can cause control problems in variable speed drive applications and is generally not used in four quadrant drives.

In summary

SERIES WOUND
• Field and armature windings are in series. • Highest starting torque. • Poor speed regulation. Over-speeding if used at no load or light load.

SHUNT WOUND
• Field and armature windings are in parallel. • Medium starting torque. • Good speed regulation. • Can be used from low to rated loads.

COMPOUND WOUND
• One field winding is in series and other in parallel with armature. • Performance optimized to suit applications. • Better than series wound. • Can be used from low to rated loads.

Normally in Industries where speed variation and control are desired, a separately excited type of DC motor is used where instead of connecting armature and field in parallel (as in case of a shunt motor),they are separately excited, meaning field and armature winding are provided with supply from separate sources.

SUMMARY OF APPLICATIONS:

Type of Motor	Characteristics	Applications
Shunt	• Approximately constant speed • Adjustable speed • Medium Starting Torque	➢ For driving constant speed line shafting. ➢ Lathes ➢ Centrifugal pumps ➢ Blowers and Fans ➢ Reciprocating Pumps
Series	• Variable speed • Adjustable varying speed • High Starting toque	➢ For traction work i.e. electric Locomotives ➢ Rapid Transit systems ➢ Trolley cars, conveyors
Cumulative compound	• Variable speed • Adjustable varying speed • High Starting toque	➢ For intermittent high starting torque loads ➢ Shear and Punches ➢ Elevators, Conveyors

AC MOTOR

As regards to the principle of operation AC Motors are classified into following groups.

- Synchronous motors
- Asynchronous motors (Induction Motor)
- Squirrel cage
- Slip-ring

INDUCTION MOTOR

In DC motor, the electrical power is conducted directly to the armature (i.e. rotating part) through brushes and commutator. Hence in this case DC motor can be called as *conduction motor.*

However in AC motors, the rotor does not receive electric power by conduction but by induction in exactly the same way as the secondary of a transformer receives its power from primary. That is why such motors are called as Induction motors. And electrical equivalent diagram of transformer and induction motor are same

The poly phase induction motor is extensively used for various industrial applications. It has following advantages and disadvantages.

Advantages:

1. It has very simple and extremely rugged construction (Especially squirrel cage Type).
2. Its cost is low and it is very reliable.
3. It has sufficiently high efficiency. In normal running condition, no brushes are needed, hence frictional loses are reduced. It has a reasonably good power factor.
4. It requires minimum maintenance.
5. It starts up from rest and needs no extra starting motor and has not to be synchronized.
6. Its starting arrangement is simple especially for squirrel cage type motor.

Disadvantages:

1. Its speed cannot be varied without sacrificing some of its efficiency.
2. Just like a DC shunt motor, its speed decreases with increase in load.
3. Its starting torque is somewhat inferior to that of a DC shunt motor.

BASIC CONSTRUCTION

The AC induction motor comprises 2 electromagnetic parts:

- Stationary part called the stator
- Rotating part called the rotor, supported at each end on bearings

The stator and the rotor are each made up of:

- An electric circuit, usually made of insulated copper or aluminum, to carry current
- A magnetic circuit, usually made from laminated steel the core used for these are , to carry magnetic flux

AC Motor uses electrical energy in AC form to convert it into mechanical energy.

SYNCHRONOUS MOTOR

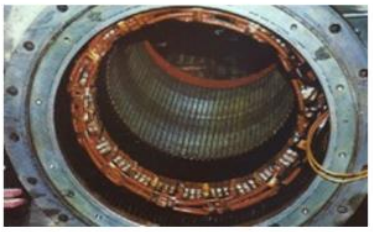
Synchronous Motors are three-phase AC motors which run at synchronous speed, without slip. A **synchronous electric motor** is an AC motor in which, the rotation of the shaft is synchronized with the frequency of the supply current.

Synchronous motors contain multiphase AC electromagnets on the stator of the motor that create a magnetic field which rotates in time with the oscillations of the line current. The rotor with permanent magnets or electromagnets turns in step with the stator field at the same rate and as a result, provides the second synchronized rotating magnet field of any AC motor. A synchronous motor is only considered doubly fed if is supplied with independently excited multiphase AC electromagnets on both the rotor and stator

BASIC CONSTRUCTION

Stator

- The stator of a synchronous machine carries the ***armature*** or ***load*** winding which is a ***three-phase winding*** .
- The **armature winding** is formed by interconnecting various conductors in slots spread over the periphery of the machine's stator. Often, more than one independent three phase winding is on the stator. An arrangement of a three-phase stator winding is shown in Figure below. Notice that the windings of the three-phases are displaced from each other in space.



CHARACTERISTICS OF SYNCHRONOUS MOTORS

Some characteristic features of a synchronous motor are as follows:

1. It runs either at synchronous speed or not at all i.e. while running, it maintains a constant speed. The only way to change its speed is to vary the supply frequency (because Ns =120f/P).

2. It is not inherently self-starting. It has to be run upto synchronous (or near synchronous) speed by some means before it can be synchronized to supply.

Synchronous motors have the following characteristics:

- A three-phase stator similar to that of an induction motor. Medium voltage stators are often used.

- A wound rotor (rotating field) which has the same number of poles as the stator, and is supplied by an external source of direct current (DC). Both brush-type and brush less exciters are used to supply the DC field current to the rotor. The rotor current establishes a north/south magnetic pole relationship in the rotor poles enabling the rotor to "lock-in-step" with the rotating stator flux.

- Starts as an induction motor. The synchronous motor rotor also has a squirrel-cage winding, known as an Amortisseur winding, which produces torque for motor starting.

- Synchronous motors will run at synchronous speed in accordance with the formula:

Synchronous RPM (N_S) = $\frac{120 \times \text{Frequency (f)}}{\text{Number of Poles (P)}}$ or, $N_S = 120\ f / P$

Example: the speed of a 24 -Pole Synchronous Motor operating at 60 Hz would be: 120 x 60 / 24 = 7200 / 24 = 300 RPM

SYNCHRONOUS MOTOR OPERATION

- The squirrel-cage Amortisseur winding in the rotor produces *Starting Torque* and *Accelerating Torque* to bring the synchronous motor up to speed.

- When the motor speed reaches approximately 97% of nameplate RPM, the DC field current is applied to the rotor producing *Pull-in Torque* and the rotor will pull-in -step and "synchronize" with the rotating flux field in the stator. The motor will run at synchronous speed and produce *Synchronous Torque*.

- After synchronization, the *Pull-out Torque* cannot be exceeded or the motor will pull out-of-step. Occasionally, if the overload is momentary, the motor will "slip-a-pole" and resynchronize. Pull-out protection must be provided otherwise the motor will run as an induction motor drawing high current with the possibility of severe motor damage.

Advantages of Synchronous Motors

The initial cost of a synchronous motor is more than that of a conventional AC induction motor due to the expense of the wound rotor and synchronizing circuitry. These initial costs are often off-set by:

- Precise speed regulation makes the synchronous motor an ideal choice for certain industrial processes and as a prime mover for generators.

- Synchronous motors have speed / torque characteristics which are ideally suited for direct drive of large horsepower, low-rpm loads such as reciprocating compressors.

- Synchronous motors operate at an improved power factor, thereby improving overall system power factor and eliminating or reducing utility power factor penalties. An improved power factor also reduces the system voltage drop and the voltage drop at the motor terminals.

9.4 Power Distribution

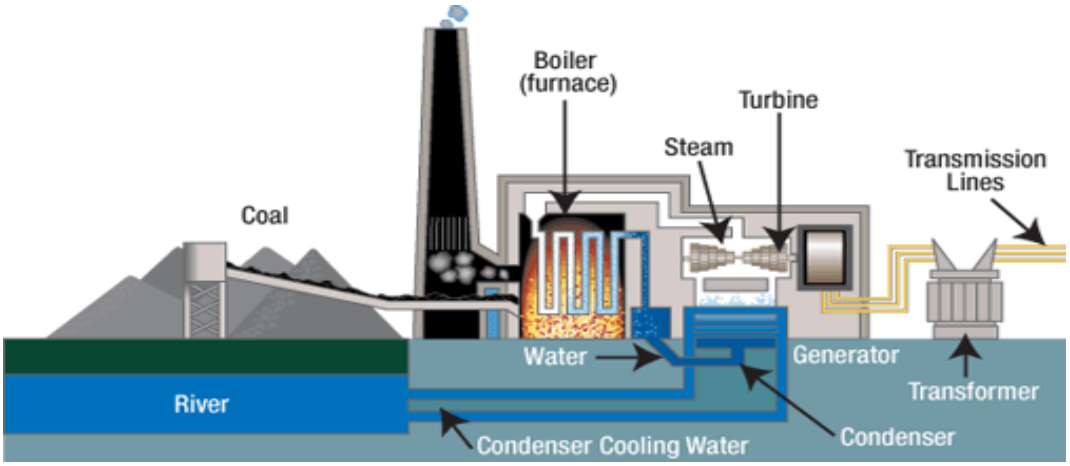
As a system engineer the prerequisite knowledge that person must have is about the vastness of network he is dealing with. As a general philosophy every SAIL Integrated steel plant has two major categories of providing power to the plant

Non-essential load: Those loads which do not fall in the category of keeping plant alive in the situation power outage are called non-essential loads. These loads are fed from external power source like External power grid.

Essential Load: Those loads which fall in the category of keeping plant alive in the situation power outage are called essential loads. These loads are fed from internal power source like Captive power plant (CPP)

CAPTIVE POWER PLANTS:

Availability of reliable power supply is paramount to all the critical processes of an integrated steel plant. It is vital for the safety of plant equipment and personnel because power outage can lead to unsafe situation like gas leakage in Coke Ovens, or damage to Blast Furnace tuyers, or melting of oxygen lances used in the steel-making process. Furthermore, stoppage in one production shop of an integrated steel plant can seriously affect the production of the next shop in the chain. Hence all integrated steel plants have their own **captive power plants** (CPPs), to cater to these critical loads, in addition to power supply from the state grid. A cross-sectional view of a thermal power station is shown below.



CPPs in SAIL are coal / gas-based thermal power plants. In thermal power stations, mechanical power is produced by a steam turbine, which transforms thermal energy, from combustion of a fuel (coal or by-product gases), into rotational energy. Pulverized coal is fed to the boiler, where its combustion takes place, thereby producing thermal energy that heats the water inside the boiler tubes. High pressure, high temperature steam then passes

through the turbine. The dynamic pressure generated by expanding steam turns the blades of a turbine. A generator that produces electricity is connected to this turbine. To utilize the exhaust steam from the turbine, condensers are used to convert the exhaust steam into condensate (water), which is pumped back to the boiler. The excess steam is used in steel plants for certain processes, like running of steam exhausters in coke ovens. Blast Furnace and Coke Oven gases are also used as fuel in SAIL's CPPs to conserve coal.

Power is normally generated at 6.6 kV, 11 kV, or 25 kV. The generator is connected through a transformer to the grid, stepping-up the voltage of the generated power to grid voltage. It is then distributed to various production shops through step-down transformers at 11 kV, 6.6 kV, 3.3 kV and 440 V.

SYNCHRONISATION OF GENERATORS

The generators in the CPPs are synchronized with the grid supply through a synchroscope which permits closing of tie circuit breakers. The pre-requisites for synchronizing these generators with the state grid supply are as follows:

- The voltage difference should be in the range of 10 % of the rated voltage
- The phase angle difference between the grid voltage and the generator voltage should not be more than 20 degrees
- The difference in frequency should be 0.11% for a system frequency of 50 Hz

PRECAUTIONS DURING PARALLELING

A majority of the equipments in a steel plant have both state grids as well CPP supply. It is important that any paralleling operation at sub-stations is done only after ensuring that the CPP supply is synchronized with the grid supply. If paralleling is done between two supply sources not in synchronism, there is a danger of flashover due to circulating currents caused by the difference in voltages of the two power sources.

ISLANDING

During system disturbances, the islanding of CPPs from the grid on Over / Under-frequency takes place to isolate the generators from grid disturbances, so that the critical loads in the steel plant get uninterrupted power supply. During islanding of CPP generators, they are out of synchronism with the grid supply. Hence, utmost care has to be taken to prevent any paralleling of the two supply sources at downstream sub-stations.

POWER WHEELING FROM DSP TO BSP, VISL AND SSP

To fully utilize the power generation potential of the 2 x 60 MW CPP of DSP, and at the same time meeting the power requirements of BSP, DSP has been wheeling 20 MW power to BSP since 15th July 2004. This has been made possible by the provisions of *open access*

in transmission systems in the Indian Electricity Act, 2003. Wheeling of DSP power has been further extended to Viswesaraya Iron and Steel Limited, Bhadravati since 1st January 2008, and to Salem Steel Plant from 23rd February 2008.

9.5 Circuit Breakers

Purpose: Circuit breakers are used for switching on and isolation of power supply. But their more critical application is:

a. protecting the power system during faults and

b. Maintaining the control philosophy by feeding the fault upto certain prescribed time so that the downstream breaker may clear the fault at its end, if it fails to do so then the upstream breaker must operate at it level.

Protective relays initiate tripping command during a fault to trip the circuit breaker, thereby isolating the system. The failure of a circuit breaker to trip can lead to catastrophe, resulting in irreparable damage to equipments, and at times, the operating personnel.

Operation: Circuit Breakers typically have three poles. In each pole there is a fixed and a moving part. The moving part joins the fixed part when a switching **ON** command is given. During a fault, the moving part separates from the fixed part. However arcing takes place between the fixed and moving contacts, which may re-strike if the separation of the contacts is not at zero current in a sinusoidal waveform. The arc-quenching medium inside the poles limits this re-striking current, thereby ensuring safe isolation.

Electrical circuit breaker is a switching device which can be operated both manually and automatically for controlling and protection of any electrical power system. As the modern power system deals with huge currents, the special attention should be given during designing of circuit breaker to safe interruption of arc produced during the opening/closing operation of circuit breaker.

According to their arc quenching (rapid cooling) media the circuit breaker can be divided as:
1) Air circuit breaker
2) Oil circuit breaker
3) Vacuum circuit breaker
4) SF6 circuit breaker

According to their services the circuit breaker can be divided as:
1) Outdoor circuit breaker
2) Indoor circuit breaker

According to the operating mechanism of circuit breaker they can be divided as:
1) Spring operated circuit breaker

Layout of Equipments in a Typical Power Distribution System

3) Hydraulic circuit breaker

According to the voltage level of installation types of circuit breaker are referred as:
1) High voltage circuit breaker (> 72 kV)
2) Medium voltage circuit breaker (1-72 kV)
3) Low voltage circuit breaker (< 1 kV)

Short summary for breakers:

Plain-break air breakers are used in low voltage and medium voltage up to 15 kV. For low and medium voltages fuses can be also used, but the main disadvantage is that they must be replaced after fault clearing. In medium voltage systems minimum oil, SF6 and vacuum breakers are also being used. For high voltages minimum oil, SF6 and blast-air breakers are used, but always with multiple interrupters in series.

AIR CIRCUIT BREAKERS (ACB)

LV air breaker;
600V/400A

LV air breaker, 400V/6300A

For interrupting arc it creates an arc voltage in excess of the supply voltage. Arc voltage is defined as the minimum voltage required maintaining the arc.

This circuit breaker increases the arc voltage by mainly three different ways:

- It may increase the arc voltage by cooling the arc plasma. As the temperature of arc plasma is decreased, the mobility of the particle in arc plasma is reduced; hence more voltage gradient is required to maintain the arc.
- It may increase the arc voltage by lengthening the arc path. As the length of arc path is increased, the resistance of the path is increased, and hence to maintain the same arc

current more voltage is required to be applied across the arc path. That means arc voltage is increased.

- Splitting up the arc into a number of series arcs also increases the arc voltage.

There are mainly two types of ACB available.

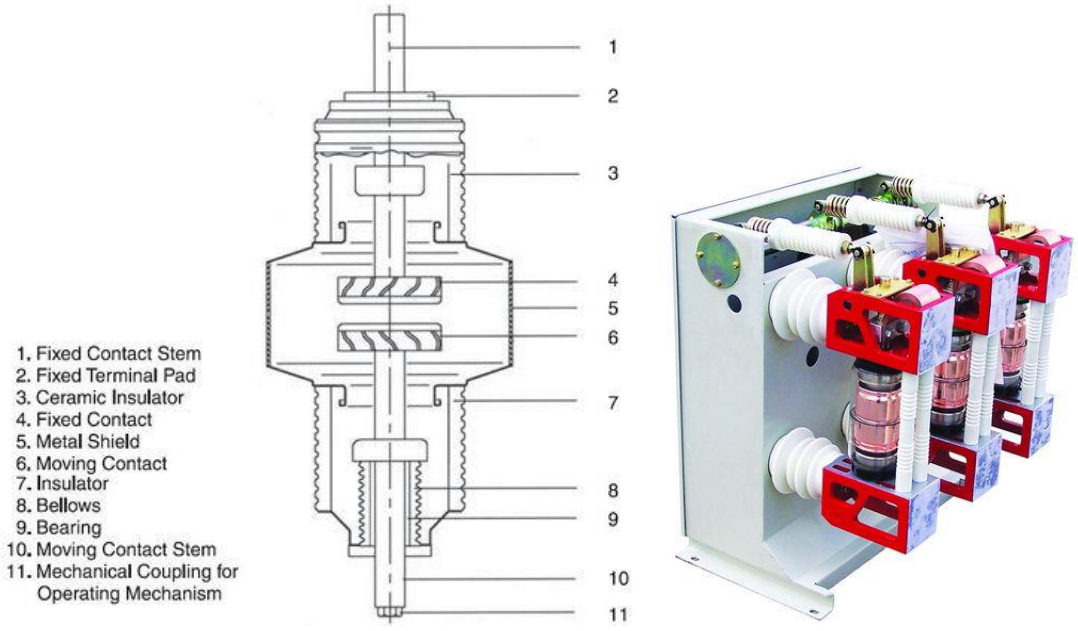
- Plain air circuit breaker
- Air-blast circuit breaker

OIL CIRCUIT BREAKERS (OCB)

Mineral oil has better insulating property than air. The oil is used to insulate between the phases and between the phases and the ground, and to extinguish the arc. When electric arc is drawn under oil, the arc vaporizes the oil and creates a large bubble of hydrogen that surrounds the arc. The oil surrounding the bubble conducts the heat away from the arc and thus also contributes to deionization and extinction of the arc. Disadvantage of the oil circuit breakers is the flammability of the oil, and the maintenance necessary (i.e. changing and purifying the oil). The oil circuit breaker is the one of the oldest type of circuit breakers.

VACUUM CIRCUIT BREAKERS (VCB)

Vacuum circuit breakers are used mostly for low and medium voltages. Vacuum interrupters are developed for up to 36 kV and can be connected in series for higher voltages. The interrupting chambers are made of porcelain and sealed. They cannot be open for maintenance, but life is expected to be about 20 years, provided that the vacuum is maintained. Because of the high dielectric strength of vacuum, the interrupters are small. The gap between the contacts is about 1 cm for 15 kV interrupters, 2 mm for 3 kV interrupters.



a) Vacuum interrupter b)12 kV, 40 kA Indoor vacuum circuit breaker

Service life of the VCB is much longer than other types of circuit breakers. There is no chance of fire hazard as oil circuit breaker. It is much environment friendly than SF6 circuit breaker.

SULFUR-HEXAFLUORIDE (SF6) CIRCUIT BREAKERS

Gas properties

Sulfur-hexafluoride (SF6) is an excellent gaseous dielectric for high voltage power applications. SF6 is a colorless non-toxic gas, with good thermal conductivity and density approximately five times that of air (6.14 kg/m^3.). It does not react with materials commonly used in high voltage circuit breakers. It has been used extensively in high voltage circuit breakers and other switchgear employed by the power industry. Applications for SF6 include gas insulated transmission lines and gas insulated power distribution substations. The combined electrical, physical, chemical and thermal properties offer many advantages when used in power switchgear. Some of the outstanding properties of SF6 which make its use in power applications desirable are:

- high dielectric strength
- unique arc-quenching ability
- excellent thermal stability
- good thermal conductivity

The SF6 gas is identified as a greenhouse gas, safety regulation are being introduced in many countries in order to prevent its release into atmosphere.

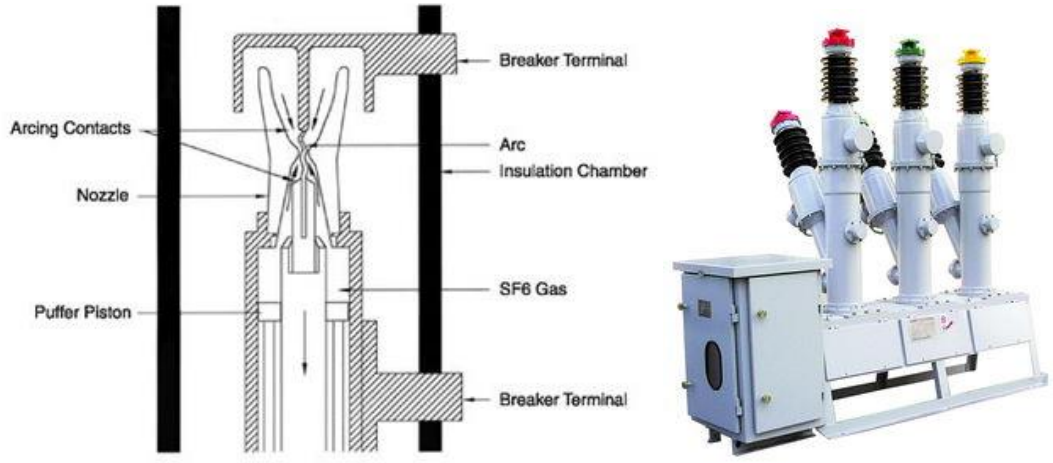
BREAKER PROPERTIES

The principle of operation is similar to the air blast breakers, except that SF6 is not discharged in the atmosphere. A closed-circuit, sealed construction is used.

There are mainly three types of SF6 CB depending upon the voltage level of application:

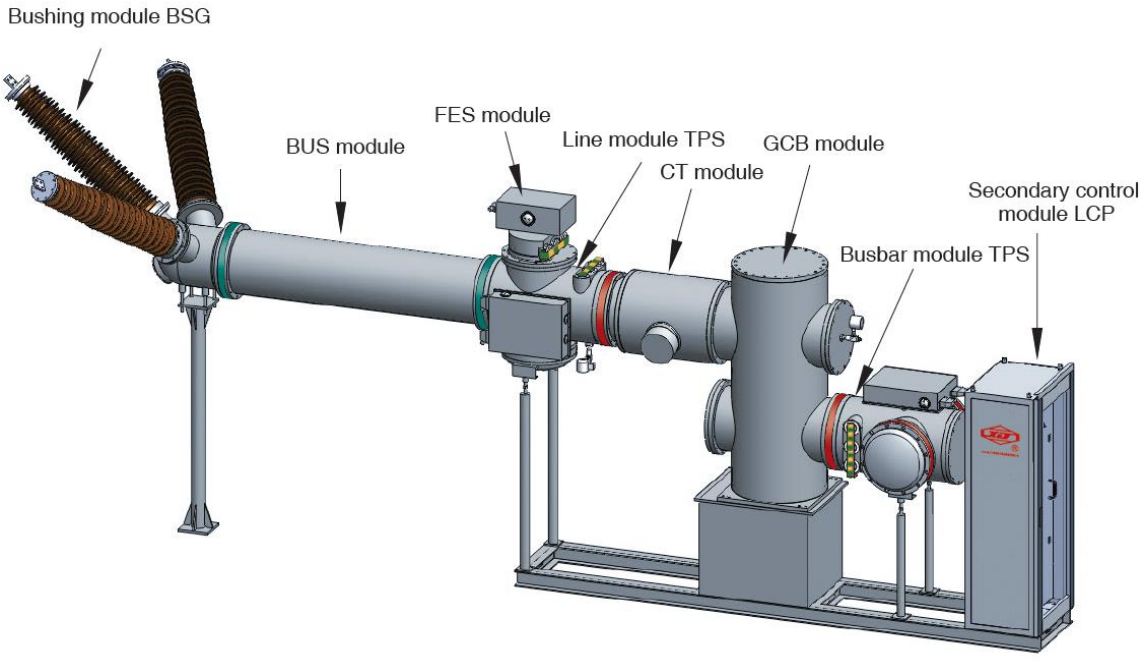
1) Single interrupter SF6 CB applied for up to 245 kV (220 kV) system
2) Two interrupter SF6 CB applied for up to 420 kV (400 kV) system
3) Four interrupter SF6 CB applied for up to 800 kV (715 kV) system

During the opening operation the gas contained inside a part of the breaker is compressed by a moving cylinder that supports the contacts or by a piston. This forces the SF6 through the interrupting nozzle. When the contacts separate, an arc is established. If the current is not very high, it is extinguished at the first zero crossing by the pushing the SF6 through the arc by the piston. If the short circuit current is high, the arc extinction may not occur at the first zero crossing, but the gas pressure will increase sufficiently to blow the arc out. By connecting several interrupting heads in series, SF6 breakers can be constructed for voltages of up to 765 kV.



a) SF6 CB scheme b) 40.5 kV, SF6 circuit breaker

GAS INSULATED SUBSTATION (GIS)



Structure diagram of ZF48–126 (L)

In GIS the high-voltage conductors, circuit breaker interrupters, switches, current transformers, voltage transformers and lightning arresters are encapsulated in SF6 gas inside grounded metal enclosures. Locations where gas insulated substation is preferred:

- Large cities and towns
- Under ground stations
- Highly polluted and saline environment Indoor GIS occupies very little space
- Substations and power stations located Off shore
- Mountains and valley regions

Gas insulated substation has gas monitoring system. Gas inside each compartment should have a pressure of about 3 kg/cm^2.The gas density in each compartment is monitored. If the pressure drops slightly, the gas is automatically trapped up. With further gas leakage, the low pressure alarm is sounded or automatic tripping or lock-out occurs.

WITHDRAW ABLE HV VCB WITH PANELS

VCBs are the preferred choice at HV; absence of air and moisture in the arc-quenching medium (vacuum) results in zero contact erosion. They offer better service than SF_6CBs, which suffer from problems of SF_6 gas leakage. The vacuum bottles used in VCBs are factory-sealed and have an operating life of up to 30,000 to 1,00,000 operations. Surge Arrestors are used with VCBs to suppress switching surges. Vacuum Contactors, a variant of VCBs are used for motors that are frequently switched on and off.

ACBs, Moulded Case CBs (or MCCBs), Miniature CBs (MCBs), AC / DC contactors, DOL starters, etc. at LV are also part of the switchgear family. They are installed individually at equipment locations, e.g., near a motor or in combination with other switchgear components as shown in the figure below.

LV distribution / control panel

EARTHING – CONCEPT AND IMPORTANCE

Earthing in an electrical system is not only an important safety measure for all electrical equipment associated with it but also an important safety measure to save human life who are on the job in an electrical premises. Earthing means connecting the electrical equipment to the general mass of earth of low resistance. The objective is to provide under and around the electrical premises a surface of uniform potential - at near zero or absolute earth potential.

All electrical installations, whether a switchyard or a sub-station have an earth grid / mat. The earthing system consists of numbers of vertically driven earth electrodes (about 40mm dia. and 3m long) into the earth in layers of salt & charcoal and connecting them to earth grid formed by GI/MS flat or MS rod laid horizontally at a depth of 500 mm beneath the top earth surface. Any electrical equipment shall be connected to the earth grid at two points positively. In EHV system the earth grid resistance shall be not more than 0.5 ohm and in other HV or LV system the earth resistance shall be not more than 1.0 ohm.

An effective earthing system aims at providing protection to human life and equipment against dangerous potentials under fault conditions. It should pass maximum earth fault current to earth thereby operating the earth fault relays located in the control panels for isolation of faulty feeders. The earth mat also minimizes electro-magnetic interference between power and control / communication systems.

9.6 Cables

Though overhead lines are used for transfer of power at EHV and HV, bulk of the power in steel plants is transferred through cables, either laid through cable tunnels or buried underground. The cost of underground cables is invariably higher than that of overhead lines with equivalent capacity. However the obvious advantages of an underground system are safety, aesthetic value of localities, and stability of supply.

All cables have stranded conductors (copper or aluminum) at the core, around which are wrapped layers of insulation. Conductor screens (shields) are employed to prevent excessive electrical stress in voids between the conductor and the insulation. Over insulation there is insulation screening followed by insulation tape , over sheath and finally armoring for mechanical protection.

The desirable characteristics in any insulating material are

- High dielectric strength
- High insulation resistance
- Low thermal resistivity
- Low relative permittivity and low tan δ

- Immunity to chemical attacks over a fairly wide range of temperature
- Preferably non - hygroscopic

Classification of Cables. Depending on the type of insulation used, the cables are classified as follows:

- Oil-impregnated Paper Insulated Lead Covered (PILC) – used at HV / LV
- Poly Vinyl Chloride (PVC) – used at HV / LV
- Cross-Linked Polyethylene (XLPE) – used from LV to EHV due to superior thermal and insulating properties
- Rubber insulated cables

PILC cable

PILC cables are widely used for LV and MV applications. Insulation between the conductors and overall insulation over the cable is provided by liquid-impregnated electrical grade paper. A lead sheath over the paper insulation provides mechanical protection for the insulation, encapsulating the impregnated fluid, and prevents environmental degradation. The lead sheath also provides a ground path under fault conditions.

This type of cable not in use nowadays.

PILC cables can be easily laid through tunnels, buried underground and laid aerially. PILC cables are used in circuits with stringent service requirements, viz., highest reliability, longest uninterrupted service life, and greatest surge, impulse and AC dielectric strength. They have high operating temperatures (90 ºC) under normal conditions.

PVC is the most widely used polymer as cable insulation. It is used at LV (power and control), MV (up to 6.6 kV) and some specialist applications like telecommunications.

PVC cables have a number of advantages, such as:

- Good electrical and insulation properties over a wide temperature range up to 80ºC

- Can withstand thermal and thermo-mechanical stresses at continuous normal and short circuit temperature condition
- Inherent fire safety provided by a tough and resilient sheath of galvanized iron, which is used for earthing purposes also.
- Provide complete protection against electrolytic and chemical corrosion – hence very useful in polluted steel plant environment
- A non-hygroscopic insulation almost unaffected by moisture
- Excellent durability and long-life expectancy
- Easy processing characteristics to achieve desired specification for end-products – easy to handle / strip
- Not affected by vibration
- Cost-effective

XLPE Cable

XLPE cables consist of the following components:

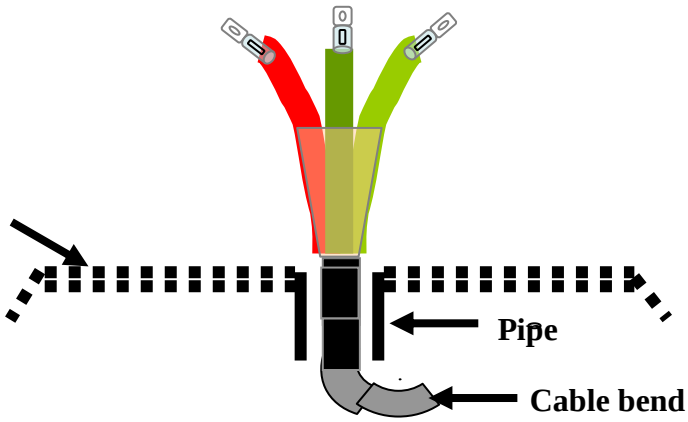
- Copper or Aluminium stranded compacted conductor
- Longitudinal water sealing of conductor
- Triple extruded and dry cured XLPE insulation system
- Conductor & Insulation Screening with semi-conducting compound
- Metallic screen over semi-conducting insulation screen
- Non-metallic flame retardant outer sheath of polyethylene or PVC which is flame retardant
- Armor of galvanized iron

XLPE cables are widely used for HV and EHV applications. They can be laid through tunnels, trenches, underground, and undersea. These cables can be loaded continuously to a conductor temperature of 90 °C. An XLPE cable may be overloaded above 90°C and the conductor temperature may reach up to 105°C for a short duration. For XLPE insulated conductors the maximum allowable short circuit temperature is 250 °C.

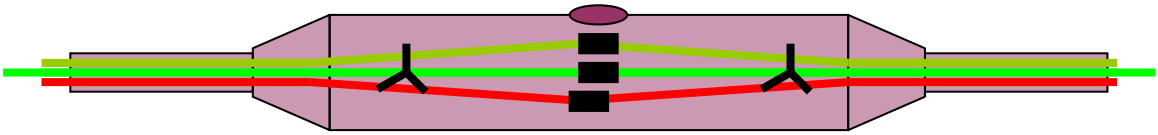
Precautions with cables. PILC cables absorb moisture if left exposed or if their outer sheath is damaged. PVC cables are not stable at temperatures above 80 ºC. XLPE cables suffer from development of water trees over a period of time. Metallic sheaths or polythene coated metal tape (Poly – Al, Poly – Cu) are used to protect water ingress (for HV / EHV cables), protect the core from possible mechanical damage, and create an earth shield. *Armouring* is done in all types of cables through steel tape or galvanized wire / strip or aluminium wire / strip to prevent mechanical damage / stress. While laying or handling cables, the minimum bending radius prescribed should be strictly followed to reduce mechanical stress.

Marking on cables: Colour codes / tapes are used for identification of the three cores. Standard marking is through colours (like Red, Yellow, Blue for Red phase, Yellow phase, Blue phase respectively, or numbers (1, 2, 3). For LT cable black colour is provided for neutral.The marking or coding is vital when connecting / jointing two cables together, or when a new cable is being connected to an existing system, so that the phasing is matched.

At the ends of a panel or equipment (motor or transformer), the end-terminations are to be made with special care. For long lengths of cables, the pieces have to be joined by means of straight-through joints, as the cables are normally available in lengths of 250 m or 500 m in cable drums. The diagrams below show a typical end-termination (when viewed from the back-side of an MV panel and a straight-through joint in the tunnel.



View of an end-termination joint



Cross-sectional view of a Straight-through Joint

Material	Advantages	Disadvantages	Max Operating Temperature
PVC	Cheap, Durable, Widely available	Highest dielectric losses, Melts at high temperatures, Contains halogens	70^{o}C for general purpose 85^{o}C for heat resisting purpose
PE	Lowest dielectric losses, High initial dielectric strength	Highly sensitive to water treeing, Material breaks down at high temperatures	
XLPE	Low dielectric losses, Improved material properties at high temperatures	Does not melt but thermal expansion occurs, Medium sensitivity to water treeing (although some XLPE polymers are water-tree resistant)	90^{o}C

9.7 Relays

OVER CURRENT AND EARTH FAULT RELAY:

These relays operate when the magnitude of the current in its circuit, supplied directly or from current transformers, exceeds a preset value. The relays have a number of current settings to make them suitable for wide range of application. Mostly two over current elements for phase faults and one earth fault element for earth fault are provided for solidly-earthed system. Three numbers of phase fault relays are desirable on system earthed through high impedance or unearthed. They are also necessary on delta side of delta-star transformers as the current in one phase may be twice that in the other two phases for a phase-to phase fault on star side. Earth fault protection may be provided by using core balance current transformers. Core balance protection consists of a ring-core current transformer which is designed to pass over 3 core cables. The output from this current transformer is utilized to energize a current operated relay. The arrangement provides very sensitive earth fault protection.

Fault currents change in magnitude and phase while being transformed in delta star transformers. An earth fault on star side produces a circulating zero sequence current in the delta winding but no zero sequence current in the lines of the delta side of the transformer. An earth fault relay on delta side will not, therefore, respond to an earth fault on the star side of the transformers. For the purpose of gradation earth fault relays of the delta and star sides thus become independent.

Over current and earth fault relays may have any one of the time- current characteristics:

a) Time-Delay
b) Instantaneous
c) Combination of both.

Time Delay characteristics may be IDMT (Inverse definite minimum time) or definite time type. In IDMT relays, the time of operation of the relay is inversely proportional to the value of current. However after a certain value of current, say 20 times, the curve remains constant at a minimum time for operation of the relay. For definite time relays, the time remains constant even if the current increases considerably above the set value of the current. Instantaneous relay operates instantaneously when current increases above the set value.

DIFFERENTIAL RELAY

The principle of operation of differential relays is based on Merz-Price System. Fundamentally the system of connection and operation is as follows.

The current transformers are placed on two ends of the protected zone(eg. winding of transformer / motor) and are connected in opposition. So long as the current at two ends of the winding is equal, equal and opposite emf's are induced in the two current transformers of that winding and there will be no current through the relay. Whenever a fault develops in the winding, the current at the two ends of that winding will not be equal and the relay will operate due to flow of differential current.

Motor Protection Relay

These relays protect the motor from five basic faults. The basic faults are:

- Over-current (Short Circuit)
- Earth Fault in any winding
- Overload
- Unbalanced supply (Negative sequence)
- Rotor fails to rotate on application of voltage (Stalling Protection)

UNDER-VOLTAGE / OVER-VOLTAGE RELAY

Under-voltage / Over-voltage relay operates at a pre-determined value of voltage. The relay is normally connected from potential transformer secondary which feeds the replica of the

primary voltage in the power circuit. Typical values of over-voltage and under-voltage are 110% and 88% respectively.

UNDER-FREQUENCY / OVER-FREQUENCY RELAY

Under-frequency / Over-frequency relays operate at a pre-determined value of frequency. The relay is normally connected from potential transformer secondary and also sometimes from 230V single phase AC mains. These relays are used to protect generators and motors.

DF/DT RELAY

This relay operates when the rate of fall (or rise) of frequency is higher than pre-determined rate of fall (or rise) of frequency. For example, if a relay is set at 0.1 Hz/sec and the actual rate of fall (or rise) of frequency is 0.2Hz/sec, then it operates. These relays isolate generators when the grid is sinking. df/dt relays with rise of frequency feature are used to protect generators from over-speeding.

PILOT WIRE RELAYS

These are differential relays used for transmission line/cable protection. There are two sets of relays, one at sending end and the other at the receiving end connected through current transformers at either end. The relays at either end is connected through a pilot wire loop through which relay operating current flows and operates relays at both the ends. During healthy condition current flowing through both the current transformers at either end will be same and the current in the pilot loop will be zero. In the event of a fault in the zone between the two current transformers, the magnitude of current will be different in the two current transformers, and differential current will flow through the pilot loop and operate relays at both the ends.

NUMERICAL RELAYS:

These are modern Microprocessor based Programmable Electronic Relays which provide a comprehensive protection for the Motors, Feeders etc. They have a distinct advantage of merging different types of protective relays in one single unit thereby reducing the size and increasing the reliability. They also provide some advance features of recording of parameters during fault which is very useful for analysis and troubleshooting. They are also

communicable type that is the data generated in the relay can be communicated to another relay in the system, to a PC or to a SCADA system for further use and analysis. Nowadays metering is also done from these numerical relays.

9.8 Electrical Insulation

INSULATING MATERIALS

Insulating materials offer high resistance to flow of current and are used in all electrical equipments. It is the insulation part in any cable or machine that is most liable to fail. Apart from electrical and mechanical stresses, heat plays the most important role in determining the life and performance of the insulating materials, and as such the operating temperature of any operating cable or machine must not be allowed to exceed the permissible temperature rise limit. Moisture and dust also degrade the insulating materials.

The insulating materials have been classified according to their ability to withstand heat. The recognized classes of insulating materials along with their assigned temperature as per IS 1271-1958 as below:

Class of Insulation	**Material**	**Temperature**
Class Y or O	Cotton Paper, Pressboard, Wood, Fibre	90°C
Class A	PVC, Vulcanised rubber	105°C
Class E	Epoxy Resins, Paper laminates	120°C
Class B	Fibreglass, Asbestos	130°C
Class F	Varnished Fibre Glass and Asbestos	155°C
Class H	Silicon Elastomer	180°C
Class C	Mica, Porcelain	Above 180°C

CONCEPT OF INSULATION RESISTANCE (IR)

Insulation Resistance (I.R.) is the resistance of the insulation provided between live conductor and body of the machine/cable armour/earth point. The value of insulation resistance is measured by insulation testers and the unit of measurement is kΩ/MΩ/GΩ and so on.

IR TESTERS (TYPES, APPLICATIONS)

For I.R. measurement a DC voltage is applied through an I.R. tester across an insulating material. The line terminal of the I.R tester is connected to the conductor terminal and the earth terminal is connected to the body/armour/earth and the test voltage is applied.

When this voltage is applied, a leakage current flows through the insulating material. This leakage current is calibrated in terms of insulation resistance expressed in kΩ or MΩ or GΩ. The I.R. value is actually the corrected ratio of the applied voltage to the leakage current flowing through the insulating material.

I.R. value is a good indication of the healthiness of the insulating material. For an ideal insulating material, the leakage current is zero; hence the I.R. value is infinite. Any deterioration in the insulating material due to heat, dust or moisture is indicated by the reduced I.R. value.

I.R. testers are of various types such as hand-driven, motor-driven or solid state type. The output test voltages vary from 100V to 5 kV depending on the type of application. Following are the preferable test voltages depending on the type of application:

I.R Testers Test voltage	**Application**
100V	Telephone Cables
500V	LT Power Cables and Control Cables, LT Motor, Transformer LT side(415V)
1000V	LT Power Cable, LT Motor, Transformer LT side(415V)
2.5kV	HT Power Cable, HT Motor, Transformer HT side(3.3 or 6.6 or 11 kV)
5.0 kV	HT Power Cable, HT Motor, Transformer HT side (33KV,11KV), EHT switchyard equipments (132 or 220 kV)

CABLE FAULT LOCATION TECHNIQUES:

Whenever there is a cable fault, the nature of the fault is ascertained by a suitable I.R. tester. The basic cable faults are phase to armour short circuit (earth fault), phase to phase short circuit (short circuit), and conductor sheared (open circuit fault).

Pre-location of cable fault is done by instruments like Murray Loop Testers, Time Domain Reflectometer (TDR) for earth fault & phase to phase fault to determine the tentative

distance of the fault from both ends of the cable. For open circuit fault only TDR is used. Fault location in optical fiber cables are done by instrument called Optical time domain reflectrometer (OTDR).

Pin-pointing of the fault is done by using Impulse Generator. In an Impulse Generator, a charged capacitor at selected voltage is allowed to discharge at every 6 seconds time interval at the fault point and the amplified discharge sound is heard through ear phones through special probes placed on the ground. The rating of the impulse generators is normally 0-8 kV and 0-25 kV for LT and HT cables respectively.

9.9 Electronic Devices

INTRODUCTION

1. Electronic devices are the backbone of the electronic industry.
2. Almost everything from children toys to life saving equipment depends upon these components.
3. Billions of components are available in the market.
4. In a large process industry like ours, a wide variety of components are used in various electronic systems.

TYPES

- **Passive components:** Fixed and Variable Resistances, Fixed and Variable Capacitors, Inductors etc.
- **Active Components:**
  1. **Vacuum Tube Device:** Diodes, Triodes, Pentodes etc.
     - **These devices are obsolete due to bulky and slow repose.** These are replaced buy semi-conducteur devices are also known as Solid state devices
  2. **Solid State Devices:**

Discrete Devices: Diodes, Transistors, Thyristors, Field Effect Transistors, UJTs, etc.
Integrated Circuits: Linear ICs, Digital ICs, Insulated gate bipolar transistor (IGBT) etc.

RESISTANCES

1. **Definition:** Resistor is the electronic device that resists the flow of current.
2. **Unit of Measurement:** Ohms (Ω)
3. **Specifications:** The resistors are specified in terms of:

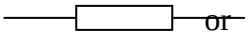
a. **Value**: Specified in Ohms

b. **Tolerance**: Allowable deviation from the specified value expressed in percentage (1%/5%/10%/20%).

c. **Power**: Resistors are designed to handle a particular amount of power. Same value resistors are available in different power ratings like quarter watt, Half watt, 1 watt etc.

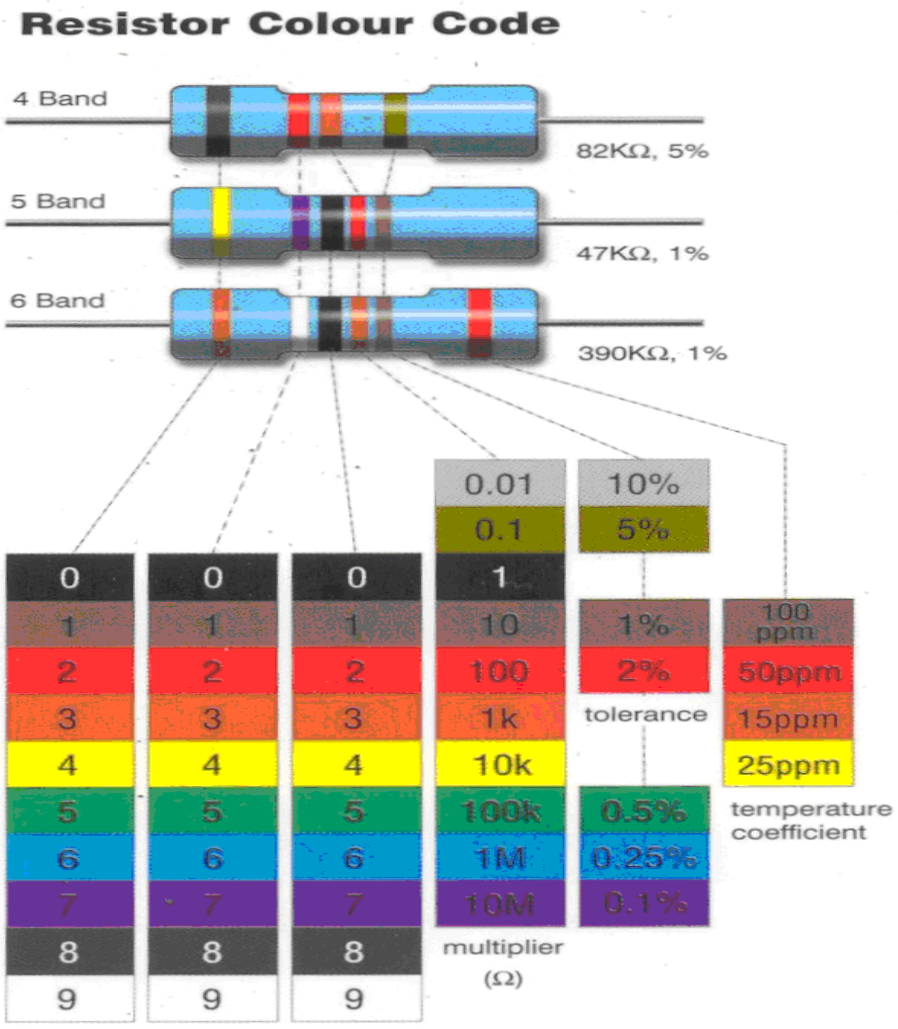
d. **Type**: Depending on the material used for fabrication, the resistors may be Carbon, Metal Film, Wire wound type etc.

4. Symbol:



5. Value Identification:

Values and Tolerance identified by Colour Coded Bands or printed on the body e.g. R33M = 0.33Ω ±20% and 4k7F=4700Ω ±1% Tolerance.



6. Applications:

a. Current Limiting Resistor

b. Loading Resistor

c. Timing Element

d. Bleeder etc

CAPACITORS

1. Definition: Capacitor is the electronic device that stores electrical charge and resists any change in voltage at its terminals.

2. Unit of Measurement: Farads (F) but generally available in microfarads (μF)

3. Specification: The capacitors are specified in terms of:

a. **Capacity or Value:** Expressed in Farads.

b. **Polarity:** Polar (DC Capacitors) or Non-Polar (AC-AC Capacitors)

c. **Voltage:** Max voltage which the capacitor can sustain without being damaged.

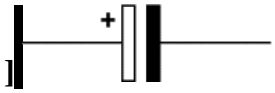
d. **Tolerance:** Allowable deviation from the specified value expressed in percentage.

e. **Packaging:** Axial Lead package, radial Lead package, Solder Type Terminals, Screwable terminals etc.

f. **Type:** Depending on the dielectric used to fabricate the capacitor, they can be Electrolytic, Ceramic Disc, Paper, Mica, Metal Polyester etc

4. Symbol:

Unipolar (AC/DC)



Polar (DC)

5. Applications:

Capacitor is a very versatile component with widespread applications for example:

a. Spark suppression on thermostats, relays etc.;

b. Reservoir and Smoothing filters in power supplies;

c. Decoupling and Coupling in amplifiers;

d. Tuning elements for multi-vibrators, delay circuits etc;

e. Filters and waveform shaping and oscillators.

INDUCTORS

1. **Definition:** An inductor is simply a coil of wire. An inductor can store energy in its magnetic field, and tends to resist any change in the amount of current flowing through it.

2. **Unit of Measurement:** Henry (H).

3. **Symbol:**

4. Applications:

a. Analog circuits and Signal Processing.

b. Filters when used with capacitors and other components. (Chokes, RF Suppressors etc.).

c. Two (or more) inductors which have coupled magnetic flux form a Transformer.

d. As the energy storage device in some switch-mode power supplies.

e. Electrical transmission systems, where they are used to intentionally depress system voltages or limit fault current. In this field, they are more commonly referred to as reactors.

5. Materials: Almost invariably copper as coil material but core can be of different materials.

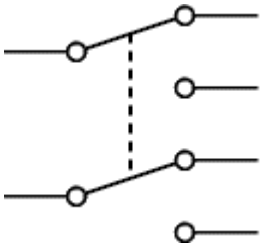
In addition to the above, several other components are used in electronic circuits like Relays, Switches, and Crystals etc.

Switches:

Definition: A switch is a device used to connect and disconnect a circuit at will. Switches cover a wide range of types, from sub miniature up to industrial plant switching megawatts of power on high voltage distribution lines.

Symbol: 

Types: Switches are classified on several bases. On the basis of number of contacts in the switch, they can be Single or Double Pole and so on. If a Switch has two positions in which it can be operated (say ON and OFF), it is called Single Throw Switch. If it has three positions it is called Double Throw.



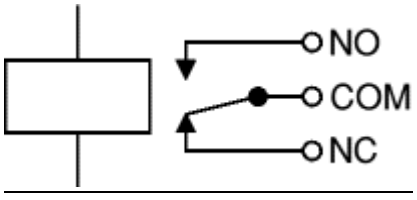
A Double Pole Double Throw Switch

Relays:

Definition: A relay is an electrical switch that opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. It was invented by Joseph Henry in 1835. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered to be, in a broad sense, a form of an electrical amplifier.

Principle: When a current flows through the coil, the resulting magnetic field attracts an armature that is mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact. When the current to the coil is switched off, the armature is returned by a force approximately half as strong as the magnetic force to its relaxed position. Usually this is a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low voltage application, this is to reduce noise. In a high voltage or high current application, this is to reduce arcing.

Symbol:

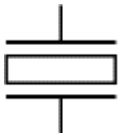


Crystals:

Definition: A crystal oscillator is an electronic circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time (as in quartz wristwatches), to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters/receivers.

Principle: When a crystal of quartz is properly cut and mounted, it can be made to distort in an electric field by applying a voltage to an electrode near or on the crystal. This property is known as piezoelectricity. When the field is removed, the quartz will generate an electric field as it returns to its previous shape, and this can generate a voltage. The result is that a quartz crystal behaves like a circuit composed of an inductor, capacitor and resistor, with a precise resonant frequency.

Symbol:



Testing:

The thyristor can be tested at site using a Battery Tester. The positive terminal of the battery tester should be connected to the Anode of the Thyristor and the negative terminal at the Cathode of the thyristor. The battery lamp shall not glow until the Gate of the thyristor is also connected to the positive of the Battery Tester. Once the lamp starts glowing, it should continue to glow even if the Gate is made open circuited because the thyristor has latched. It shall stop glowing only when the Anode or Cathode wire is also removed. It should be kept in mind that sometimes thyristor does not latch because the battery is not able to supply the latching current. In this case, at least three batteries should be used in series and the batteries should be changed if they are old.

In laboratory the same test can be conducted using two power supplies (one for Anode Cathode circuit and other for Gate Cathode circuit) and suitable load resistance.

9.10 Testing, Measuring Instruments And Tools.

DIGITAL MULTI-METERS:

A multimeter or a multitester, also known as a volt/ohm meter or VOM, is an electronic measuring instrument that combines several functions in one unit. A standard multimeter may include features such as the ability to measure voltage, current and resistance. There are two categories of multimeters, analog multimeters and digital multimeters (often abbreviated DMM.)
A multimeter can be a hand-held device useful for basic fault finding and field service work or a bench instrument which can measure to a very high degree of accuracy. They can be used to troubleshoot electrical problems in a wide array of industrial and household devices.

QUANTITIES MEASURED:

Contemporary multimeters can measure many quantities. The common ones are:

- Voltage in volts
- Current in amperes
- Resistance in ohms

Additionally, they also include circuits for:

- Continuity that beeps when a circuit conducts; useful for checking continuity ofwires.
- Testing of Diodes

Some Multimeters may also measure:

- Capacitance in farads.
- Frequency in hertz
- Duty cycle as a percentage.
- Temperature in degrees Celsius or Fahrenheit.
- Conductance in siemens.
- Inductance in henrys
- Audio signal levels in decibels.

Various sensors can be attached to multimeters to take measurements such as:

- Light level
- Acidity/Alkalinity(pH)
- Wind speed
- Relative humidity

DMM are specified by their resolution often specified in no of digits displayed on the readout of the multimeter (3 ½ digit or 4½ digits etc). The half digit can display either a zero or one and is the leftmost digit of the display. Thus a 3 ½ digit multimeter can display signal levels from 0 to 1999.

9.11 Drives and Control

SPEED CONTROL OF DC MOTORS

Introduction to DC Drives:

DC Drives are used to control dc motor. DC drives have two main components: a converter and a regulator. A converter is an electrical circuit that converts AC power to DC power. DC drive converters typically use a device called a Silicon Controlled rectifier (SCR) i.e. thyristor for this conversion process. SCRs transform AC current into a controlled form of DC current. A regulator is the control portion of the drive. The regulator is the "smarts" or processing logic that determines what voltage and current is supplied to the motor. The voltage/current output from the drive can manipulate the speed or the torque of the motor (thus, the tension of a process load can also be controlled). The changes to the power supplied to the motor depend on the logic in the regulator and the type of feedback from the motor. Feedback devices, such as tachos or encoders, are sensors on the motor. A tachometer (tacho) is a device that monitors the actual speed of the motor. A tacho can send a signal back to the drive telling it how fast the motor is actually running. The drive regulator can compare that signal to drive reference, and determine if more or less voltage is needed at the motor to get the actual speed of the motor equal to the programmed speed. Because DC drives manipulate the voltage supplied to the motor, they are deemed variable voltage control. A drive using feedback sensors is said to have closed loop control.

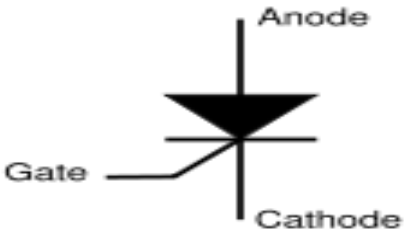
In general, DC drives can control motor speed in two ways.

a. by controlling the voltage supplied to the armature to obtain speeds below the base speed of the motor, or

b. by reducing the current supplied to the field to obtain speeds above the motor's base speed.

WHAT IS A THYRISTOR OR SCR?:

The name thyristor defines a family of four-layer semiconductor device, consisting of alternating P type and N type materials (PNPN).The most popular member of the thyristor family is the Silicon Controlled Rectifier (SCR) which is a three terminal device capable of unidirectional conduction. The term **Thyristor is often used in literature as a synonym of the SCR.**



A thyristor usually has three electrodes: an anode, a cathode, and a gate (control electrode). When the anode is positive w.r.t. cathode (forward biased) and a pulse is applied to the gate, the SCR begins to conduct, and continues to conduct until the voltage between the cathode and anode is reversed or reduced below a certain threshold value. sing this type of thyristor, large amounts of power can be switched or controlled using a small triggering current or voltage.

SPEED / TORQUE CONTROL

a).SPEED CONTROL OF A DC MOTOR **:** Speed of a Separately excited DC Motor can be controlled by

a) Controlling Armature Voltage

b) Controlling Field excitation

Generally the speed of a dc motor can be controlled up to base speed by Armature Voltage control and above base speed it can be controlled by the field i.e. the field current.

TORQUE CONTROL OF DC MOTOR**:**

In applications like Coiler, Uncoiler, Tension Reel, it requires direct control over the motor torque rather than the speed, this can be accomplished by controlling the Armature Current (amperes), which is proportional to the torque.

PROTECTION AND TROUBLE-SHOOTING:

Protections used in Thyristor Converter to protect motor and converter:

1. Protection from Over Current: Followings are the some protections from overcurrent
   - Instantaneous Overload Relay
   - Thermal Over Load Relay: In this type of relay thermal element (bimetallic strip) is used.

- In thyristor converters of higher voltage, over-current protection has been provided relying on the gate control of thyristors, i.e., the gate shift or gate block.

2. Protection from Over Voltage: Over Voltage Relays used to protect system from over-voltage.

3. Fuses:

   Thyristor Converter uses semiconductor fuses for over-current protection of the Thyristors.The carrying capacity of the semiconductor elements (Thyristors) is chosen to be greater than the fusing current, so that when an overcurrent or a short circuit occurs, the corresponding fuse or fuses are fused, interrupting the current, protecting the semiconductor elements (Thyristors).

4. Protection from Surges:

   Surges are a sudden and temporary increase in electrical current or voltage. ACSS (A.C.Surge Suppressors) and DCSS (D.C.Surge Suppressors) are used in Thyristor Converters to protect from surges.

5. Overspeed Relay: In some drives Centrifugal Switch/Relay is mounted on the shaft of motor which is set to trip drive in case of Overspeed of the drive.

6. Breakers on AC side and DC side: High speed Circuit Breakers on AC and DC side are used to isolate the system when a fault occurs in the system.

Trouble Shooting:

In general, there are two types of fault messages : Alarm and Fault.

Alarm warns of some malfunction.No protective function is tripped nor is the operation of the system interrupted. Faults switch off the system and protect it against damage. To troubleshoot a drive, one should have a clear idea of system. He should go through the drawings and manuals of the system. In analog drives, some limited faults/alarms are displayed .Depending upon the type of fault/alarm, one should proceed to rectify the problem.

In modern digital system, if an alarm or fault occurs, an error code is displayed. This error code is stored in the fault logger together with the fault signal and event time. Previous alarm and fault occurrences can be read from the fault logger and displayed even if the original fault indication has been reset. In maintenance manual/troubleshooting manual, Alarm / Fault code and its meaning along with possible error or corrective action is suggested.

SPEED CONTROL OF AC MOTORS:

AC V/s DC DRIVE COMPARISON

AC and DC drives both continue to offer unique benefits and features that may make one type or other better suited for certain applications.

AC DRIVES MAY BE BETTER BECAUSE. . .

- They use conventional, low cost, 3-phase AC induction motors for most applications.
- AC motors require virtually no maintenance and are preferred for applications where the motor is mounted in an area not easily reached for servicing or replacement.
- AC motors are smaller, lighter, more commonly available, and less expensive than DC motors.
- AC motors are better suited for high speed operation (over 2500 rpm) since there are no brushes, and commutation is not a problem.
- Whenever the operating environment is wet, corrosive or explosive and special motor enclosures are required. Special AC motor enclosure types are more readily available at lower prices.
- Multiple motors in a system must operate simultaneously at a common frequency/speed.
- It is desirable to use an existing constant speed AC motor already mounted and wired on a machine.
- When the application load varies greatly and light loads may be encountered for prolonged periods. DC motor commutators and brushes may wear rapidly under this condition.
- Low cost electronic motor reversing is required.
- It is important to have a back up (constant speed) if the controller should fail.

DC DRIVES MAY BE BETTER BECAUSE. . .

- DC drives are less complex with a single power conversion from AC to DC.
- DC drives are normally less expensive for most horsepower ratings.

- DC motors have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose:
- Cooling blowers and inlet air flanges provide cooling air for a wide speed range at constant torque.
- Accessory mounting flanges and kits for mounting feedback tachometers and encoders.
- DC regenerative drives are available for applications requiring continuous regeneration for overhauling loads. AC drives with this capability would be more complex and expensive.
- Properly applied brush and commutator maintenance is minimal.
- DC motors are capable of providing starting and accelerating torques in excess of 400% of rated.
- Some AC drives may produce audible motor noise, which is undesirable in some applications.

AC DRIVES - PRINCIPLES OF OPERATION

Adjustable frequency AC motor drive controllers frequently termed inverters are typically more complex than DC controllers since they must perform two power section functions, that of conversion of the AC line power source to DC and finally an inverter change from the DC to a coordinated adjustable frequency and voltage output to the AC motor. The appeal of the adjustable frequency drive is based upon the simplicity and reliability of the AC drive motor, which has no brushes, commutator or other parts that require routine maintenance, which more than compensates for the complexity of the AC controller. The robust construction and low cost of the AC motor makes it very desirable for a wide range of uses. Also, the ability to make an existing standard constant speed AC motor an adjustable speed device simply by the addition of an adjustable frequency controller creates a very strong incentive for this type of drive.

AC CONTROLLER TYPES

A number of different types of AC motor controllers are currently in common use as general purpose drives: Pulse Width Modulated (PWM), Current Source Input (CSI), and the Load Commutated Inverter (LCI). Each type offers specific benefits and characteristics but the PWM type is being popularly used.

VARIABLE FREQUENCY BASED DRIVE:

- **VFD : VARIABLE FREQUENCY DRIVE**

what exactly is a VFD?
It stands for Variable Frequency Drive.
They are used for running an AC motor at variable speeds or let them ramp up their speed to give them a smooth startup.

VFDs work by adjusting the frequency of the motor to adjust the rpms.
To do this, a VFD will actually convert the voltage twice:
1) First, it converts our three-phase AC to DC. This is accomplished with diodes.
2) Then it cleans the DC with a capacitor.
3) Next, it will convert the DC to AC. This is accomplished with transistors acting as switches.

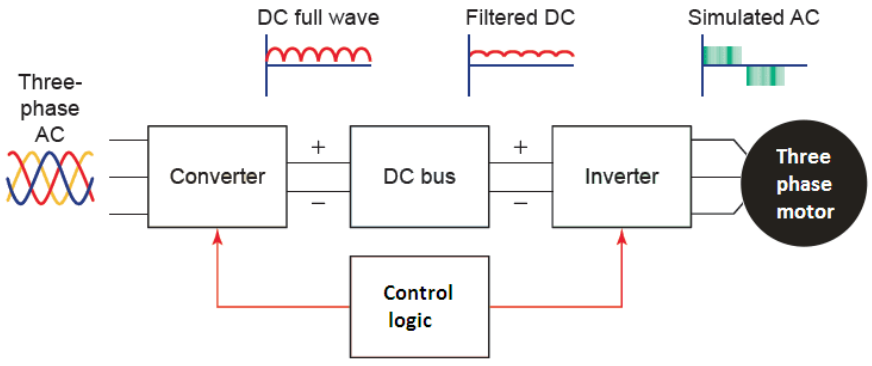
Utilizing these "switches" is what allows the VFD to adjust the frequency that the VFD supplies to the motor. This, in turn, controls the speed of the motor.

Even though the drive controls the frequency and voltage of power supplied to the motor, we often refer to this as speed control, since the result is an adjustment of motor speed.

There are many reasons why we may want to adjust this motor speed. For example, to

- Save energy and improve system efficiency
- Convert power in hybridization applications
- Match the speed of the drive to the process requirements
- Match the torque or power of a drive to the process requirements
  Improve the working environment
  Lower noise levels, for example from fans and pumps
- Reduce mechanical stress on machines to extend their lifetime
  Shave peak consumption to avoid peak-demand prices and reduce the motor size required

<u>BLOCK DIAGRAM OF VFD DRIVE</u>



▪ VVVFD: VARIABLE VOLTAGE VARIABLE FREQUENCY DRIVE

A VVVF drive is acronym of variable voltage variable frequency drive. This is a solid state unit having capability to deliver power with variable voltage and variable frequency. It shall be possible to run motors at different speeds.
The speed of the motor shall be varied as per the process/functional requirement. The same can be achieved by using VVVf drive. Number of Drives are used in SPP, mainly to achieve micro speed in EOT crane and in other application like speed control of pumps, blowers, etc.

BASICS OF VVVF DRIVE
Why both voltage and frequency needs to be varied?
We know that, Speed N =120 x f/P where N is speed of the motor f is frequency of the supply voltage P is number of poles of the motor.
The speed is proportional to frequency. By changing the frequency, we can vary the speed.
But flux Ø = v/f.
If frequency alone is changed by keeping the voltage constant, flux Øvaries, Speed also varies along with flux. We know that Torque is proportional to product of flux (Ø) and armature current (Ia). Since flux is changing, the torque also changes.
This is undesirable in many applications. And also, If the frequency alone is reduced, the inductance of the motor coil will be very low. ($XL = 2\pi fl$) and therefore the motor winding draws excessive current which may result to burning of the motor.
Hence we have to vary both voltage and frequency to maintain constant flux in turn constant torque.
Conversion of AC voltage to DC voltage is done by diodes. Inversion from DC voltage to Ac voltage is done by Insulated Gate Bipolar Transistor (IGBT) in a simple VVVF Drive.

Advantages

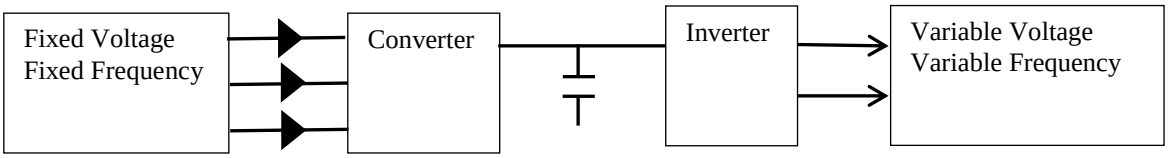
- Variable speed at motor shaft
- Conservation of power (In case of pump loads)
- Quick reversal (contactor is not required).
- Reduced wear of brake liners due to application of brake at low speed using Drive.
- Smooth acceleration and deceleration using Ramp Up and Ramp down time toavoid sudden load on mechanical system and smooth handling of loads without Jerk.
- Due to absence of contactors, pitting of contact tips is avoided and maintenance is reduced.
- Good reliability and availability
- Reduction of inrush current

- Inbuilt protection like OC/SC

Disadvantages

- Initial cost
- Harmonics generation.

BLOCK DIAGRAM OF VVVF DRIVE



9.12 Maintenance Practices

Maintenance of all equipments is a must to reduce the faults in installations under normal and abnormal conditions. The role of maintenance is becoming more pronounced because industries are expanding in size, and volumes of production are going up. The complexity / inter-dependability of sub-units and functions is increasing, particularly in an integrated steel plant, where the output of one production shop is the input of the next.

The steel market, like other industries is booming. Hence the production targets are higher than before. There is a thrust on maximum utilization of existing assets, which in turn means less reserve capacity to fall back upon. The consumers too are demanding uninterrupted power supply, which is critical for a number of operations in the steel industry.

TYPES OF MAINTENANCE

Maintenance can be classified as

1) Preventive or Scheduled Maintenance,

2) Predictive or Condition-based, and

3) Breakdown Maintenance.

PREVENTIVE OR SCHEDULED MAINTENANCE

It is carried out as per a predetermined maintenance plan or schedule. The frequency of maintenance of various equipments is based on

- Recommendations of manufacturers / suppliers of equipments
- Past experience of maintenance personnel which takes into account the problems faced and the work environment. Frequency of operation of an equipment. For example, electrical equipments in polluted areas like Coke Ovens and Sinter Plants require more frequent cleaning of insulators than in areas like Rolling Mills. Circuit Breakers feeding arc furnace transformers which have more switching operations (50 to 60 per day) require more frequent maintenance than circuit breakers feeding distribution transformers which have lesser switching operations (2 or 3 per year).

Adherence to scheduled maintenance is a must, which serves as off-line inspection also. Preventive measures are taken while the equipment is under shutdown, particularly for electrical equipments for safety purposes. A record of preventive maintenance activities is maintained and analysed to assess the health of the equipment on a long-term basis. It is important that maximum work is done in planned maintenance than during forced outage or breakdowns.

PREVENTIVE / SCHEDULED MAINTENANCE OF ELECTRICAL EQUIPMENTS

TRANSFORMERS

For oil-filled power transformers, the operation of fans, pumps and tap changer should be checked. In arc furnace transformers, the oil in the diverter switch should be replaced once in three months as it gets carbonized due to large tap changing operations at high currents. Proper oil-level should be maintained in the conservator. The colour of silica gel in the oil breather should be blue and when it absorbs moisture it becomes pink and at that time it shall be re-activated by heating.

For dry-type transformers, a blower or vacuum cleaner should be used for thorough cleaning of the transformer and its enclosure. Inspection should be carried out for any physical damage to windings, leads, connections, etc. In synthetic liquid-filled transformers, proper care should be taken while handling the liquids as they are poisonous.

The tightness of external bolted electrical connections should also be checked for all types of transformers. The bushings should be inspected for cracked porcelain and deterioration. If required, cleaning of bushings should be done.

Before charging the transformer, the IR value of its winding, between phase to earth and between phases, should be checked by an insulation tester. If oil is used for cooling oil filtration should be done until it achieves its specified Breakdown Voltage (BDV) value.

Clearance from Regional Central Electricity Authority (CEA) is to be obtained for charging of newly installed HT substations and HT transformers.

All transformer rooms should also have adequate number of exhaust fans to prevent ingress of dust and also to prevent overheating. Fire Detection and Alarm (FDA) and Fire Hydrant Systems are to be installed in Transformer Rooms as additional Fire Fighting Systems.

PANELS AND BUSBARS

Panels and busbars in sub-stations contain the circuit breakers, support insulators, CTs, Bus PTs, and auxiliary transformers, in addition to protection and control gear. They have to be thoroughly cleaned by blowers or vacuum cleaners. All bolted electrical and mechanical connections should be tightened. All insulators should be inspected for cracks or tracking. In the case of epoxy insulators, space heaters are provided with auxiliary AC supply to prevent ingress of moisture. Space heater circuits should be checked for their healthiness.

All entry points for rats and lizards should be sealed with cotton waste / sheeting / foam / taphole mass mud in MV and LV panels. To prevent ingress of dust into the panels, sub-station premises should be pressurized through a **good ventilation system**.

CABLES

Cables form the backbone of power distribution. They should be laid properly inside panels, in cable racks and trenches. Handling of cables and their joints should be done with care so as to prevent any physical damage to their insulation. Cable terminations in panels and at equipments (motors or isolators or transformers) should ensure adequate clearance. Bending radius of cables should be as per standards for the type and voltage rating of the cable.

Cable tunnels have a large number of cables laid side by side in racks. Tunnels should be adequately ventilated through exhaust fans located at suitable intervals in ventilation shafts. Dewatering pumps installed in the tunnels to remove any seepage water should be properly maintained.

CONSTRAINTS IN PREVENTIVE MAINTENANCE

Due to increased utilization of equipments, availability of shutdowns is lesser, resulting in reduced equipment availability. At times, quality of repair also is compromised. Another problem plaguing the maintenance function is the fast rate of technical obsolescence. Maintenance personnel may not have the skills or training for proper maintenance of new equipments. Technological obsolescence also creates the problem of non-availability of

spares. Furthermore, conventional fault diagnosis methods are time-consuming and inaccurate. Most electrical faults are not visible to the naked eye. The cost of breakdowns is excessive, because the fault is detected after considerable equipment damage or stoppage of production.

There is unnecessary dismantling of equipment in scheduled maintenance. The shutdown hours may be unnecessary irrespective of equipment health. Outage of equipment also means production loss. There is also a danger of over-maintenance.

PREDICTIVE (CONDITION-BASED) MAINTENANCE

Merely attending defects / replacing damaged components during preventive maintenance does not eliminate the problem. There have been instances of failure of equipments even after maintenance. To overcome the problems mentioned above, the emphasis is shifting from time-based preventive maintenance to conditioned-based predictive maintenance.

Through condition-based maintenance, equipment availability as well as reliability can be enhanced. Hence tools and techniques that predict internal faults in electrical equipments are gaining popularity because the shutdown hours are logically reduced due to better advanced planning. Thus over / under-maintenance is also avoided and cost of maintenance is optimized.

One of the simplest practices of condition-based maintenance is carrying out routine inspection and tests of the critical parameters of equipment. Like we carry out various health checkups of our body and if we find any abnormality then we get admitted in hospital.

For example for a transformer regular checking and inspection of Load current, tap position, input & output voltages, oil temperature, winding temperature, Buchholz relay gas accumulation, oil level, condition of breather, observation of oil leakage etc. can be done. Regular DGA (Dissolved Gas analysis) and Oil BDV and water PPM measurement are also done in order to avoid any surprises.

Nowadays condition monitoring equipment / tools like temperature sensor, vibration sensor, detection of partial discharge, dissolved gas analysis, residual life analysis etc. are in use with proper diagnostics which has reduced surprise failures and helped in planning maintenance / repair / replacement of equipment.

BREAKDOWN MAINTENANCE

Breakdown Maintenance is the most undesirable type of maintenance. As mentioned earlier, conventional fault diagnosis method are time-consuming and inaccurate. Most electrical faults are not visible to the naked eye. There is also a tendency of neglecting faults during operation or by-passing controls / interlocks. Neglecting faults can lead to complete

stoppage / total breakdown of the equipment. Bypassing controls / interlocks give temporary solution but create permanent deficiency in the system as minor defects become major ones. Unexpected stoppage results in expensive capital investment and massive production loss, which in turn leads to interruption in the integrated production chain. The opportunity loss particularly in today's booming economic scenario is also substantial. Breakdowns also create unsafe situation for equipment / personnel due to - flashovers, fires, physical damage, etc. Refer to the section on *Electrical Safety* for more information on the nature of damage due to breakdowns.

Root Cause Failure Analysis or RCFA is the latest trend in maintenance management to arrive at the main reason for the failure of equipment, so that they can be prevented in future.

STANDARD OPERATING PRACTICES (SOPS) / STANDARD MAINTENANCE PRACTICES (SMPS)

SOPs and SMPs should be strictly followed for all electrical equipment. These are available in the operation and maintenance manuals provided by manufacturers / suppliers of equipment. SOPs / SMPs can be modified based on past experience and plant-specific conditions. Refer to the section on *Electrical Safety* for more information on safe work practices. All maintenance activities should be carried out using the correct materials and tools prescribed by the manufacturer.

9.13 Electrical Safety

Key Principles

Electrical hazards, specifically shock, arc flash, and arc blast, can result in serious injury or death to electrical personnel. There also is a general tendency to by-pass standard shutdown procedures or safety interlocks to save time. This is more so during breakdowns, with the entire focus on restoration of power supply to the affected equipment. This can lead to potentially hazardous situations. Hence all electrical hazards at the workplace must be identified, so that action can be taken to prevent them.

It is mandatory to display requisite danger board near to live electrical equipment written in English, Hindi & local language.

ELECTRICAL HAZARDS AT THE WORKPLACE

Some of the major hazards / unsafe situations and steps to prevent them are:

- Movement of ladders, earthing rods, and discharge rods in the EHV switchyards

  Line to ground clearance should be more than that prescribed by the I.E. Rules (2.75m for 11kV, 3.70m for 33kV, 4.60m for 132kV, 5.50m for 220 kV). Carry the items horizontally not vertically.

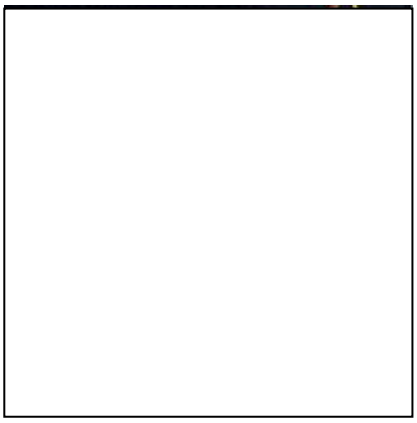
- Opening of wrong / charged HV panel back covers, transformer HV terminal boxes, and isolator panel doors. Correct labeling of panel No. / Feeder Name etc. for power supply feeder should be done on covers / boxes.

- Back-feeding in LV outgoing feeders having an alternate source of power supply

  Testing for absence of voltage by a twin-bulb test lamp to be done.

- Working at heights in EHV switchyard and overhead lines Use of safety belts / harness, and local earthing to prevent shock from line to ground capacitance to be done.

Work procedures, tools, and PPEs



An important electrical safety principle is to use safe work procedures, tools, and personal protective equipments (PPEs). The PPEs required while working on electrical equipment are

- Insulated hand-gloves
- High voltage indicator or twin-bulb test lamps to check for absence of voltage before permitting work to be carried out
- Insulated rubber mats
- Insulated screw drivers and pliers

PLANNING FOR SAFETY

Electrical work must be **planned** before it is executed. All work procedures should be reviewed, updated, and modified periodically as needed. The plan should include a **standard shutdown procedure** which includes a general checklist. **Safety instructions** should be given to personnel by the concerned executive / supervisor, explaining the potential hazards, before starting work, even though it may sound too obvious or repetitive.

DESIGNING FOR SAFETY

While designing electrical systems, safety is a key concern. Safety by design focuses on

- Isolation of the circuit through off-load isolators or draw out type circuit breakers.

  For working on MCCBs, that cannot be drawn out, and equipment connected to them, safety instructions should be pasted on the panels and explained to personnel. If proper isolation is still required, then the upstream draw out-type circuit breaker feeding the MCCB should be drawn out.

- Introducing components or barriers that prevent accidental contact of live parts. during routine maintenance and troubleshooting.

- Ensuring standard phase-to-phase and phase-to-ground clearances as per the voltage level of the equipment.

  In a steel plant, the level of pollution from chemical fumes, dust or moisture, is high in certain locations. Hence additional clearances are specified as per IPSS. For example, the phase-to-phase clearance in an 11 kV panel should be 127 mm, as against the standard clearance of 110 mm.

- Using current-limiting over-current devices to decrease the incident energy and arc flash hazards associated with arcing faults.

The healthiness of all protection systems should be continuously monitored through trip circuit supervision relays and faults alarms. During shutdown of equipments, the protection settings, along with the healthiness of instrument transformers and relays should be checked.

The key electrical safety principles focus on the protection of owners, employers, and employees, as well as the equipments. To ensure a safer workplace, electrical professionals must also change their existing cultures, beliefs and practices and follow electrical safety standards and regulations.

STANDARD SHUTDOWN PROCEDURES

All electrical shutdown procedures should follow guidelines laid down by the Indian Electricity (I.E.) Rules, 1956. While the I.E. Rules lay down guidelines for electrical safety and shutdowns, no standard formats have been specified for the line clear permit shutdown forms. Hence different plants within SAIL itself have different shutdown forms / procedures. These shutdown procedures lay down special precautions in specific areas to ensure safety practices while attending to the equipment under breakdown or planned maintenance. However maintenance in live condition is allowed for commutators / slip rings

of LV / MV motors up to 40 V. Working on live lines with hand-gloves is also permitted up to 400 V.

TYPES OF ELECTRICAL SHUTDOWN

There are basically three types of shutdowns that have an electrical linkage:

1. Shutdown of electrical equipment for carrying out work by electrical agencies
2. Shutdown on electrically driven stationary equipment for carrying out work by other than electrical agencies
3. Shutdown on mobile equipment for carrying out work by other than electrical agencies

PROCEDURE FOR SHUTDOWN

For Electrical Agency:

Shutdown of electrical equipment / installations (whether stationary or mobile) for carrying out work by electrical agencies is issued on a separate form.

In case of possibility of back feed, a **NO-BACKFEED** form has also to be used in addition to the normal shutdown form. The use of **NO-BACKFEED** form is highly important in a steel plant like ours, because approximately 90% of the equipments have dual source of supply and there is every possibility of back-feed if proper shutdown practices are not followed.

For Non-Electrical Agency:

Shutdown on electrically driven stationary equipment for carrying out work by other than electrical agencies is issued on a separate form.

For Mobile Equipment:

Shutdown on mobile equipment like cranes, charging cars, etc. for carrying out work by other than electrical agencies is issued on a separate form.

Note: Readers are advised to acquaint themselves of the shutdown forms used in their respective plants.

ACTIONS FOR SHUTDOWNS

For stationary as well as mobile equipment, the following basic activities have to be performed –

1. Switch off the source of power supply
2. Isolate the power supply source

3. Provide earthing, if required.
4. Provide caution board like **MEN AT WORK**, **DO NOT SWITCH ON**, or **EARTHED**, on the equipment closing switch or panel door.

ADDITIONAL ACTIONS FOR MOBILE EQUIPMENTS

In addition to the above mentioned actions, following additional actions are required –

1. Provide stoppers, red flags / red lights
2. Inform the operators of adjoining cranes, and operation in-charges in writing
3. Guard the area under the crane properly
4. Ensure that the operator of the crane under maintenance is available in the crane for any operation of the crane during the shutdown
5. Isolate cut points of the bus bars properly
6. Ensure that working people are not standing / moving freely on the crane

RECORDING OF SHUTDOWNS

The following practices should be followed for keeping proper records of all shutdowns:

1. Office (carbon) copy of the shutdown form kept with the shutdown-issuing authority
2. Recording of the shutdown is done in the log-books of both the supervisor as well as the shift / executive-in-charge
3. Recording of all the activities carried out separately in Shutdown Registers

If shutdown has been given to more than one agency on the same equipment, the shutdown permit number issued to one agency should be mentioned on the shutdown permit of the other agency as well.

LOSS OF SHUTDOWN SLIP

In case the original shutdown slip is missing, only one step higher level person is authorized to cancel such shut downs.

THE INTER-PLANT STANDARDS ON SAFETY – THE *PERMIT TO WORK* SYSTEM

The *Permit to Work* (PTW) system covers all types of shutdowns in an integrated steel plant. The PTW system aims at the adoption of uniform shutdown permits for all types of jobs, irrespective of the functional discipline. Furthermore, activities in steel plants and mines invariably require a coordinated approach in which multiple agencies are involved.

This aspect assumes greater significance when the activity is either hazardous in nature or is carried out in areas of hazardous ambience.

An Inter Plant Standard, namely IPSS:1-11-007-01 was prepared by the Standards Committee on Appliances and Procedures with representatives of all member steel plants and associated organizations. It has been adopted in June 2001, though not fully implemented by all steel plants. It touches upon even those areas where presently no shutdown procedures exist or where the ownership of equipments is not clear. The heads of department are required to clarify on such grey areas and clearly fix responsibility.

In the PTW system there are two agencies releasing the shutdown – the shutdown giving authority and the shutdown issuing authority. The PTW system lays down comprehensive guidelines for seeking, granting, and returning of the permit. It may be noted that the permit is valid for the same date and for a limited period only. If the job exceeds the time frame mentioned in the permit, a fresh permit has to be obtained.

Jobs where *Permit to Work* is required –

a. Work on electrically operated equipments

b. Work on pipelines / equipments handling chemicals, acid gases, steam, water, oil etc, at normal / below / above atmospheric pressure and temperature

c. Work on or in the vicinity of moving machines / equipments / gas prone areas / high tension lines/ bare conductors

d. Work in confined spaces

e. Demolition and excavation

f. Connection and interfacing between new and old units

g. Work at height

h. Any other equipment / location / area which may be associated with hazards

Procedure for obtaining *Permit to Work*

1. Only authorised representative of the executing department has to ask for shutdown in the given format

2. PTW form is in duplicate, one for the executing agency (white coloured) and other for the issuing authority (yellow coloured)

3. Before issuing the PTW, Issuing Authority / Owner department shall ensure that:

    i. The equipment has been stopped.

ii. **CAUTION** tags and **MEN AT WORK** boards have been displayed.

iii. Red flags, barricades, stoppers, earthing bars, etc. have been placed at appropriate locations

iv. For air, gas, steam, hydraulic fluids, acid, chemical, water, etc., valves should be closed and locked or blanks provided

v. Electrical fuses should be removed

vi. Sample analysis of gas / air should be done

vii. All agencies / concerned persons should be informed

viii. All persons working in vicinity should be informed

ix. Hazards of location should be explained to person seeking the permit

Check Points before granting permission:

(Write **Yes** / **No** / **Not required** as applicable)

1. Whether the job protocol exists?
2. Have caution boards/ tags been displayed?
3. Have fuses been removed?
4. Has earthing been done?
5. Have Hydraulic/ Air/ Gas/ Steam/ Acid valves been closed?
6. Has emergency key of the valves been put in safe custody?
7. Has Gas/ Air sample analysis been done?
8. a. Whether the department / section(s)/ individual(s) likely to be affected have been communicated about the job/ shut down ?

   b. If yes, which department / section / individual have been informed?

9. a. Have associated hazards and precautionary measures been explained to executing agencies?

   b. Have all personnel / agencies in nearby vicinity been informed?

   c. Any other precautions taken? If yes, their details

10. Has concerned plant / equipment been put out of operation / switched off?

Return / Withdrawal of *Permit To Work*

- On job completion and removal of materials, the executing authority returns the permit to the issuing authority.
- After verifying all safety aspects, the issuing authority gives clearance. White coloured copy is returned to the executing agency after signing by the issuing authority. Thus the executing authority has record of completion / return of permit.

- **On loss of permit** – cancellation / return by one level higher person is to be done.

Indian Electricity (IE) Rules, 1956 – Key Provisions

The I.E. Rules, 1956 is a highly exhaustive document. Some of the key provisions from it are being dealt with here.

Voltage Classification

The I.E. Rules defines the following voltage classification in Chapter I, Section 2 [1(av)]

Low Voltage	up to 250 V + 6% variation
Medium Voltage	up to 650 V + 6% variation
High Voltage	up to 33 kV + 6% variation
Extra High Voltage	beyond 33 kV and above

Authorisation Rules

The rules for authorization of electrical personnel to work on equipment have been specified in Chapter I, Section 3. Personnel authorised under rules 36(2), 51(1) and 64(1) of I.E. Rules. The authorisation form specifies the equipment / apparatus / voltage level for which a person is authorized. The authorising person should satisfy himself that person being authorised is competent.

Competent Persons for Issuing / Receiving Shutdowns

- Competent issuer of shutdowns should be at least Chargeman / Supersvior for LV / MV, and Executive for HV / EHV
- Competent receiver of shutdowns should be at least Chargeman / Supervisor / Switch Board Attendant for LV / MV / HV, and Executive for EHV
- Persons of lower rank can be declared competent if the authority is satisfied the person is capable

As per I.E. Rules, the minimum qualification for Supervisory staff is Degree / Diploma in Electrical. Persons with ITI in Electrical can assist the Supervisors. The I.E. Rules also specify a minimum of 6 months' training in a Central Electricity Authority (CEA)-approved institute plus visits and in-plant training. Relaxation in minimum qualification or training duration / nature of training can be done by the appropriate authority (state or central government) on the owner's request.

A record of authorized persons has to be maintained by all establishments, which shall include their name, designation, qualification, applicable rules, etc. in a register. Both the authorizing and authorized persons should sign in the register, once a year. The records have to made available for inspection to an appropriate inspecting authority within the establishment or by the Electrical Inspector of the State / central government.

Reporting of Electrical Accidents

All electrical accidents should be reported as per Rule 44A. The report of accident should to be sent to State / Central Electrical Inspector. Report of fatal accident has to be faxed within 24 hours. A detailed written report should be submitted within 48 hours to the Electrical Inspector. All accidents should be reported in the prescribed forms specified in Annexure-XIII of the I.E. Rules, 1956.

Rule 108 (1) (b) (iii) specifies that any **abnormal or dangerous occurrence** should also be reported to the Electrical Inspector.

Inspection of Electrical Premises

Chapter II of the I.E. Rules deals with Inspectors, while Chapter IV Rule 46 deals with periodic inspection of all electrical premises. All new equipments / installations have to be compulsorily inspected and tested by CEA's Electrical Inspector. The cost of inspection and testing is also specified in the I.E. Rules and has to be paid to the CEA.

Safety Precautions for Maintenance / Testing

<u>Power System Equipments</u>

Operation, maintenance, and testing of power system equipments require elaborate equipment-specific shutdown procedures for their safe isolation. No maintenance should be carried out in live condition, except in certain cases (refer *Working on Live Equipment* below). The equipment should be properly earthed to protect personnel and equipment from hazards due to any accidental charging of supply.

PPEs should be used while issuing shutdowns. A cable or busbar should be tested for absence for voltage by a HV indicator, with the person wearing hand gloves and standing on

an insulated rubber mat. After absence of voltage is established, it should be discharged and then finally earthed. Certain shutdowns may not require earthing, depending on the type or location of work.

All MV and some LV circuit breakers have electrical spring charging provision of closing mechanism. While inserting such breakers into SERVICE position, the control supply (AC/DC) should be kept off, and the spring discharged to prevent any accidental closing of the circuit breaker while in motion, which could result in a flashover if the breaker poles are very near the charged bus.

Though testing is normally done at low voltages, earthing of all testing instruments should be ensured, and they should be placed on rubber mats. Testing probes should be insulated. During HV testing, the area where the equipment is being tested should be barricaded. After HV testing, the testing instrument as well as the tested equipment should be thoroughly discharged.

Most electrical panels have low voltage 240 V AC or 110 V / 220 V DC for control and protection circuits, which have to be kept on due to interlocks between different panels / equipments and sub-stations. The working personnel should be aware of the control terminals that are live. Since control and relay chamber is generally at a height, the personnel should stand on wooden stools or benches while working.

While measuring voltage across a device, the voltmeter should be isolated from ground, and the maximum voltage capability of the voltmeter should not be exceeded. Voltages above 230 V should be preferably measured by an Avometer and not by a multi-meter, as their size is small and the components are placed quite close to each other.

Working on Live Equipment

- Not permitted for EHV / HV
- Authorised persons, can work on MV / LV, after taking necessary precautions
- Two authorised persons should work together - always
- Rubber gloves mandatory for working on 230 V and 400 V
- Personnel should be standing on rubber mats / dry wooden platforms
- Bare hand working with insulated tools without body touching earth / metallic parts; when necessary to work on a "live" circuit, one should work with one hand to prevent a deadly hand-to-hand (through the chest) shock current path
- Proper labeling of equipment likely to require inspection, or maintenance when live. The labeling, should warn of the potential arc flash hazards and the requirement for PPEs. The labeling should be in both English and the local language.

Electronic Card Handling:

I. Generally, a card containing ICs particularly CMOS ICs should not be touched without using an earthing wrist band as this may damage these ICs due to static charges. Such cards should be handled by touching only the edges of the PCB.

II. Also, generally, the cards should not be plugged in or out of the connectors while the power is on. Although now a days, some manufactures allow this (Hot Swap Modules) but it is a safe practice to switch off all the power to the cards before putting it in or out whenever possible.

III. While soldering or de-soldering a component, all the inputs including the power supply should be switched off. Care should be taken to replace the faulty components only with exact spares. Any deviations due to any reasons like non-availability of the exact spares should be well thought over by a competent person. For example, if a particular resistance is burning out very often in a card, we should not blindly put a resistor of higher wattage as this may result in failing of another (and probably more critical) component.

IV. Spare cards should always be store in their original (mostly anti-static) packing. In case this is not available, care should be taken to store them in moisture free and dustproof environment. Rats' excreta are very dangerous for the cards and it fatally damages them.

Using a Digital Multimeter:

Before Connecting the Multi-meter in the circuit under test:

i. Features of the multi-meters differ depending on Make/Model. Make yourself fully conversant with the features, Sockets arrangement and functions of the particular meter that is being used before starting any measurement. Read the O & M manual of the meter thoroughly and strictly follow the safety instructions given in the manual.

ii. Always ensure that the correct mode (Voltage: AC/DC, Current AC/DC or OHMs) is selected on the meter as per the requirement. Note that the same socket is generally provided on the meter for Voltage as well as Resistance Measurements. Ensure that multi-meter resistance mode is not selected when it is being connected in Live circuits.

iii. Remember that two different sockets are generally provided for Low and High Current measurements. The low current socket has internal fuse protection but the high current socket has no protection. Ensure that the maximum current being measured is not more than the meter rating.

iv. Never measure voltage when probes are in "Current" sockets.

v. Select the correct range depending on the expected level of Voltage/Current being measured. If unsure about the levels, start from highest range.

vi. Ensure that the probes are in good condition and there are no joints/damage to insulation.

vii. Always use original/standard color – coded probes. Black probe should always be in the Common Terminal socket of the meter. Never use two probes of same color.

viii. Never use probes without proper Banana Pins that fit in the multi-meter socket. The pins of the probes should sit firmly in the sockets and there should be no loose connections. Also the probes should have proper measuring prods in the front for connecting to the circuit under test.

ix. The probes should be free and not twisted, entangled or wrapped around the multi-meter.

During Measurements:

i. Always hold the two probes of the multi-meter in different hands. Either ask another person to hold the meter or use the stand of the meter to firmly place it on a safe place.

ii. Do not bend or turn your face away from the live circuit while measuring voltages to see the reading. Keep your attention on the probes otherwise the prods may slip and cause accidents. In case multimeter is to be used by one person, use proper alligator clips for hooking to the circuit under measurements so that hands are free.

iii. Stand on rubber mats while making the measurements. Avoid use of digital multi-meters to measure voltages in a highly inductive circuit like Brake Magnets or Motor Fields etc. as high voltage develops across the inductors when the current is broken and this may damage the internal circuitry of the meter and cause injuries to the personnel. In case such measurements are to be done, ensure that the probes are removed from the circuit before current is cut-off.

Chapter – 10

COMPUTER

10.1 Introduction

General Concepts of Computer

- Digital computer is an electronic device that works on the binary number system (base-2 number system) that represents values using two digits, 0 and 1 (known as Binary Digit or Bit). Owing to its straightforward implementation as two state devices in electronic circuitry, the binary system is used internally by all digital computers.
- Bit or Binary Digit is the smallest storage element for computer
- One Byte consists of 8 bits. One byte is typically used to represent one character
- Computer data storage capacity is expressed as KiloBytes (1024 Bytes), MegaBytes (1024 x 1024 Bytes), GigaBytes (1024 x 1024 x 1024 Bytes)
- Many components of computer are timed devices and use a clock. A clock is pulse train of values 1 and 0 occurring at a specified frequency known as clock speed and measured in cycles/ second or Hertz. Operations are carried out on each clock pulse. Typical clock speed of a Personal Computer today is 3 Giga Hertz or more.
- Computers are able to support multimedia data consisting of text, picture and sound. Laptop is a portable Personal Computer

Computer Generations I to IV and Examples

- Thousands of dedicated valves (vacuum tubes) were used to create ‘First generation computers’. One example of ‘First Generation Computer’ is ENIAC (Electronic Numerical Integrator and Computer) built in USA around 1945. ENIAC publicly validated the use of electronics for large-scale computing, which was crucial for the development of modern computing
- At the end of the fifties the vacuum tubes were replaced by the Transistors, giving rise to the ‘Second Generation’ computers. By using the transistors and improving the machines and the programs, the computers got quicker and more economical.
- The explosion in the use of computers began with 'Third Generation' computers. This was the result of invention of the integrated circuit (or microchip). Computers built with integrated circuits came to be known as with 'Third Generation' computers.
- The invention of the microprocessor, by Intel company engineers led to the development of 'Fourth Generation' computers, which are built on microprocessors. These small, low-cost computers are owned by individuals and businesses and are now dominant in most market segments.

Advantages of Computers

- The main characteristics of a computer are its speed, accuracy, doing variety of tasks, doing repetitive jobs and automatic program execution
- In today's world everything we do has a computer element embedded. If we have the basic computer knowledge and training in computer, we can be upto date in the existing environment
- Using the computer, one can do in-depth analysis of data and take decision about the future course of action, in matter of seconds. We can plug the shortcomings in advance with appropriate measures.
- Electronic mail and web-browsing have spread rapidly to cover the whole globe. Now, a few keys on the computer would bring instant connectivity with our business partners.
- Computers provide highly accurate answers and calculations. Hence, computerized financial estimate and balance sheet are dependable irrespective of the persons who presented it.
- Computers help in Elimination of repetitive tasks and result in higher productivity and benefit to our Organisation.

Computer Fundamentals

Definition of Computer

Computer is an electronic device that

- Operates under control of instructions stored in its own memory unit.
- Accepts data.
- Processes data arithmetically and logically.
- Produces output of processing and stores results.

Understanding Hardware and Software

- Computer equipments including input devices, CPU, memory, output devices, auxiliary storage is known as Computer Hardware. Hardware is what we can see and touch. It is a set of physical components.
- Computer Software is a set of programs containing a detailed set of instructions that tells computer exactly what to do.

Parts of Computer and Functions

Central Processing Unit (CPU)

- The computer CPU executes instructions given in a program.

- The instructions fall into major types of input/ output instruction, arithmetic instruction, logic instruction, branch instruction and character manipulation instruction.

Main Memory

- Read Only Memory (ROM) is a storage where data is permanently written during fabrication, whose contents can be read but cannot be altered. Hence ROM is a non-volatile memory, which means that the memory contents are retained even when the computer is switched off. The same contents are available when switched on.
- Random Access Memory (RAM) is a storage where data can be repeatedly written and read. Hence RAM is a volatile memory which means that the memory contents are erased when computer is switched off.
- Main memory is required to store programs and the data processed by the programs. RAM is used as main memory in computers.

Secondary Storage

- Computers load the program instructions from hard disk to main memory (RAM) and then execute these instructions. Since RAM is volatile, the results of processing and data needs to be stored in permanent secondary storage media like hard disk.
- Hard disks are smooth metal plates coated on both sides with thin film of magnetic material. A set of such plates is fixed to a spindle one below the other to form a disk pack, which gets rotated. Magnetic heads do read / write operation on circular tracks.
- Compact Disk Read Only Memory (CD-ROM) is a disc of special plastic with a thin layer of aluminium applied to the surface. Information is created in the CD by creating pits on the surface by laser. Any data file (e.g. sound, video, or text) can be stored in a Compact disc. Many of the original Operating system and other system software are now being distributed in CD-ROM. Normally CDs support about 700 Mega Bytes of storage. CD-R is a write-once/ read-many media, CD-RW is a media where data can be erased and rewritten.
- Digital Video Disk (DVD) is a medium where a number of disks are bound together to offer several layers of data. Information is created in the CD by creating pits on the surface by laser. Each disk layer is accessed by the device for read or write by changing the intensity of the laser to different levels. Here also we have read and read-write versions available. The capacity of a DVD is roughly four times that of a CD-ROM. CD drives that can handle CD read or writes and DVD read is known as Combo Drive.
- Magnetic tape drive consists of a spool where a magnetic tape is wound. Between 2 spools, a number of read/ write heads are mounted, for reading or storing information on independent tracks.
- Digital Data Storage (DDS) media like Digital Audio Tape (DAT) has been adopted for general data storage, storing large volume of computer data. In appearance it is

similar to a compact audio cassette, using 4 mm magnetic tape enclosed in a protective shell, but is roughly half the size. For example DDS2 is around 40 GB, DDS-4 is around 72 GB etc.

- Pen Drives are flash memory data storage devices integrated with a USB (universal serial bus) connector. They are typically small, lightweight, removable and rewritable. Flash memory is non-volatile computer memory that can be electrically erased and rewritten in large blocks. To read or write data, the pen drive must be connected to a USB port and draw all necessary power from the supply provided by that connection.

Input Devices

- Input devices are used to feed data into computer. Examples of input devices are Keyboard, mouse, bar code reader, microphone for sound recording etc. Devices like hard disk, floppy disk, CD-ROM, pen-drive, touch-screen monitor are used for input when they contain data. With advanced wireless networking, it is possible to have a wireless handheld terminal with limited functionality for use in locations like slab yard.

Output Devices

- Output devices give data output from computer. Examples of output devices are monitor, printer, speaker etc. Monitor for computer can be a CRT (Cathode Ray Tube) or TFT (Thin Film Transistor Technology). TFT monitor has tiny transistor for each picture element on screen and has very fast re-drawing of display. Devices like hard disk, floppy disk, CD-RW, pen-drive, touch-screen monitor are used for output when data is to be stored in them or displayed on them. Other output devices are various types of printers like Dot matrix, laser jet, Ink jet and line printers.
- Any device that we connect to our PC needs to communicate and for this a software known as driver software is necessary to be installed in the PC. Driver software is responsible for our PC handshaking with the device. For example, If a PC-network has a printer installed, than all PC in the network having driver software of the said printer (Device Driver) installed in them, can take printouts.

10.2 Applications of Computers in Steel Industry:

Some of the functions computerized are given in the following sample list

Finance & Accounts

- Bills & Claims processing
- Stores & Sales accounting
- Stock and Asset management
- Payroll Processing
- Budgeting and control

Materials Management

- Item Master & Vendor Master management
- Indenting & Procurement
- Receipt, Storage, Issue, Inventory

Human Resource

- Employee Master & Reporting Relationship
- Nomination Management
- Recruitment, Promotion
- Separation & Transfers
- Performance Management System

Process Control Applications

- Optimization of coke oven operation for minimum energy use, maximum coke production & coke quality.
- Control of moisture, charge level control, composition control, minimum fuel for Sinter Plant operations.
- Optimisation of stove operation, heat and mass balance of Blast Furnace.
- Prediction of oxygen blowing, flux additions in BoF.
- Secondary cooling control, cut length optimisation in caster shop.
- Reheating furnace control, mill setup, gauge control, width control, in-process material tracking in Mills

10.3 Operating Systems

Definition of Operating System

- An Operating System (OS) is the software that manages the sharing of the resources of a computer and provides an interface to access those resources. An operating system works on system data and user input, and responds by allocating and managing tasks and internal system resources. An operating system performs basic tasks such as controlling and allocating memory, controlling input and output devices, scheduling the processing of jobs, facilitating Computer networking and managing files.

Examples of Operating System

- Examples of Common Operating System are MS-DOS, Windows, Linux, and Solaris.
- Most of the Operating systems work in timesharing mode, where all the jobs to be done are put in queue and CPU time gets shared among these jobs.

- Batch jobs (or offline jobs) are set up so they can be run to completion without human interaction, with all input data preselected through commandline or program parameters. Example of a batch job is payslip preparation for all employees.
- "Online" or interactive jobs are those which prompt the user for input. Example of online jobs is receiving/ payment and recording of cash transactions, e-payment of salary, various indenting systems, railway reservation system etc.
- A real-time application is one in which the correctness of the computations not only depends upon the logical correctness of the computation, but also upon the time at which the result is produced. If the timing constraints of the system are not met, system failure is said to have occurred. Example of such systems are optimized cut-length set point download in caster process, plant status display etc.
- The applications that we execute using computer in steel industry are a mix of the above types of jobs.

10.4 Office Automation Software

MS WORD

- A file created by WORD program is known as a document and contains .doc/.docx file extension. Word program is typically used to write note-sheet, Inter-Office-Memo etc.
- Command File New opens a new document, whereas File Open opens an existing document. Document needs to be saved to retain the modifications.
- It is possible to give margins, insert table, align text, give text font, text colour, fill with colours, draw shapes, insert picture, draw lines, give paragraph spacing, bullet / numbering, do spelling check.
- Command File Print helps us to print the document in a printer.
- Command File Exit makes us close and exit from Word program.

MS EXCEL

- A file created by EXCEL program is known as a Workbook and contains .xls/.xlsx file extension. One Workbook can have a number of Worksheets. EXCEL program is typically used to make analysis of data, do calculations using formula, create graph etc
- Command File New opens a new Workbook, whereas File Open opens an existing Workbook. Workbook needs to be saved to retain the modifications
- Data in each Worksheet is filled in cells which have row (1,2,3 etc) and column (A,B,C,D etc) addressing (A23, V56 etc). Each cell can take data like numerical,

character, function or formula. The results of formula get calculated automatically on change of data.

- It is possible to draw graphs like X-Y, bar-graph, line-graph, pie-chart etc, sort data, do matrix operation, do query on data.
- Command File Print helps us to print the data / graph in a printer.
- Command File Exit makes us close and exit from EXCEL program.

MS POWERPOINT

- A file created by POWERPOINT program is known as a presentation and contains .ppt/.pptx file extension. PowerPoint program is typically used to prepare slide presentation.
- Command File New opens a new presentation, whereas File Open opens an existing presentation. Presentation needs to be saved to retain the modifications.
- It is possible to choose layout, background for slide, insert or duplicate slide, insert picture from file, setup slide-show with animation and auto or manual slide transition.
- PowerPoint has features to include notes as part of presentation to help the presenter.
- Command File Exit makes us close and exit from PowerPoint program.

Intranet and World-Wide-Web

- An Intranet is a company-specific network that uses software programs based on the Internet TCP/IP protocol and the web browser. Intranet is the application of Internet technologies within an organization private LAN and web servers. Example of intranet is the internal mail system. Intranet increases internal communication, reduces paper distribution cost and works on open protocols.
- Internet is "network of networks" that consists of millions of smaller domestic, academic, business, and government networks, which together carry various information and services, such as electronic mail, online chat, file transfer and web pages.
- The World Wide Web (www) is defined as the universe of network-accessible information, accumulation of human knowledge, consisting of all the resources on the Internet.

Day-to-day applications using web like e-mail, web-browser etc

- E-mail: Electronic mail or e-mail is a store and forward method of composing, sending, storing, and receiving messages over electronic communication systems

like intranet or internet. E-mail sometimes leads to unwanted messages ("spam"). E-mail contains address of the sender and the address of the receiver. We can use internet e-mail systems like yahoomail.com, rediff.com, gmail.com etc without extra expense. Our SAIL/ plant-based e-mail systems also allow us to send to / receive mails from anyone in the world.

- A web browser is a software application that enables a user to display and interact with text, images, videos, music and other information located on a Web page at a website on the World Wide Web or a local area network.
- A web based search engine is an information retrieval software system designed to help find information stored in a computer system on World Wide Web. Example is www.google.co.in, www.yahoo.com etc.
- A website is a location on the World Wide Web, that contains a home page which is the first document users see when they enter the site and multiple links. The site is invoked by giving the location address on the browser software. Each site is owned and managed by an individual or an organization.

  Examples of a few important websites

  - SAIL : www.sail.co.in
  - Indian Railway information: www.indianrail.gov.in
  - Internet railway booking: www.irctc.co.in
  - The Hindu newspaper www.thehindu.com
  - Searching for specific information www.google.co.in
  - Railway eTicketing System www.irctc.co.in

Advantages of Web

- Globally establish our company's presence round-the-clock, provide technical support.
- Advertising and Multimedia content.
- Provide quick business information and better Customer service.
- Product catalog, tendering, sales.
- Electronic payment.

Meaning of Computer Virus and its Effect

- Computer viruses are small software programs that are designed to spread from one computer to another and to interfere with computer operation.
- A virus might result in malfunction of the PC, corrupt or delete data on our computer. Viruses are easily spread by attachments in e-mail messages and Pen drive. It is essential that we never open e-mail attachments unless we know who it's

from and we are expecting it. Pen drive must be scanned with a antivirus software when it is put to use.

Anti Virus Program

- To help avoid viruses, it's essential that we keep load in our computer the latest antivirus tools. We also have to follow a few basic rules when we surf the Internet, download files, and open attachments. Some of the popular anti-virus programs available are Symantec, AVG, NORTON etc.

Introduction to E R P

ERP – Enterprise Resource Planning - is a computer software that attempts to integrate all departments and business functions across a company or an enterprise onto a single computer system. ERP a single, integrated software program that runs off a single database so that the various departments can more easily share information and communicate with each other. It is a software package that promotes seamless integration of all information flowing through a company adopting Best Global Business Practices. An ERP system typically has modular hardware and software units that communicate on a Local Area Network. It enhances tracking, financial reporting, employee benefits and business performance.

Some of the ERP products are SAP, Baan, ORACLE, Peoplesoft and JD Edwards. SAIL Corporate Management has finalized SAP as the ERP product to be implemented by all SAIL units embarking on ERP implementation initiative. As per the corporate approval, we have been empowered to procure SAP licenses for SAP ECC 6.0. SAP stands for Systems Applications and Products in Data Processing. SAP is highly integrated and provides immediate, real-time updates of all related information to all the organisational functions. It has multiple currency and language capabilities. SAP is also designed to support company's global business Operations.

In Steel industry the typical functions that are computerised include Production Planning, Order processing, Quality, testing, certification, Road rail movement, dispatches, invoicing, Equipment classification, repair planning, preventive maintenance, Engineering shop activities, Material management, Marketing, Financial accounting and costing.

Plant with ERP in place, has set up ERP data centres housing servers, firewalls, network switches, LAN, Storage system, with necessary cabling, physical access control, etc. Generally there will be Primary Data Centre and Secondary Data Centre at different geographical locations. ERP installations in SAIL normally have 2 data centres in the same location but as separate physical installations with real time data mirroring so that in case of one data centre going down the second data centre automatically takes over and the user is not aware of the switchover.

For further security of data ERP systems have a backup data centre at a Disaster Recovery Site at a separate geographical location (normally a separate seismic zone) with a changeover time of a few hours and minimum data loss to ensure business continuity. Redundant cables are laid for disaster recovery purpose. Each plant has also taken up upgradation of network devices and links to support the requirements of the ERP. The network is designed to have diverse routes to create redundancy, with network interface points with other networks like Metal Junction, SAIL network and internet, with network security and network management features.

10.5 Do's and Don'ts

Computer Standard Operating Procedures

Do's

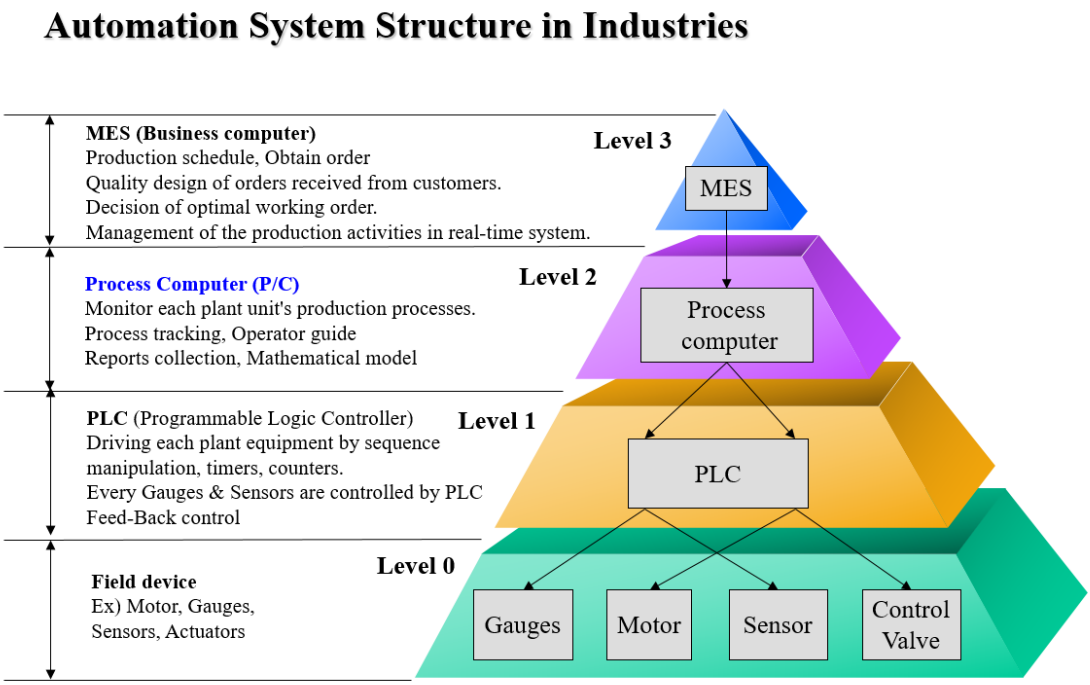
- Input power supply with proper earthing is very essential. It is recommeded to check and correct the voltage especially neutral wire to ground voltage (should be less than 5 volt) periodically.
- When switching ON computer, first start the UPS (Uninterruptible Power Supply), then monitor and then the Computer. While switching OFF switch OFF CPU, monitor and then UPS.
- Save all work and Shutdown the PC in case of main power failure and the UPS is supplying power to PC.
    - UPS (Uninterruptible Power Supply) takes raw AC input power and gives output of steady 230 V AC power supply. There is a battery in UPS which sustains power to PC for about 20 minutes after power fail. This time is sufficient for us to save our work and do normal shutdown. It is also possible to connect UPS port to a PC port and automatically shutdown computer in case of power failure using a special program
- Use the Start Button on the Windows Taskbar to shutdown your computer. It is also necessary to first save any files you were working with and close all running applications. This is called a clean shutdown.
- Connect and power on all peripherals (printer, monitor, scanner, and modem) before powering on the computer.
- Keep keyboard, screen, printer and other peripherals clean. Use plastic covers to protect computers and peripherals when not in use. Keep media like floppy, CD, DVD in dust-free cover.
- Logoff the computer when you have finished or are leaving for an extended period of time.
- Always report any abnormality to concerned agency and keep log.
- Use an Antivirus program and update it frequently.
- Backup your data like email, office documents in a pen-drive or CD regularly.

- Use hard-to-guess password and do not keep password information in local hard disk.

Don’ts

- Don't Switch external devices on and off several times hoping that this may be a cure.
- Don't Eat or drink near the keyboard and mouse.
- Don’t download or install any software without prior approval.
- Don’t open emails or email attachments from senders you do not recognize.
- Don’t move PC peripherals in power-on condition.

10.6 Digital Transformation



Level-2 automation is used for complex processes to optimize the process based on software modelling. The level-2 system also generates plans and schedules for the production and process. Level-2 system takes all the inputs from level-1 system and generates output and set points for the operator as well as for level-1 system.
There are two types of software model i.e.
• Off line advisory model - In this type of model the level-2 system gives advice to the operator based on calculation fortuning the process.
• On line model - In the on-line model the level-2 system directly manipulates the set points of level-1 controller based on calculations from the model.

SYSTEM ARCHITECTURE AND COMMUNICATION DIAGRAM

In the following text a preliminary architecture of the Coking Process Management System is given. Most significant parts are shown in Figure 3.1.

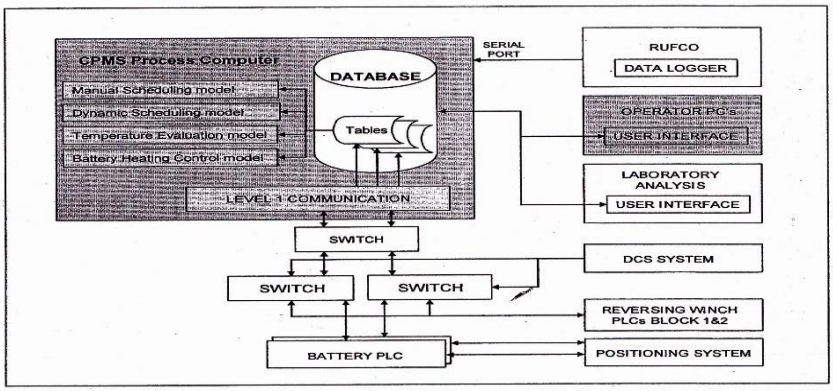


Figure 1 CPMS logical structure and main data flows

Level 2 Automation Systems of BF

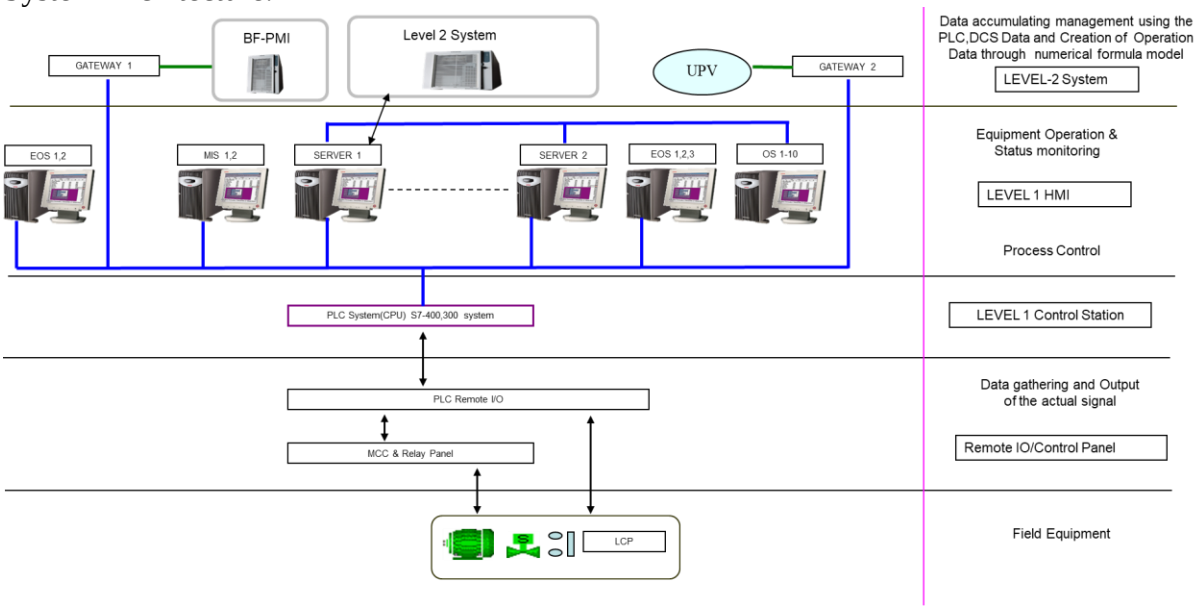
Level-2 Process Supervisory System is the sophisticated supervisory system placed above control automation layer (Level-1). The primary function of the Level-2 Process

Supervisory System is to enhance operational efficiency, product quality, and safety through Process Optimization Models.

Key Components of Level-2 System:

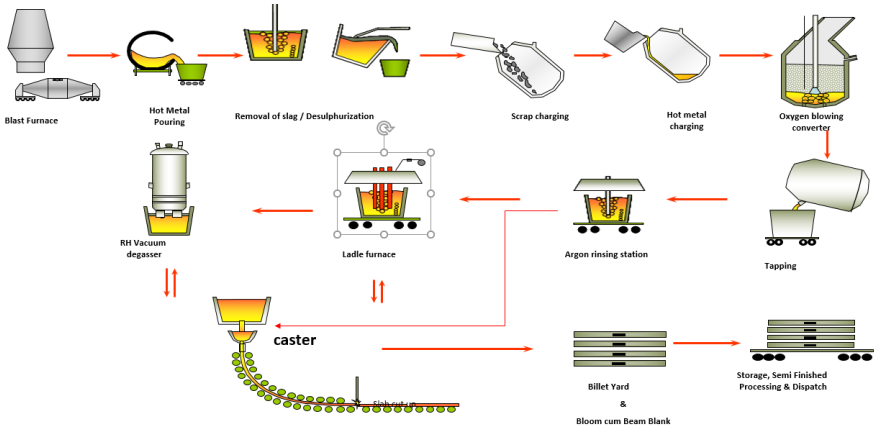
Supervisory Expert System	Process Reporting system	Data logging & archiving	Process Reporting system

System Architecture:

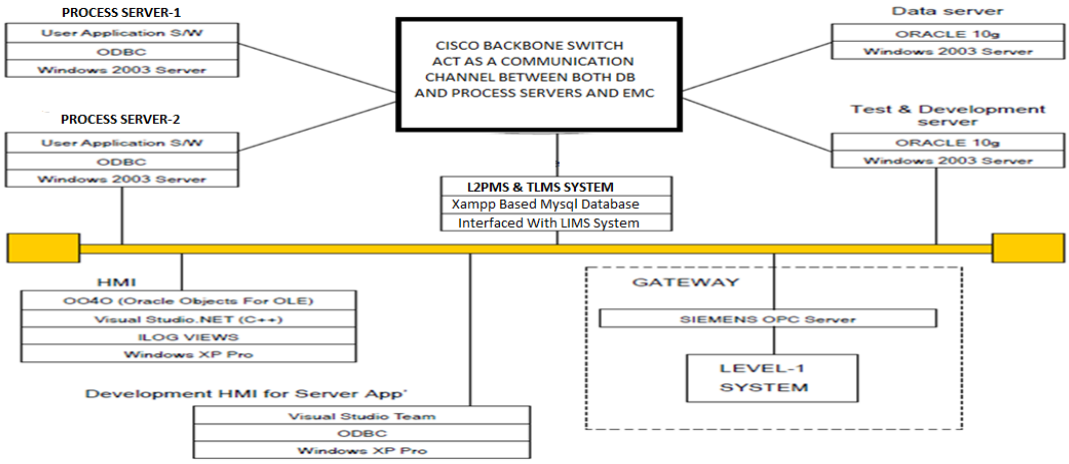


Level 2 Automation Systems of SMS Complex

PROCESS FLOW DIAGRAM OF BOF-CCP COMPLEX



Level 2 Architecture



Functions of Level-2 Automation

- Data Exchange
- Process Control and Optimization
- Production Planning
- Reporting

Benefits of Level-2 Automation

- Uniform Practice
- Improved Process hence quality
- Reduction in Energy and alloying material consumption
- Optimized Treatment time
- Traceability
- Transparency of operation

Industry 4.0

There have been four industrial revolutions throughout history, each marked by significant advancements in technology, production, and society. First Industrial Revolution was characterized by the mechanization of production, with the introduction of steam power and

the development of textile manufacturing machinery. Second Industrial Revolution happened with introduction of new technologies such as electricity, the internal combustion engine, and the telephone. These innovations enabled the growth of new industries such as steel production and transportation and led to increased globalization and urbanization. Third Industrial Revolution was marked by the introduction of digital technology, including computers, the internet, and telecommunications. This led to the growth of the information age, and enabled new forms of communication, commerce, and entertainment. The fourth industrial revolution is still ongoing and is expected to continue to transform our world in profound ways. This has brought a wave of technological advancements and transformations to the manufacturing industry. It is characterized by the integration of new technologies such as the Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), robotics, and automation, among others. The main objective of Industry 4.0 is to optimize the production process by creating a smart and connected manufacturing ecosystem. These technologies are transforming the way we live and work and are enabling the creation of smart and connected ecosystems.

Digitization, Digitalization and Digital transformation

Digitization, digitalization, and digital transformation are all related concepts, but they refer to different processes.

Digitization refers to the conversion of analog information into a digital format, such as scanning paper documents into electronic files, or converting analog audio or video recordings into digital formats. The digitization process involves taking physical information and turning it into a digital representation that can be stored and manipulated using computers.

Digitalization is the process of using digital technologies to transform how businesses operate and deliver value to customers. It involves the adoption of digital technologies, such as cloud computing, mobile devices, and software applications, to improve business processes, automate tasks, and increase efficiency.

Digital transformation is a broader term that encompasses both digitization and digitalization, but also involves a fundamental rethinking of how businesses operate and create value. Digital transformation involves using digital technologies to create new business models, products, and services, and to fundamentally change how businesses interact with customers, partners, and employees. It involves a holistic approach to innovation, with a focus on leveraging digital technologies to achieve business goals and drive growth. This is the integration of digital technology into all areas of a business, resulting in fundamental changes to how the business operates and delivers value to customers. It involves the adoption of new technologies, processes, and business models to drive innovation, efficiency, and growth.

Design Principles

Industry 4.0 and digital transformation are based on a set of principles that guide their implementation. Some of these design principles include:

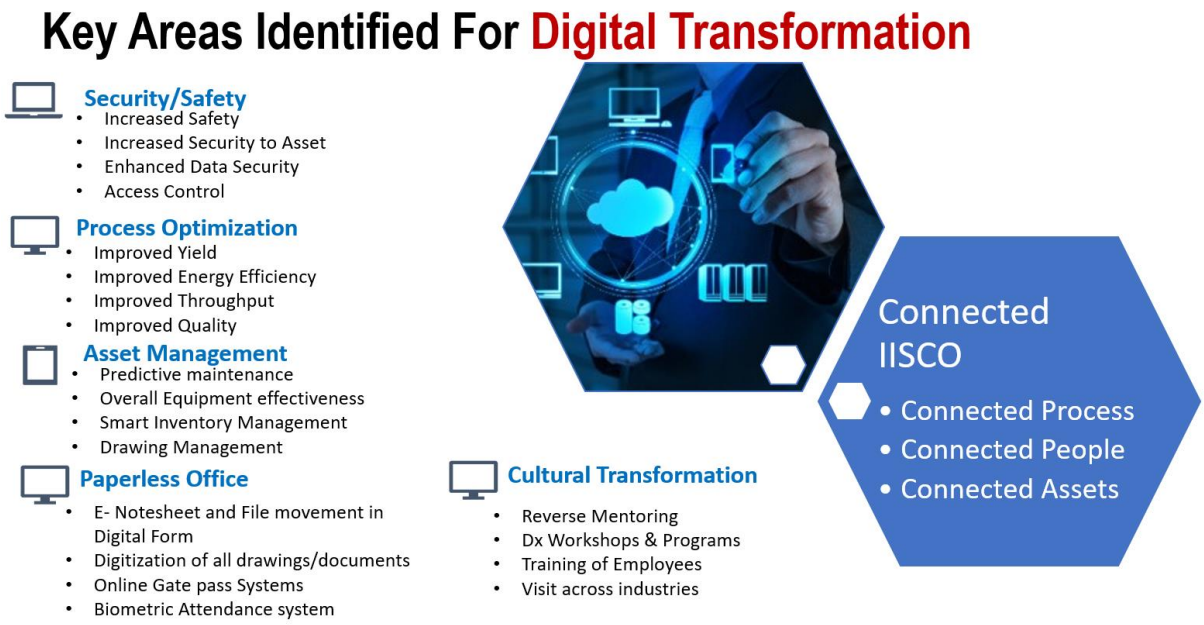
- Interoperability: This principle involves the ability of machines, devices, sensors, and people to connect and communicate with each other.

- Virtualization: This principle involves the creation of digital models of physical objects and systems, which enables businesses to simulate and test new products and processes before they are actually implemented.
- Decentralization: This principle involves the distribution of decision-making power across various levels of the organization, which enables greater agility and responsiveness.
- Real-time data: This principle involves the use of real-time data to monitor and optimize production processes, enabling businesses to make faster and more informed decisions.
- Service orientation: This principle involves the focus on creating value for customers through the delivery of innovative services and solutions.

Emerging Technologies

Industry 4.0 and digital transformation are driven by a range of emerging technologies. Some of the most important ones include:

- IoT: The Internet of Things involves the connection of devices and sensors to the internet, enabling the collection and analysis of vast amounts of data.
- AI and ML: Artificial intelligence and machine learning involve the use of algorithms to analyze data, identify patterns, and make predictions.
- Robotics: Robotics involves the use of machines to automate repetitive and dangerous tasks, increasing efficiency and reducing costs.
- Augmented Reality (AR) and Virtual Reality (VR): AR and VR technologies enable businesses to simulate and visualize products and processes in a virtual environment, enabling faster and more accurate decision-making.
- Additive manufacturing: Additive manufacturing, also known as 3D printing, involves the creation of products by layering materials on top of each other, enabling greater flexibility and customization in production.
- Cybersecurity: Cybersecurity is a critical component of digital transformation. As organizations adopt digital technologies to transform their business operations, they are also exposing themselves to new risks and threats related to cybersecurity. Cybersecurity refers to the protection of digital assets, such as computer systems, networks, and data, from unauthorized access, theft, and damage. Cybersecurity is essential for protection of sensitive data and critical infrastructure, compliance with regulations and maintaining customer trust. To achieve cybersecurity in digital transformation, we must adopt a proactive and holistic approach to security. This includes implementing measures such as access controls, encryption, and security monitoring, as well as educating employees about cybersecurity best practices. It also involves building a cybersecurity culture that prioritizes security throughout the organization, from the top down.



Details of High Impact Projects Completed

Development of Online Platforms viz. of Unified Plant View(UPV), Laboratory Information Management System (LIMS), Torpedo Ladle Management System(TLMS) has been done with in-house resources.

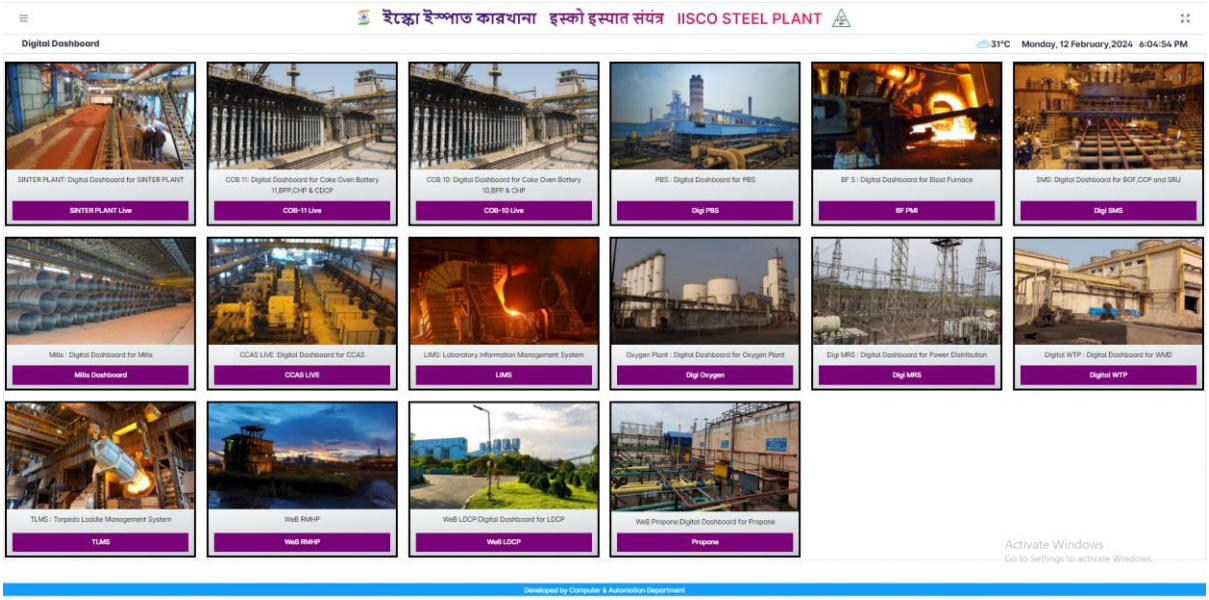
Unified Plant View (UPV) is a single, comprehensive and integrated view of all the plant operations. With Unified Plant View, information from different data silos of various systems and applications are brought together into a single interface, making it easier to manage and monitor your plant operations. The system includes process, production, and techno-economic data of different production and auxiliary units, providing a complete and real-time understanding of the state of the plant.

Unified Plant View is a web based online application which captures real time process data and status of equipment and shops from DCS/PLC/Level 1/Level2 systems. UPV can be accessed from LAN inside the plant and over smart devices (Mobile/Tablet/Laptop) from outside the plant with proper authentication.

Digital Dashboards

Web-based monitoring system of all production and auxiliary units which provides real-time and archived data of critical process parameters for efficient monitoring and management of the entire production process. Operators and managers can quickly identify areas of concern, track key performance indicators, and make data-driven decisions to enhance overall efficiency and performance.

Digital Dashboard for RMHP (WeB- RMHP), Sinter Plant (Sinter-DI), COB-10 & COB-11 (COB LIVE), PBS (Digi-PBS), BF #5 (BF-PMI), LDCP (WeB-LDCP), CCAS (CCAS-Live), SMS (Digi-SMS), Mills (Mills-Online), Oxygen Plant (OxyOnline), WMD (Digital WTP), MRS (Digi MRS) have been developed.



Benefits:

- Real time Monitoring of Process, Production & CMS for Critical Equipment
- Digital view of important process
- Machines operation in real-time

Process Models & Digital Twin

Process Models Developed In-house

Basemix Mass Balance Model	Sinter Quality Prediction Model	Burden Calculation Model	Predictive IGV model for Turboblowers
Burden Distribution Model	Shaft Track Model	Heat Balance Model	Performance Prediction of HP Heaters
Stave Condition Monitoring	Heat Flux Model in BF	Tuyere Health Management	
Cohesive Zone Prediction Model	Hearth Management Model (DCI)	Production Forecast Model in BF	
Operational Index Model in BF	Heat Pacing Model in SMS	Ferro Alloy Consumption Model	

Digital Twin for BF-5

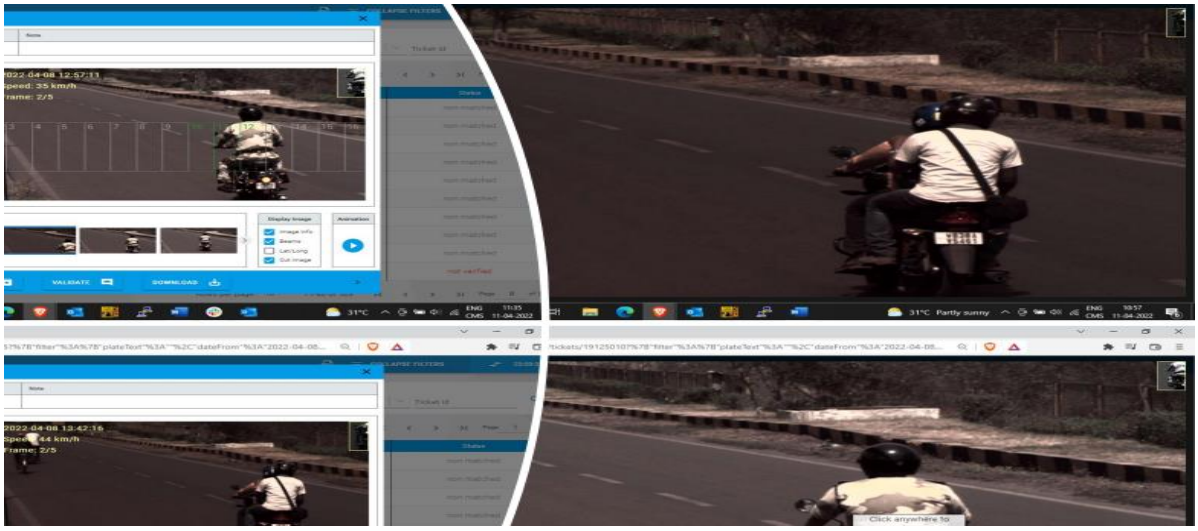
3D Visualization based System having Detailed view of Blast Furnace Process, & Its Equipment in real-time vis-à-vis change in furnace parameters over a period of time.

Digitalization in Safety, Security & Surveillance Systems at ISP

Vehicle Tracking System (VTS)
300 nos. of portable GPS devices have been procured. All road routes of the plant have been mapped. Route taken by vehicle along with information on speed/stops of vehicle is displayed online on real time basis in a large screen in control Room.
Provide 24*7 monitoring of outside vehicles entering the plant for analysis purposes
Pop-up messages for speed violation, undue stoppages and customized Report generation facility is available for deriving useful intelligence inputs.
Vehicle Tracking system for improving productivity, efficiency and profitability.

Drone Surveillance at ISP
One no. of Drone has been procured with requisite DGCA clearance. Helps in surveillance of remote and strategic locations during daytime and at night. Handy in gathering information as well as survey of inaccessible locations where CCTV is not installed. Augments existing CCTV based Security system.

Vehicle Speed Monitoring System
Installation of speed Enforcement System and awareness system has been done at 09 locations.



Chapter – 11

MINING

11.1 Introduction

Steel is an alloy made by combining iron and other elements. Varying the amount of alloying elements and the form of their presence in the steel controls qualities such as the hardness, ductility, and tensile strength of the resulting steel. Different types of raw materials required for steel making are :

a) IRON ORE
b) COAL
c) LIME STONE
d) DOLOMITE
e) MANGANESE
f) QUARTZ

Ratio of Raw material consumption in steel making.

Iron Ore : Coal : Limestone/Dolomite = 1: 1 :0.2

Quality of raw materials

		Lump	Fines
a) Iron ore-	Fe%	62.30 – 63.20 %	62.0 – 63.0 %
	Alumina-	2.60 – 3.00 %	2.80 – 3.30 %
	Silica -	1.80 -- 2.80 %	2.30 – 3.60 %

Name of mines of BSL/RSP/BSP

BSL

1. Kiriburu Iron Ore Mine
2. Meghahatuburu Iron Ore Mine
3. Gua Ore Mine
4. Manoharpur Ore Mine
5. Bhawanathpur Limestone Mine
6. Tulsidamar Dolomite Mine

1. Ramnagar Colliery
2. Chasnala Colliery
3. Jitpur Colliery

RSP

1. Bolani Ores Mines
2. Barsua Iron Mine
3. Kalta Iron Mine

4. Taldih Iron Mine

BSP

1. Dalli Mechanised Mine.
2. Rajhara Mechanised Mine
3. Jharandalli Mechanised Mine
4. Dalli manual Mine
5. Mahamaya Iron Ore Mine
6. Dulki Iron Ore Mine
7. Kalwar Nagur iron Ore Mine
8. Rowghat Mine
9. Nandini Limestone Mine
10. Kuteshwar Limestone Mine
11. Hirri Dolomite Mine

Exploration-:

Exploration is the first step for planning of any mine and its also decides the life of any mine. Before planning for Mining in any mine lease, exploration work is being done first at the grid of 200m*200m and after that at 100m*100m to confirm the quality & quantity of ore in that mines. Based on these exploration hole blending ration, excavation plan etc is decided.

11.2 Mines Operation

Drilling

Breaking of ground is necessary for easy excavation, loading, transporting and crushing of the material i.e. (RoM) in the crushing plant. For breaking the ground drill holes have to be drilled and blasted. For this purpose a place is almost leveled with help of dozer. Depending on the bench Height and capacity & size of drill M/C, spacing and burden of holes are determined. To avoid toe formation in the bottom of benches, an extra drilling of 10% of Bench height is done, which is called sub grade drilling.

A thumb rule which is in practice are as follows ;

a) The burden of drill holes is 200 to 300 times dia of the holes.
b) Spacing is 1.2 times of burden.
c) Subgrade drilling -10% of bench height.

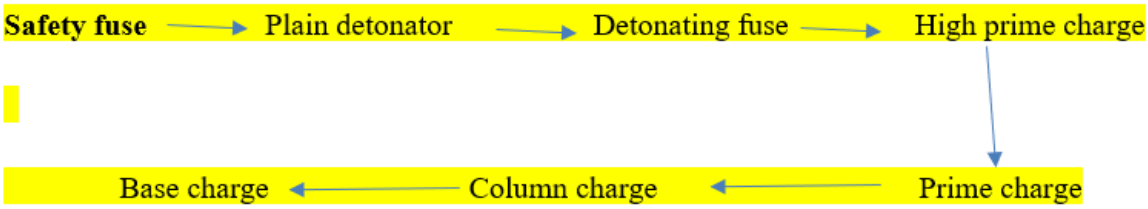
Marking of holes done on the surface in a square or staggered grid pattern and drill is placed and allowed to drill. Only wet drilling shall be practiced using auto dust collector or curtain.

Blasting

Blasting is done to ~~provide~~ get fragmented rock mass for easy excavating by shovel or excavator. It's the lifeline of a mines operation. Different types of explosives are used for rock fragmentation.

a) High prime charge
b) Prime charge
c) Column charge
d) Base charge
e) Site Mixed Emulsion (SME) Explosive

The basic blasting circuit (connection) for an open cast mines is as under:



Now a days practically all the big mines are using "NONEL" in place of Detonating Fuse for blasting to avoid the air blasting and minimizing the ground vibration. **Nonel** is a shock tube detonator designed to initiate explosions, generally for the purpose of blasting of rock in mines and quarries. Instead of electric wires, a hollow plastic tube delivers the firing impulse to the detonator, making it immune to most of the hazards associated with stray electrical current. It consists of a small diameter, three-layer plastic tube coated on the innermost wall with a reactive explosive compound, which, when ignited, propagates a low energy signal, similar to a dust explosion. The reaction travels along the length of the tubing with minimal disturbance outside of the tube

Advantage of using nonel technology :

a) Nonel tubes do not destroy the bubbles energy of explosives whereas in detonating fuse the flames traveling is in contact with explosives destroying it's bubble energy. In this way by saving the explosive energy it leads to cost saving and better fragmentation.
b) Each hole gets blast at different timing thereby extra free face is created leading to better fragmentation
c) Less throw and better muck pile

d) Less vibration

Operation schedule/deployment/monitoring

Operation schedule is a daily/weekly operation plan taking into consideration of quality parameters &targeted production. It's match between available benchwise blasted material quality, quantity and available shovel combination.To get a desired result the benchwise shovel operation must be monitored through out the shift.

Quality/monitoring

It's a desirable practice that wining of ore shall commence after blasting of ore body. Before blasting all extraneous material shall be removed. Bench-wise quality excavation is monitored by scheduling deployment of shovels in a shift. The shift operation should follow the plan for getting the desired quality.

11.3 Safety

The safety of persons employed in mines and the equipment are the responsibilities of the statutory persons specially deployed as per guidelines of DGMS viz. Mining Mate/ Foreman / Electrical supervisors /Astt. manager / Mines Manager &other engineers working in the mine. There are hazards associated with blasting, transportation of coal/ore, use of electrical energy. As a general rule all persons working in mines must wear personal protective equipment's (PPE), follow general principles laid down in permission letters by the Directorate General of Mines Safety Official as per MMR 1961/CMR2017.General condition of mines atmosphere shall be congenial, airborne dust shall be suppressed at the place of formation by water sprinkling etc..

All Equipment's like Excavator, Dozer, Drill etc. shall be kept at a safe distance during blasting to avoid damage from flying fragments.

Shovels shall be so placed and operated that there shall not be any undercuts and over hangs. Quarry lighting/mine lighting shall take care of glare also. Mines shall be well lighted so that movement of men and machine are not disturbed.

Separate walkway for men shall be established. Traffic of dumpers/truck shall be controlled and a separate haul road shall be established for light vehicles.

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Chapter – 12

INSTRUMENTATION & PROCESS CONTROL

12.1 Introduction

Instrumentation & Process Control is one of the core functions in any integrated steel plant across various processes and equipment.
Instruments in the industry form the basic sense organs for the different parameters and provide information about the process, production, quality, and also safety. The acquired information is processed into workable logics and necessary outputs are delivered to meet the quality and quantity norms. Instrumentation works to facilitate the process to operate at optimum to maximum efficiency at reasonably low resource consumption within the design limitations.

An integrated steel plant is a conglomeration of various industrial units operating in a programmed mode to meet the objective of production of steel to international standards. Application of instruments and weighing systems are spread throughout the length and breadth of the plant. To cater to the needs of different units of the plant, the department is functionally divided into different areas/zones:
Each section/zone has a team of engineers and technicians working in close tandem with the operation personnel on a round-the-clock basis for meeting the department objective to provide reliable measurements, controls, interlocks & protection systems for safe operation and resource optimization ensuring enhanced quality and productivity.

Major activities in Instrumentation are:

1. Round the clock Measurement and Control of process parameters across all sections of Plant.
2. Maintenance and upkeep of various instruments in different areas.
2. Evolving efficient control strategies for improvement in the product quality and process yield.
3. Developing suitable optimization techniques and implementation of these techniques on real time and continuous basis.
4. Emphasis on improving process efficiency and reduction in cost of production.
5. Developing methods of analysis of the process and retrofitting the suggested actions there upon.
6. Providing innovative and cost effective solutions for various operational problems.
7. Coordination and active involvement in implementation of all new projects.
8. Enriching the human skills by imparting technical and human values.

9. Coping up with the dynamic and challenging technological advancement.
10. Maintaining the ISO standards for testing and calibration of instruments.
11. Realization of Interlocks/Protections corresponding to process alarms/tripping set points.
12. Maintenance of Fixed/Portable type CO Detectors and LEL(Methane) Detectors.

For achieving the above, the department uses standard and proven sensors, test & master test equipment certified by NABL Accredited Laboratories, latest microprocessor based controllers, Programmable Logic Controllers, Distributed Digital Control Systems, Computerized Data Acquisition Systems and Analytical equipment for the analysis of various liquid and gases for process optimization and human safety.

Indigenous tailor made developments in the field of combating obsolescence of technology and equipment, process modeling and advanced control systems have taken a front seat in refining the performance of the department.

12.2 Instrumentation and Process Control in various Departments

Central Instrumentation Laboratory

Instrumentation Department is equipped with a centralized laboratory to cater the repair and calibration needs of instruments installed throughout the plant.

Process instruments and test instruments are calibrated in the Instrumentation Laboratory against standards traceable to national/ international standards to meet the requirement of ISO 9001:2015 Quality Management System.

Planning and Training

Planning section co-ordinates the various activities related to procurement of material and services for the different sections of the Department. Compilation of annual requirement of materials, preparation of specifications, process for codification, preparation of indents, scrutiny of offers, and collection of material from store and issue to concerned sections are handled by this section.

Training programs to refresh and update the technical knowledge of the workforce is continuously taken up by the Department through this section. Being a specialized field, many in house programs are designed and conducted throughout the year. These programs are updated and upgraded depending on the technological needs. New programs are designed to meet the increasing need of latest concepts of Instrumentation & Process Automation.

All the aforesaid activities are carried out in SAP Platform.

Field Maintenance Wing

Field Maintenance Group carries out field jobs related to impulse pipe and cable repairs, laying of cable & conduits, new installation of field sensors, in-situ repair and calibration of field Instruments, mechanical jobs like fabrication of orifice plates, junction boxes and pull boxes, cabinets for instrument protection, modification and capital repair jobs. This

wing takes up all Mechanical, Electrical, and Civil nature jobs required for Instrumentation.

Coke Oven & Coal Chemical Section.

This plant produces metallurgical coke and various by-products like TAR, Phenol, Naphthalene, Benzene, Toluene, Xylene etc. The process consists of blending of different stocks of coal, crushing to its desired fineness weighing and heating it in ovens at desired temperature in absence of air for a given period. During the process Coke oven gas is produced, from which valuable organic by-products are extracted.

The main areas in CO & CCD sections are Coal Handling Units, Coke Oven Batteries, Coke Sorting Units, Exhauster House, Tar Plant, Benzol Recovery Plant, Benzol Rectification Plant, Ammonium Sulphate Plant, Acid generation Unit, Naphthalene Stripping Plant, Ammonia Still, Biological Oxidation & Demand (BOD) Unit etc.

This complete section of CO & CCD is equipped with various measurement and control systems as given below. The role on Instrumentation in Coke Ovens & Coal Chemical area is more crucial because of the complex process and handling of inflammable chemicals like Benzene, Toluene, Xylene etc.

- Electronic weigh feeding systems with monitoring, controlling and setting the flow of coal for all the silos along with necessary protections and interlocks

- Distributed Control System (DCS) or PLC based control system for Coke Oven Batteries coking process optimization.

- Hydraulic actuators like Reineke & Askania with Microprocessor based system for CO Gas Pressure control in Battery GCM (Gas Collecting Mains)

- Control of important parameters like High Pressure Ammonia Liquor and Gas Boosting Station delivery pressure Control is done through VFD.

- Distributed Control System (DCS) or Microprocessor based controllers for By product generation units.
- Pressure/Differential Pressure transmitters with remote sealing in Tar handling units Plant.
- Pneumatic Final Control elements

Sintering Plant Section.

Raw material for sintering plant is obtained from RMHP, Coke Ovens, RMP, Mills Scale, Storage bins. They are mixed in proportion and fused in furnaces. Sinter is send to Blast Furnaces.

The major measurement and control include:

1. Belt Weighing/ Rate feeder control in stock bins
2. Exhauster control through DCS/PLC.

3. Machine protection and process interlocks/protections.
4. Hammer crusher interlocks and protection.
5. Temperature & Vibration measurement in Exhausters.
6. Nucleonic type Moisture measurement Analysers.
7. Process optimization, quality & operator guidance are the key areas where Instrumentation systems play a role in Sintering Plant.

The important measurements are as follows:

1. Bunker level and weighing systems of mixing station

2. Moisture measurement & control after primary mixing.
3. Water flow measurement & control

Exhauster

- Vibration & temp. of motor and exhauster bearings temperature
- Lubricating oil pressure & temperature
- Winding temperature of motor

Gas Mixing Station

- CO gas & BF gas pressure & flow
- Mix gas pressure measurement & control
- Ratio control
- C alorific Value (CV) Analyzer measurement.

Sintering Machine

- Sinter Charge Bunker level measurement
- Moisturemeasurement&controlofsinterchargeatsecondarymixingdrum
- WaterflowatSMD(secondarymixingdrum)
- Pressure measurement
- Air pressure & flow measurement
- Gas to air ratio control
- Hearth temperature measurement & control
- Exhauster outlet and collector vacuum
- Vacuum and temperature measurement at wind boxes along the length of the machine
- Machine & Sinter cooler speed measurement & control along with drum feeder speed measurement

- A
  ngle of Repose measurement & Control

ESP

- Vibration and temperature measurement at IDF and bearings
- Suction and discharge pressure

Nut coke charging - Bunker level control

Calorific Value Analyser (C.V.Analyser):

For proper combustion to take place in the furnace, it is essential to have a steady and sufficient Calorific value of the mixed gas. With fluctuations in the pressure of the BF and CO gas, online measurement of the calorific value and adjusting the flow of the CO Gas is essential.
Gas pressure is controlled at the point of inlet and after pressure control valve the ratio of BF and CO gases are controlled using Calorimeter Value Analyzer.
measure and control

CO Gas Analyser

a. For better process control, it is necessary to monitor exhaust gases composition.
b. The Gas analyser system is used to analyze SO_2, CO, CO_2 & O_2 in the exhaust gases of main ESP Stack.

Opacity meter-

c. For any modern plant, it is essential to monitor dust concentration in exhaust gases. Opacity meters are installed or continuous monitoring of dust concentration at main ESP and Room de-dusting Units.

Moisture Measurement

d. To improve quality and productivity, it is necessary to get accurate moisture content in raw mix.
e. Infrared moisture measurement systemare used for on line moisture measurement and control of raw sinter mix.
f. Nucleonic Moisture Sensor are used to add correct coke in raw mix. Coke moisture compensation is required to achieve this requirement.
g. Nucleonic moisture sensors are also installed in coke hopper.

Belt Weigh feeder

h. The quality of sinter product is directly related to accuracy of the proportioning of raw mix. Belt Weigh Feeders are installed to control the accurate proportioning of Iron Ore, flux, mill scale, flue dust, lime dust, coke, in plant sinter return, Blast Furnace return in PKG-1 (Machine area) and 05 nos. of BeltWeigh Feeders of IPA makeare installed in PKG-2 (Raw Material area).

Belt Weigher

i. To measure and control monitor material flow and total material passed through important belts, Belt Weighers have been installed.

Bunker level

Load Cell based bunker level measurement system and Ultra Sonic/ Radar type bunker level measurement system are installed for bunker level

Automatic Bunker filling and Level Control System

Capacitance/ admittance type level sensors are installed for Automatic Bunker filling and Level Control System.

ESP Level Control System

Capacitance/Admittance type level switches are installed in ESP bunkers.

Vibration Monitoring System

Bently make displacement type

SPM make velocity type and

Mogensen make acceleration type

Vibration monitoring systems are installed to monitor the vibration//Axial displacement of all the HT Motors/ Equipments.

Temperature Monitoring System:

Consists of Temperature scanners with10/12 RTD/ Thermocouple input
Additionally critical RTDs connected to DCS directly

TC-.K type for wind legs temperature.
S-Type for Ignition Furnace temperature
Pyrometer for S100 belt temperature

Chute Jamming Devices are installed for detection of chute jamming.

Flow measurement & Control System

For Gases like Coke Oven Gas, Mixed Gas and Blast Furnace Gas – DP based flow eters
For combustion air to furnace – DP based flow meters
For water flow meters – DP based flow meters

Besides these the following are also installed for efficient running of the plant
Flow Switches for difference parameters
Pressure Switches difference parameters& interlocks
For Belt Temperature Control System – Radiation Pyrometer
Water Level Control System.

Refractory material Preparation Section.

This shop produces calcined lime and sinter dolomite for steel melting shop and sintering plant respectively. Lime Kiln & Rotary Kilns are used in this process. Following main parameter are measured and controlled:

1. Kiln temperature Measurement & Control
2. Draught Measurement
3. Boiler Drum Level Measurement & Control
4. Waste gas Pressure Control system
5. Electronic Weighing System
6. Refractory Material has main areas of operation viz., Lime Kiln, Rotary Kiln and TBDB shop.

Modern Lime Dolomite shops also use Gas Booster & non-rotary Kiln wherein Gas pressure Control is done at Boosters.
For achieving better process control & quality in these are the parameters measured are as follows:

1. Lime Kiln

-Lime temperature
-Calcination temperature

-LSHS oil temperature; pressure &flow measurement with oil flow counter

-Shaft level measurement & control

2. TBDB Shop -Temperature measurement for tempering Kiln

-CO gas pressure measurement

3. Rotary Kiln

-Furnace temperature
- CO gas pressure & flow measurement & control

Blast Furnaces Zone.

In Blast Furnace zone, Instrumentation plays an important role in the following units.

- Raw material bunkers & charging System
- Blast Furnace main
- Cast house and de-dusting system.
- Stoves & Hot Air Preparation
- Coal Injection/Tar injection units
- Slag granulation units
- Dust Catcher & Gas cleaning Units
- TRT System for Top Pressure control & Power generation
- Pump Houses and water supply system

The major requirements for Blast Furnaces are Air Blast from Turbo Blower at constant temperature, pressure and flow and proper feeding of charge material in furnace. Many of the furnaces are operating with BLT(Bell Less Top) charging system for a controlled charging inside the furnace to optimize the burden distribution. Optimized burden distribution avoids hanging and slipping of burden inside the furnace and improves productivity.

The major measurement and control includes:
1. PLC/DCS based Instrumentation &Control System for furnace and stoves.
2. PLC based stock house charge management system.
3. BLT based charge distribution control system
4. PLC/DCS based Coal Tar /Coal Dust Injection Control system

5. Microprocessor based Weighing System for charging in all furnaces
6. Oxygen Enrichment system
7. Stove Dome Temperature measurement & control system
8. Selsyns / CMR for Burden position in Furnace
9. Gas Analysers – CO, CO2, H2
10. Gas Cleaning Plant Related Instrumentation system
11. Controllers for pressure and flow of excess gas in Bleeding station.
12. Tuyere leakage detection system.
13. Hot Metal Runner Temperature through Pyrometer/Dip type measurement system

Major areas where process is monitored and controlled in Blast Furnaces are Stoves, Furnace proper, GCPs, SGPs and Coal Dust Injection system, water supply and furnace cooling system, .

Stoves constitute the heart of blast furnace process.For controlled and efficient heating of stoves, provision has been made for

- Mix Gas Pressure control
- Air/Gas ratio control
- Dome Temperature control

In the furnace area, various controls and safety interlocks have been provided to run the process efficiently and smoothly.

- Hot Blast Temperature control
- Top Pressure Control
- RAFT Control
- O2 Flow Control

In Blast Furnaces, Coal Dust Injection Plant has been commissioned which has drastically brought down the Coke Rate. This plant is highly automated and various controls and safety interlocks have beenprovided.

In addition to the main units, auxiliary units like Gas Cleaning Plant and Slag Granulation Plants are equipped with various instruments for monitoring the process.

Steel Melting Zone (Convertors, Casters & Refining Units like VAD, RH Degasser, Laddle Furnace etc.

Steel is made from Hot Metal produced in Blast Furnaces in Steel Melting Shop through LD process. The steel produced from SMS are casted in Billets/bloom/Beam Blank and slab casters are sent to Plate mill/Rail Mill/Hot Strip Mill/Wire Rod Mill/Universal Section Mill etc. for rolling.
The main function of Continues Casting Shop is to produce steel slabs/blooms directly from the molten steel coming from SMS and sending them to Mill for rolling:

In SMS zone, Instrumentation plays a very important role in the following units:

- Mixer Shop
- Convertor Shop
- Argon Rinsing Unit (ARU)
- Vacuum Arc Degassing Unit (VAD)
- Ladle Furnace & R.H. degassingUnit
- Continuous Casting shop(CCS)
- Desulphurization Unit (DSU)
- Gas Holder for LD gas
- Pump Houses for Water treatment

The important measurements and controls include temperature, Flow, Pressure, Level, Weight of different raw materials used, Vibration of motors, analysis of the LD gas to determine Oxygen & CO content, etc.

In Converter Shop, the entire process is monitored and controlled through DCS (Distributed Control System)/ PLC (Programmable Logic Controller). Numerous processes as well as safety interlocking are implemented through DCS/PLC and all the process parameters can be monitored and controlled through the display Screens of all the three LD-Converters.

Different control loops are in operation in convertor shop viz. Blowing Oxygen flow control, Draught regulation, Booster fan inlet pressure regulation, etc.

O2 flow control determines the quantity of oxygen required to achieve the targeted grade of steel. Dry Gas Analyzers (before ID Fan) and Wet Gas Analyzers (after ID Fan) and Common Duct Analyzers measure CO, CO2, H2 and O2.

Draught regulation keeps the Gas Cleaning Plant working perfectly within the desired process parameters.

Booster Fan inlet pressure regulation keeps the Gas Recovery Plant operating within the designed safety parameters.

Vibration of Induced Draft Fans and Booster Fans are monitored online and recorded. Danger and tripping signals are provided as part of the machine protection system.

In Converter shop, LD gas analysis is of vital importance. Gas is analyzed for its CO and O_2 content. This analysis is a determining factor for the recovery of LD Gas. LD gas recovered is a rich fuel and is used in reheating furnaces. Therefore its recovery greatly helps in reducing the energy consumption per ton of steel. Gas analysers of latest technology are installed to achieve this purpose.

Converter shop being a potential gas prone area, ambient CO is monitored at predefined locations round the clock to prevent any gas poisoning hazard.

In ARU, “Celox” probes are used for determining the temperature as well as the bath oxygen activity. Based on this the Aluminum required for killing of steel is calculated and displayed in “Multilab Celox” a PC based instrument. The flow and pressure

measurement of Argon gas used for stirring is also important parameter to monitor.

Vacuum Arc Degassing Unit is very important in SMS for secondary steel making. Here the vacuum measurement is very important parameter to monitor and control. A number of control loop sand interlocking are incorporated for various process parameters. The PRDS (pressure reducing and de-super heating) and bottom stirring argon flow control is of great importance. The microprocessor based controllers, molten steel measurement indicator and Multi lab-Celox instruments are installed here.

Ladle furnace and RH-degasser units is added to SMS to increase secondary steel making facility.

In LF the liquid steel temperature, argon flow control for bottom stirring, furnace draft control, cooling water flow/ pressure and vibration measurements are important measurements.

In RH-Degasser the measurement and control of all the parameters is done through PLC system. The vacuum measurement, closed and open cooling water cycle monitoring instruments, PRDS instruments, Vessel heating and pre-heating burner instrumentation systems, Celox and Hydris measurement are the important measurements.

The water flow control systems of mould cooling (all zones) and secondary cooling (all zones in slab caster and all zones in bloom casters) are mainly controlled in automatic mode. The mould differential temperature, casting speed and slab/ bloom surface temperature measuring in instruments are important ones.

Automatic Mould Level Control is used in Casters for monitoring and controlling the Level of Moulds in Casters. Nucleonic type/ Eddy current based Mould Level measurement & Control is used in such cases.

The measurement of Hot metal/liquid steel temperature is the most critical in the steel melting process/metallurgical process in SMS. The temperature measurement is being done at all points between tapping to casting of steel. Expendable thermocouples (B-type) are used for temperature measurement. These thermocouples are fixed to a lance assembly and dipped into the bath of hot metal/liquid steel to measure the emf developed. Microprocessor / PC based secondary instruments process the measured emf and display the accurate temperature. In addition lamps indicating “Measurement Ready”, “Measurement going on” and “Measurement complete” signals are also provided for operator convenience.

There is a LD Gas Holder for recovery and export of LD gas generated from the steel making process. If the gases coming out of converter process meet recovery conditions these gases are recovered and stored in LD gas-holder. For holder operation, several

interlocking schemes are also implemented through PLC. The gas analyzers, gas-holder volume, gas-holder pressure, Gas Holder Level, Diaphragm displacement (deviation), export flow etc. are the parameters monitored. In few plants, a CV (calorific value) analyser system is also commissioned in the LD gas export line to monitor the CV of recovered LD gas.

Instrumentation in Rolling Mills & Re-heating Furnaces.

The blooms/ billets are preheated in the reheating furnaces of these mills before being rolled into different products like angles, channels, TMT rods, plain rods, wires, rails and structurals.The merchant mill, Wire Rod Mill and R&SM dedicated reheating furnaces.
The important control parameters involved in the process of making finished products are:

Furnace Parameters:

- Furnace Pressure measurement and control
- Furnace Soaking zone TemperatureControl
- Furnace Heating Zone Temperature measurement &Control
- Mixed gas press measurement & Control
- Mixed gas press measurement and Control & Combustion Air Control
- Flow optimization of fuel and air in different zones
- Monitoring of O2 % in flue Gas
- Cooling Water flow monitoring and Control

Rolling Mill Parameters

- Temperatures before and after rolling at different heavy duty stands
- Equalising temperature at cooling bed
- Cooling water flow and pressure
- Machine Health monitoring
- Load end and free end bearing temperature of machines
- Winding temperature of machines
- Overhead Tank Level measurement
- Liquid Analyzer (pH, Conductivity and Turbidity) measurement
- Profile Gauge
- Nucleonic/X-Ray based Thickness Gauge
- Width Gauge
- Flatness Gauge

Gas Mixing and Gas booster Station :

The Coke Oven and Blast Furnace gases are mixed in proper ratio to get the gas of desired calorific value. This mixing is done at this station, subsequently the gas is boosted to higher pressure of 1800 mmW Can delivered to the distant M I L L S. The critical control parameters at this place are:

- BFgasflow
- COgasflow
- COenrichmentflow

- Mixedgaspressurebeforeandafterbooster
- BF and CO ratio control

Instrumentation in Energy Management Systems.

Energy Centre is equipped with centralized & computerized energy monitoring system (CEMS) and a back-up support system for some of the critical energy parameters related to energy such as BF, CO, LD, Liquid Fuel, Steam, Compressed Air, Nitrogen & Oxygen etc. are monitored continuously. These signals are brought to the Energy Centre through remote terminal units placed at different locations in the plant as mentioned below:

All these parameters are monitored & data logging is done continuously in the Energy Centre.

The EMD department centrally controls the distribution different gases and also the network pressures of these gas lines are maintained to avoid unsafe very low and high pressures.

A digital backbone on Ethernet and FO based protocol has been developed to collect data about different energy inputs and consumptions from different units of plant to a centralized server for analysis of energy consumption

Instrumentation in Water Management Deptt:

Water management department is responsible for maintaining various Pump Houses installed for water supply requirement for Iron & steel making and Drinking Water Supply throughout the Plant.

The following are the major measurements and controls in Pump Houses.

- Pumps Suction Pressure measurements.
- Pumps Discharge Pressure measurements.
- Header Flow measurements
- Water temperature measurements
- Sump level measurements.
- OHT level measurements.
- Winding and Bearing temperature measurements for protection of Pump and motor.
- Automatic changeover of duty to stand-by pumps if discharge pressure becomes low.
- Instrumentation for DM water treatment Units.
- pH, conductivity, turbidity measurements to ensure water quality.
- Magnetic flow meters, Ultrasonic flow meters.

Instrumentation in Power Plants & Blowing Stations.

The role of Instrumentation in Power & Blowing Station is:

- To enable reliable Monitoring of All the necessary measurements.

- To maintain automatic controls of parameters like Boiler drum level, main steam temperature, hot well level, turbine speed etc.

- To provide safety interlocks like protection against Ball Mill explosion through 'after mill temperature interlock' in Boilers and axial shifts protection in Turbine.

- Regular up keep of instruments during capital repairs.

- Strive towards betterment of the plant by improving the level and reliability of instruments.

- Potential free contact based alarm annunciation is used to bring the operators attention to the deviating parameters. In other areas of the plant, monitoring and control is through stand alone indicators, recorders and controllers.

- In the turbines the necessary axial shift protection system is achieved in various machines by the Bently Nevada Turbovisory system. In the older Blowers, hydraulic antisurge system is installed to prevent the surging of the machine.In some of the machines, the protection is achieved through electronic anti-surge control system and surge detector. In comparatively newer machines electronic speed governor through electro-hydraulic converter is also provided to control the speed of the turbine.

  The following measurements have very high importance in the normal operation of the plant:

  1. Boiler Drum level

  2. Boiler Drum pressure

  3. Furnace draught

  4. Axial shift

  5. Lube oil pressure

  6. Vacuum measurement
  7. Turbine speed

  8. BF and CO gas flow

  9. Steam flow

Instrumentation in Oxygen Plants.

Oxygen is one of the most critical inputs in the steel making process. The customers for oxygen are Blast Furnaces, SMS, FSNL, Medical department and cylinder filling

forwelding purpose. Liquid oxygen, nitrogen and argon are also sold commercially to outside customers.

Major units of Oxygen Plant are as follows:-

- Air Separation Units
- Air Turbo Compressors
- Oxygen Turbo Compressors
- Liquid Oxygen Tank
- Cylinder filling Station.
- Pressure Reducing and Metering Station.
- Pump Houses

In Oxygen Plant, there are air separation units (ASUs). Oxygen Plant is the place where one can find very wide range of Instrumentation Systems from pneumatic systems(transmitters, secondary instruments)in the older units Distributed Control System in the new units. Other than the conventional measurements of flow, temperature, pressure, level etc.there are measurements of vibration & axial shift etc. for machine protection as well as Oxygen analysers measuring right from the ppm level to the 100% level. Nitrogen analysers are used to measure the presence of N_2 in the argon produced from the distillation column. CO_2 analysers based on infrared absorption are used to measure the presence of CO_2 in the air entering the distillation column. Moisture analysers are used to detect the presence of moisture in the air entering the distillation column. Other than the conventional automatic control schemes there is anti surge control scheme.

The latest addition to the Oxygen Plant is the Air Separation Unit having the latest DCS system communicating to the field devices through Foundation Field Bus.

Instrumentation for Quality Management System.

Calibration & Maintenance of

- Process Instruments used for monitoring and control of various Process parameters to ensure accuracy, quality, safety and environment.
- Test instruments used for calibration of process instruments.
- Getting calibrated the master instruments from NABL accredited labs with traceability to international standard. Master instruments are used to check test instruments.
- Weigh Bridges, standardized test weights, Standard weights.
- keeping calibration records in soft form for 3 years.
- ISO audits.

Instrumentation in Safety & Environment Management.

Role of Instrumentation in safety and environment management these days cannot be ignored.

CPCB is very strictly monitoring on line the pollution created by industries on real time basis. All industries are required to follow the norms and guidelines set by CPCB.

Safety is to be taken seriously these days. Our TOP management is very strict about any safety violations and any unsafe acts.

The following instruments/ analyzers are installed and maintained for safety & environment requirement.

- On line Carbon monoxide detectors in confined and gas leakage prone areas with audio visual alarming.
- SOx / NOx Analysers in chimneys/stacks
- Opacity/Dust monitors in Chimneys/Stacks
- pH monitor water discharge outside plant periphery.
- Chlorine leakage monitoring at different Chlorine stations.
- Centralised Environment management systems.
- Oxygen monitors in confined/oxygen deficient areas.

Process and Commercial Weighing Systems.

Another important section in Instrumentation department is the Weighment section. It deals with maintenance, repair and calibration of different weighing systems required for monitoring as well as accounting purpose.

Different types weighing systems used in integrated steel plants are divided in two major categories are

- Process Weighing Systems – These weighing systems are used to weigh the materials required for optimizing production, quality and controlling theprocess.
- Commercial Weighing System – These weighing systems are used basically for material receipt and dispatch purposes in the plant

Modern weighing systems are highly accurate, reliable and user friendly and play a vital role in real time process management system resulting in improved production, productivity, product quality and operational safety.

Weighing systems installed in these areas are:

1. Mechanical type.

2. Electronic type

Some important weighing systems are:

1. Receipt and Dispatch road weigh bridges

2. Receipt and dispatch rail weigh bridges

3. BF cast house charging system

4. Bell less top bin weighing system

5. Batching system

6. Hopper weighing system

7. VAD tank weighing system

8. Weigh line in-motion weighing system

9. CDI injection vessel weighing system

10. Weighing system of Coal Silo

11. Bulk material charging system

12. Weigh feeders- to control the material feed rate

13. Belt conveyor weighing system

14. Bagging scale

15. Platform scale

12.3 Instrumentation & Control for different process parameters:

Temperature :

Temperature measurement in Steel Plants is having wide variety of needs and applications. Temperature measurement is done for mediums viz. water, Lubrication oil, Hot metals, various types of gases and chemicals. Based on these applications sensors and devices are used. Temperature measurement can be classified into three main types:

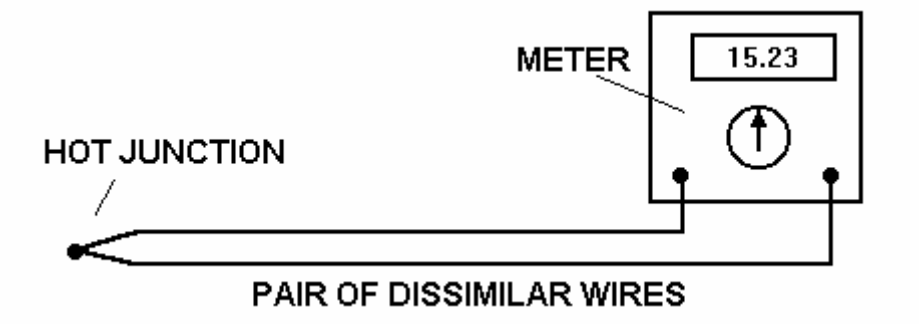
a) Thermometers
b) Probes
c) Non-contact

Some major used temperature sensors are as following:

THERMOCOUPLES

When two wires with dissimilar electrical properties are joined at both ends and one

junction is made hot and the other cold, a small electric current is produced proportional to the difference in the temperature. Seebeck discovered this effect. It is true no matter how the ends are joined so the cold end may be joined at a sensitive millivolt meter. The hot junction forms the sensor end.



Most thermocouple metals produce a relationship between the two temperatures and the e.m.f as follows.

$$e = \alpha(\theta_1 - \theta_2) + \beta(\theta_1^2 - \theta_2^2)$$

Where α and β are constants for the type of thermocouple. The relationship is nearly linear over the operating range. The actual characteristic and suitable operating temperatures depends upon the metals used in the wires. The various types are designated in international and national standards. Typical linear operating ranges are shown for standard types. It is important that thermocouples are standard so that the same e.m.f will always represent the same temperature.

RTD

An RTD is a device which contains an electrical resistance source (referred to as a "sensing element" or "bulb") which changes resistance value depending on it's temperature. This change of resistance with temperature can be measured and used to determine the temperature of a process or material. RTD's are purchased with 2, 3 or 4 lead wires per element. Three-wire RTD construction is most commonly used in industrial applications.

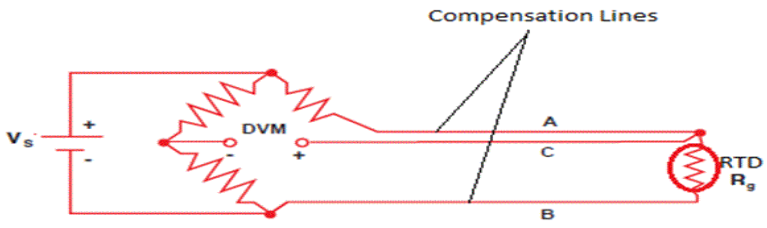


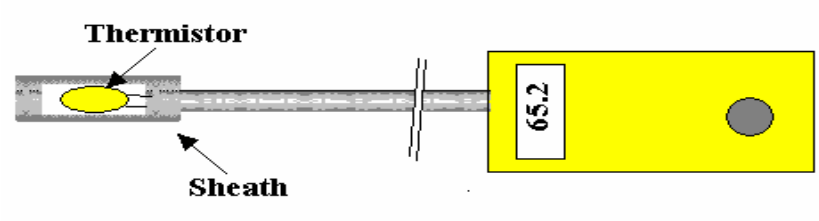
Fig.4. Three wires RTD Bridge

THERMISTOR

It is a special type of resistance sensor made from a small piece of semiconductor material. The material is special because the resistance changes a lot for a small change in temperature and so can be made into a small sensor and it costs less than platinum wire. The temperature range is limited.

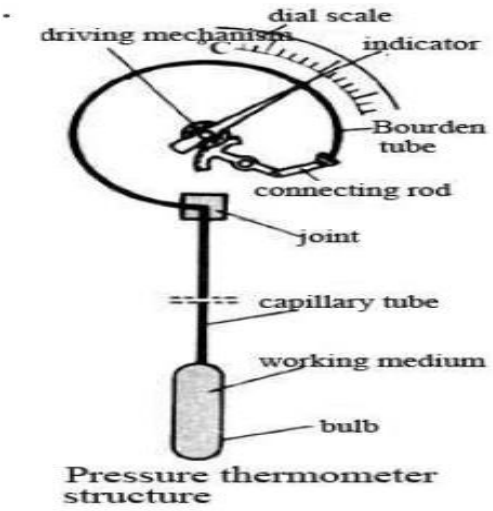
They are only used for a typical range of -20 to 120◦C and are commonly used in small hand held thermometers. The relationship between resistance and temperature is of the form

$$R = Ae^{B/\theta}$$



LIQUID EXPANSION and VAPOUR PRESSURE SENSORS

These are thermometers filled with either a liquid such as mercury or an evaporating fluid. Any rise in temperature produces expansion or evaporation of the liquid so the sensor becomes pressurised. The pressure is related to the temperature and it may be indicated on a simple pressure gauge. Ways and means exist to convert the pressure into an electrical signal. The movement may also directly operate a thermostat. These instruments are robust and used over a wide range. They can be fitted with electric switches to set off alarms.



Pressure thermometer structure

1. **BIMETALLIC TYPE**

   Here two metals are rigidly joined together as a two-layer strip and heated; the difference in the expansion rate causes the strip to bend. In the industrial type, the strip is twisted into a long thin coil inside a tube. One end is fixed at the bottom of the tube and the other turns and moves a pointer on a dial. The outward appearance is very similar to the pressure type. They can be made to operate limit switches and set off alarms or act as a thermostat.

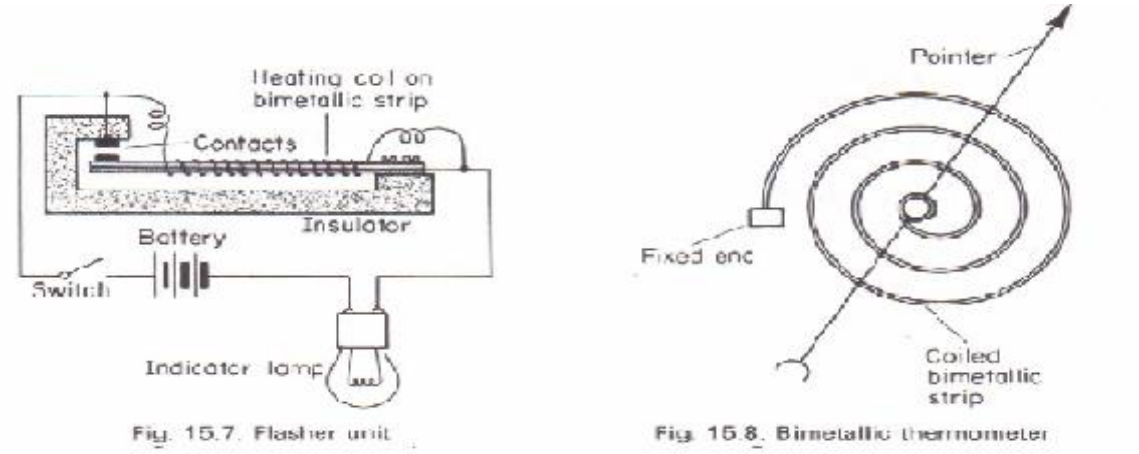


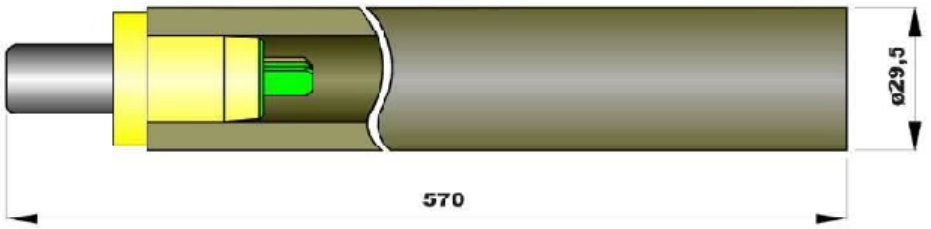
Fig. 15.7. Flasher unit

Fig. 15.8. Bimetallic thermometer

2. **Thermoelectric temperature measurements**

To measure the temperature of hot metal applications, some noble metal thermocouples dipped in the molten metal bath to provide the best measurement. Now a days, expendable thermocouples such as shown in fig. are the most economical and effective way to fulfill the required accuracy, reproducibility and reliability. Which are rigorously selected in order to guarantee an accuracy of 0 to + 3 °C at 1554 °C (Pd melting point). Positherm thermocouples are available in type S, R or B calibrations

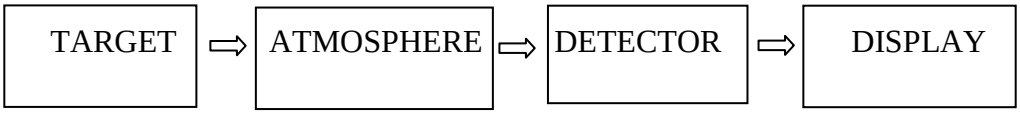
Pyrometers



I

7. **.Infrared Pyrometers**

Infrared pyrometers allow users to measure temperature in applications where conventional sensors cannot be employed. Specifically in cases dealing with moving objects (i.e., rollers, moving machinery, or a conveyer belt) or where non-contact measurements are required because of contamination or hazardous reasons (such as high voltage) where distances are too great, or where the temperatures to be measured are too high for thermocouples or other contact sensors.



- **Pressure** :

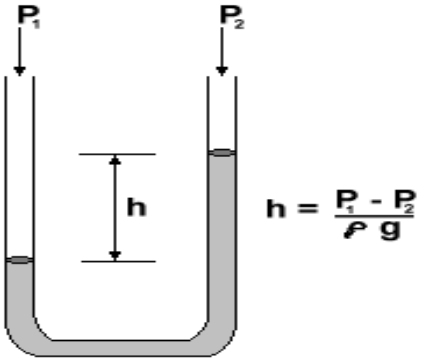
Pressure measurement is an important parameter in steel industry. It includes various methods based on the criticality of the process. Some widely used pressure measuring instruments are as following:

a) Pressure gauge

It is a mechanical type Pressure measuring Instruments used to measure and display pressure in an integral unit.

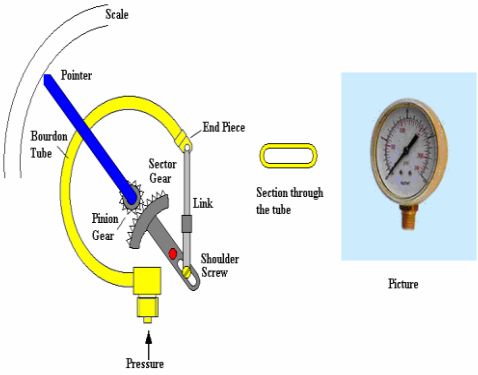
Burdon tubes are used as the measuring element inside the Pressure gauge.

b) Manometers



Manometers are one of the oldest types of pressure measurement. It is used to measure the gauge pressure, differential pressure and absolute pressure. Here the U tube is made of glass and is filled with a fluid known as Manometer fluid. One end of the u tube is closed with sample gas while another end is kept open to the atmosphere. The difference between the two levels indicates the Pressure of sample gas.

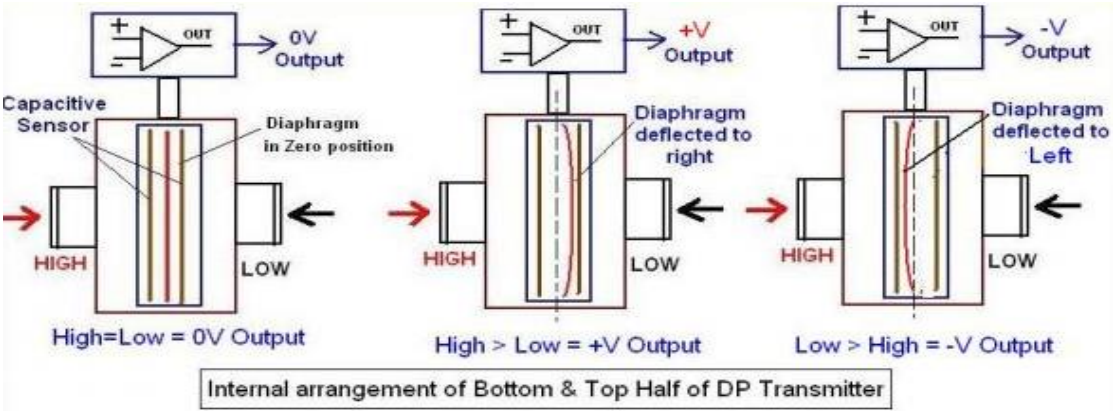
c) Pressure Transmitter



A pressure sensor measures pressure, typically of gases or liquids. It converts pressure into analog electrical signals using piezoelectric materials. To measure other parameters e.g. flow, level, density, viscosity Differential pressure Transmitter is used in industrial applications. DP Flow rate measurement is one of the most common applications for differential pressure transmitters. By measuring the difference in fluid pressure while the fluid flows through a pipe it is possible to calculate the flow rate.

Differential pressure flow meters have a primary and a secondary element. Generally the primary element is designed to produce a difference in pressure as the flow increases. Primary element are mainly Orifice plate, venturi, flow nozzle and pitot tube.

The secondary element of the flow meter is the differential pressure transmitter. It is designed to measure the differential pressure produced by the primary element as accurately as possible.



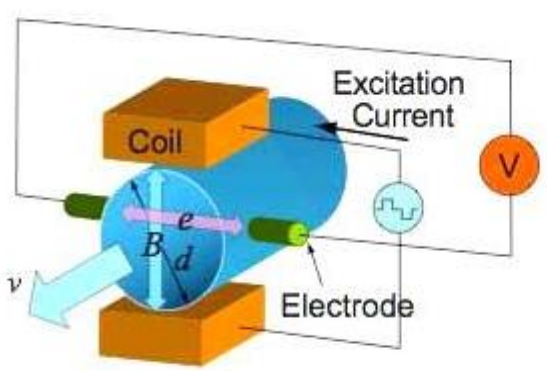
- **Flow:**

  Flow measurement is an important process in steel industries. Flow measurement system measures the movement, or flow rate, of a given volume of fluid and to express it through an unambiguous electrical signal. Several types of methods are used for this purpose based on the applications and medium of flow.

  Some of the Flow measuring instruments used widely is as following:

  a)Magnetic Flow Meter

  A magnetic field is applied to the metering tube, which results in a potential difference proportional to the flow velocity perpendicular to the flux lines.



$B \propto N \cdot Iex$

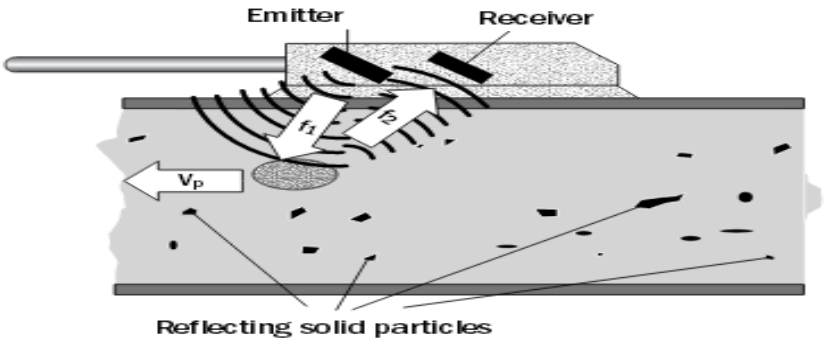
B: Magnetic Flux Density
N: Number of Coil Turns
Iex: Excitation Current

$e = k \cdot B \cdot v \cdot d$

e: Electromotive Force
k: Constant
v: Mean Flow Velocity
d: Internal Diameter

b) Ultrasonic Flow meter

An ultrasonic flow meter is a type of flow meter that measures the velocity of a fluid with ultrasound to calculate volume flow. Using ultrasonic transducers, the flow meter can measure the average velocity along the path of an emitted beam of ultrasound, by averaging the difference in measured transit time between the pulses of ultrasound propagating into and against the direction of the flow or by measuring the frequency shift from the Doppler effect.

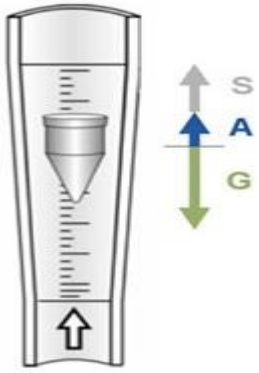


c) Variable Area type Flow meter

A variable area type Flow meter is a meter that measures fluid flow by allowing the cross sectional area of the device to vary in response to the flow, causing some measurable effect that indicates the rate. Rotameter is an example of a variable area meter, where a weighted "float" rises in a tapered tube as the flow rate increases. The float stops rising when area between float and tube is large enough that the weight of the float is balanced by the drag of fluid flow.

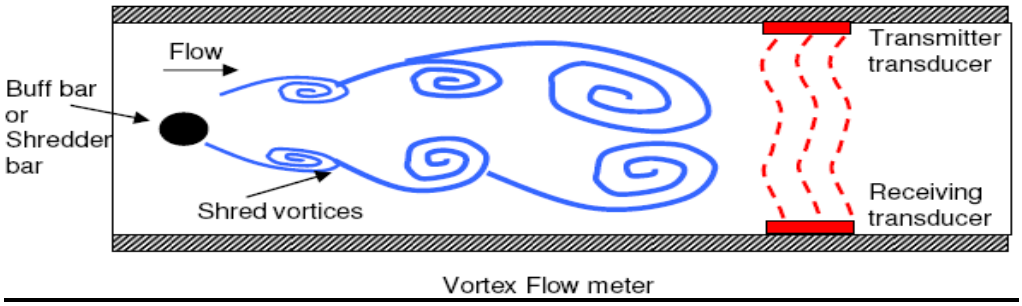
Three main Forces acting on the Float are:

- The Buoyancy i.e. A, depends on density & medium of flow along with volume of float.
- The weight i.e. G, depends on mass of float
- The Flow Force i.e. S, it changes transionally with change of flow.



d) Vortex Flow meter

The vortex flowmeter is used for measuring the flow velocity of gases and liquids in pipelines. The measuring principle is based on the development of a Karman vortex, where an oscillating vortexes occur when a fluid such as water flow past a bluff (as opposed to streamlined) body. The frequency that the vortexes are shed depends on the size and shape of the body. It is ideal for applications where low maintenance costs are important.



Vortex Flow meter

- **Level:**

In Steel Plants Level measurement is done for various purposes. Based on the applications & processes the method of measurement is decided and selection of instruments is made accordingly. Widely used Level measurement instruments are as following:

a) Glass Level Gauges

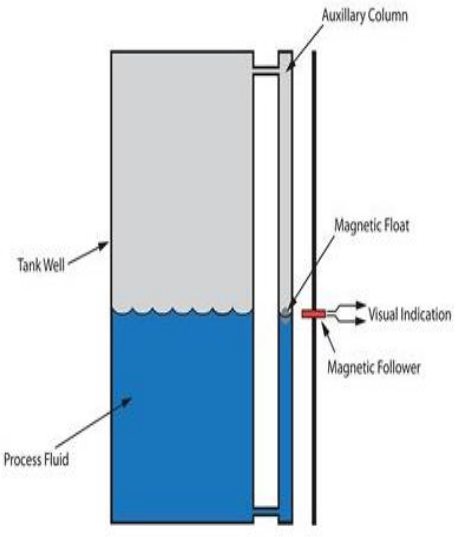
They are the simplest of methods available for liquid level measurement. The clear visibility provided by their design is their biggest advantage, while the fragility of the glass that may result in spills or compromise on the personnel safety is the disadvantage.

b) Displacers, Bubblers and Differential Pressure Transmitters

Bubblers, differential pressure transmitters and displacers are all different hydrostatic measurement devices. Changes in temperature cause a change in a liquid's the specific gravity of the liquid; similarly changes in pressure also affect the specific gravity of the vapor that is present over the liquid. As a result of these changes, the accuracy of the measurement is reduced.

c) Magnetic Level Gauges

They are similar to float devices, the communication of the liquid surface level occurs magnetically. The float in this case is a set of strong permanent magnets, which move in an auxiliary column that is attached to a vessel by two process connections.



The float is laterally confined by the column so it remains close to the side wall of the chamber. The position of the float moves up and down according to the fluid level, which is indicated by a magnetized shuttle or a bar graph that moves along with it, showing the float's position and thereby indicating the level.

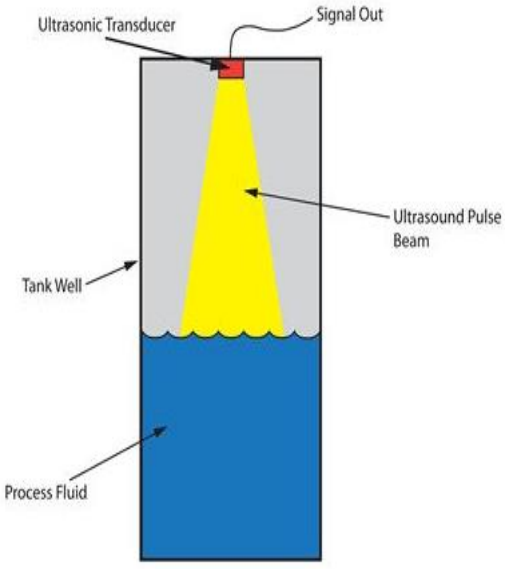
d) Capacitance Transmitters

The basic operating principle is based on the variance in capacitance which itself is based on the variation in the liquid level. The change in capacitance is induced by an insulated rod coupled to the transmitter and the process fluid, or by a non- insulated rod coupled to the transmitter and the reference probe or the vessel.

There is a proportional rise in the capacitance as the fluid level rises and fills the apace between the plates. Using a capacitance bridge the overall capacitance is measured, which provides a continuous Level Measurement.

e) Ultrasonic Level Transmitters

Ultrasonic level transmitters are capable of measuring the distance between the transducer and the surface level based on the time taken by the ultrasound pulse to travel from the fluid surface to the transducer and back (TOF).

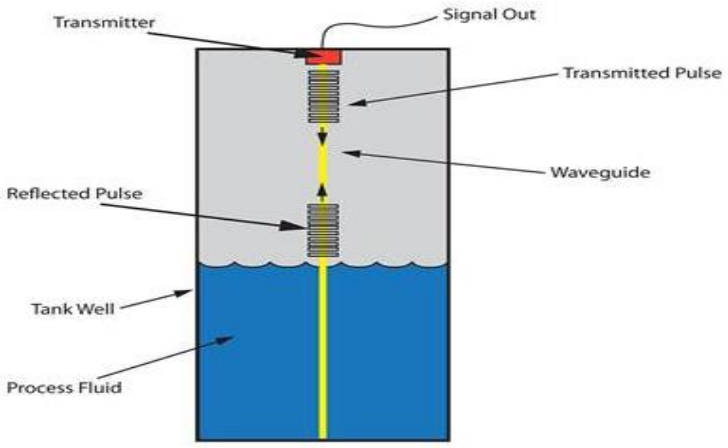


The operational frequency of these transmitters is tens of kilohertz and the transit times are approximately 6 ms/m. The composition of the gas mixture in the headspace and its temperature affect the speed of sound (340 m/s in air at 15°C). Even though the sensor compensates for temperature, it is limited to atmospheric measurements in nitrogen or air.

f) Radar Level Transmitters

In Radar type level transmitters, the microwave beam is directed downward from a horn or a rod antenna placed at the top of a vessel. The fluid surface reflects the signal back to the antenna, and the distance is calculated by the timing circuit which measures the round trip time (TOP).

In radar technology, the critical factor is the dielectric constant (Er)of the liquid.
Another type of transmitters is guided wave radar (GWR) transmitters, which provide highly accurate and reliable measurements. In these transmitters, a flexible cable antenna or a rigid probe channelizes the microwave from the top of the vessel down to the liquid level and then back to the transmitter. The change from a lower to higher Er causes the wave to be reflected.



g) <u>Nucleonic type Mould Level Measurement System</u>

Scintillation counter is device to detect and measure radiation (Cobalt-60 Radioactive γ - Ray) by means of tiny flashes produced in crystal (made up of NaI), which is subsequently amplified, by a sensitive photo multiplier tube and an electronic amplifier card. The signal conditioning unit converts the signals to electrical signal which is then taken care of by Controller Unit.

- **<u>Calorific Value /Wobbe Index/CARI Meter:</u>**

  In Steel Plants to ensure proper combustion and optimized utilization of fuel gases measurement of Calorific Value/Wobbe Index/ CARI Meter is Calculated.

<u>Calorific Value</u>: The amount of energy produced by the complete combustion of a material or fuel. Measured in units of energy per amount of material.

It may be expressed with the quantities:

- energy/mole of fuel (kJ/mol)
- energy/mass of fuel
- energy/volume of the fuel

Wobbe Index: The Wobbe Index (WI) is the main indicator of the interchangeability of fuel gases and is frequently defined in the specifications of gas supply and transport utilities. Wobbe Index is used to compare the combustion energy output with different composition of fuel gases. If two fuels have identical Wobbe Indices then for given pressure and valve settings the energy output will also be identical. The Wobbe Index is a

critical factor to minimize the impact of fluctuations in your fuel gas supply and can therefore be used to increase the efficiency of your burner or gas turbine applications.

$$\text{Wobbe Index} = \frac{\text{Heating Value}}{\sqrt{\text{Specific Gravity}}}$$

$$\text{Where, Specific Gravity} = \frac{\text{Density of Fuel}}{\text{Density of Air}}$$

- **CO Monitor**

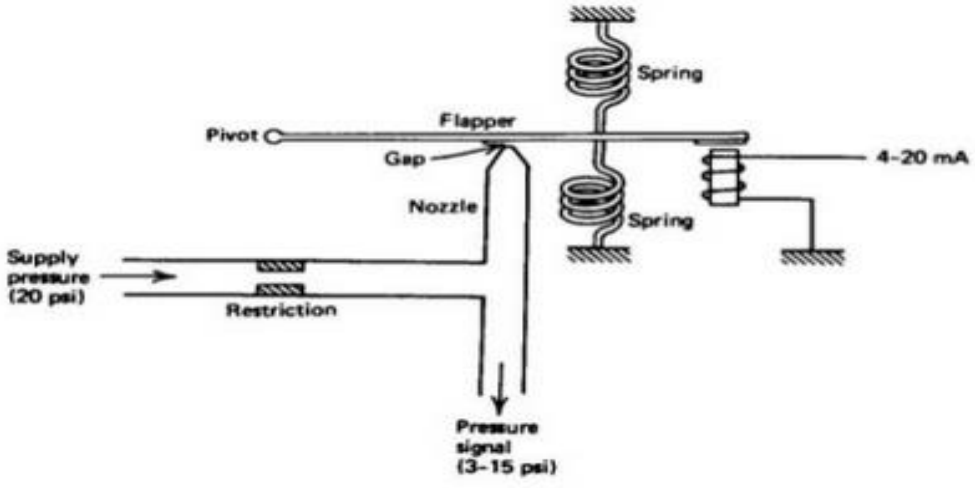
Carbon monoxide (CO) is a colorless, odorless, and tasteless gas that is slightly less dense than air. CO as an air pollutant originates from internal combustion engines and equipment that burns various fuels in an incomplete or inefficient manner. CO gas analysis is required in industries for ensuring proper combustion of fuel gases in various applications. Measuring CO in these applications may be important for energy balance, energy recovery, and maintaining product quality. In combustion applications, such as boilers, furnaces, and heaters, CO measurement can be used with temperature and oxygen content to evaluate efficiency and burner performance. To tune a boiler for maximum efficiency and fuel savings.

CO Monitors works on electrochemical and infrared methodologies.

- **Electropneumatic Convertors:**

  Electro-pneumatic Converts transforms current or voltage input into proportional output pressure. They are often paired with valves, pneumatic relays, and flow regulators in process control applications.

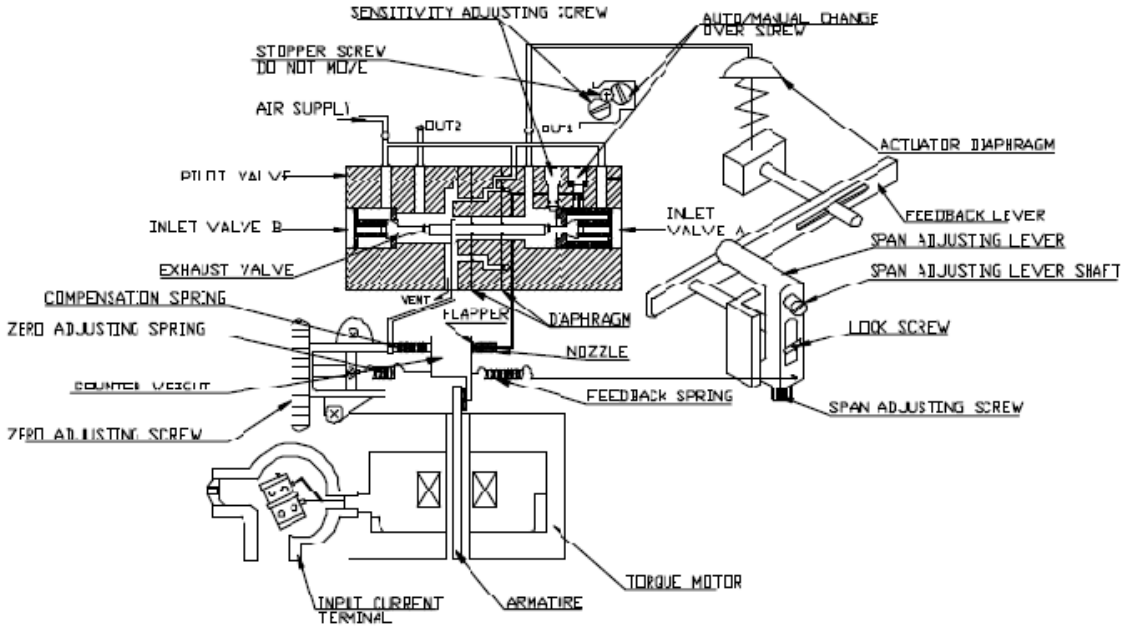
  Electro-pneumatic (also known as E/P or I/P) convertors typically accept a standard current loop, often 4-20 mA, or a 0-5V or 0-10V voltage signal. As in all transducers, the device's output values must be calibrated with the input range to ensure accurate output pressure. Important calibration specifications include **zero**, the lowest possible pressure matched to the lowest input value, and **span**, the numerical value between the minimum and maximum output. Adding the span to the zero value yields the maximum output pressure for a calibrated device. Analog E/P convertors were common in most pneumatically controlled automation systems during the mid- to late-20th century. Digital pressure controllers are now standard in most applications.



- **Electro pneumatic Positioners:**

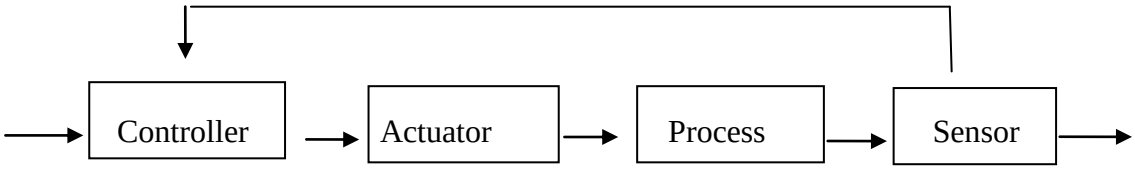
  The electro-pneumatic positioner is used in Control Valves with pneumatically operated actuators. The valve is operated by means of electrical controller or Control Systems with a control signal of 4 to 20 mA or split ranges of 4~12/ 12~20 mA. The Electro-Pneumatic Positioner converts this control signal into a pneumatic output in proportion to the lift of the control valve.

  This equipment works on the force balance principle and uses a flapper/ nozzle & set of springs to bring the forces under equilibrium at the required valve position with respect to the signal/command given to it. When the input signal from the controller is applied to the torque motor, the armature receives a torque in counter clock wise direction, due to this torque the counter weight/ flapper moves towards left side and the clearance between the Nozzle & the Flapper increases, due to which, the back pressure in the Nozzle decreases.



- **Final Control Element/Actuators**:

Final Control Element/Actuator is the mechanism by which an agent acts upon an environment. The agent can be either an artificial intelligent agent or any other autonomous being (e.g. human, other animal, etc). This mechanism puts something into automatic action. It transforms an input signal (mainly an electrical signal) into motion. Electrical motors, pneumatic actuators, hydraulic pistons, relays, comb drive, piezoelectric actuators & thermal bimorphs are some examples of such actuators.
The final control element is the last element of the closed control loop that implements the control action. It receives the output signal (control or actuating signal) from a process controller and adjusts accordingly the value of the manipulated variable by changing the amount of matter or energy entering the process in a way to bring the controlled variable (process variable) to its set point.



Types of Actuator:

There are four principal types of actuator:
a) Pneumatic
b) Hydraulic
c) Solenoid
d) Electric Motor

A control valve is a valve with a pneumatic, hydraulic, electric or other externally powered actuator that automatically, fully or partially opens or closes the valve to a position dictated by signals transmitted from controlling instruments.

- **Pneumatic actuator with valve**

The pneumatic valve is an air-operated device which controls the flow through an orifice by positioning appropriately a plug (Fig. 1 and 2).

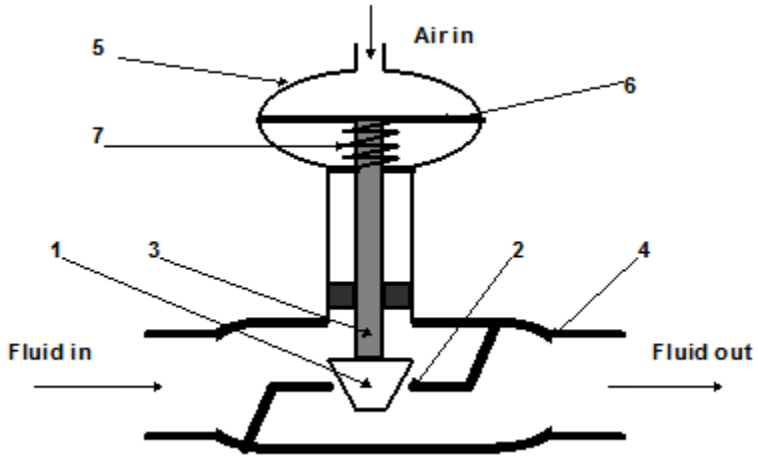


Fig.1 Air-to-close pneumatic actuator with valve

The plug (1) is placed in the orifice (2) of the valve and attached to the end of the stem (3). The orifice is placed inside the body of the valve (4) made of cast iron, alloy steels, alloy steels plus corrosion-resistant alloys, or bronze. The upper part of the final control element is an actuator (5). A diaphragm (6) divides this actuator in two chambers. The upper end of the stem is supported on the diaphragm. When the airs pressure (the output signal from a pneumatic controller) above the diaphragm increases, the diaphragm deflects and the stem moves downwards thus restricting by the plug flow of the fluid through the orifice. This type of a pneumatic valve is called Air-to-close valve.

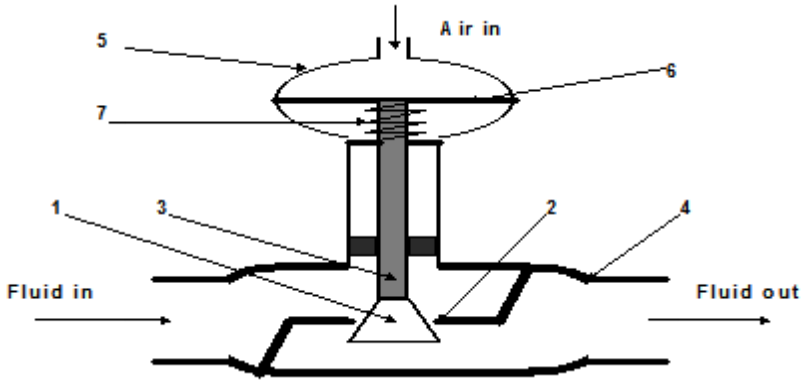


Fig.2 Air-to-open pneumatic actuator with valve

When the air pressure goes down the stem under the action of a spring (7) will move upwards, thus opening the orifice. There is another type of valves, which operate in opposite action, i.e., when the air pressure increases the plug opens the orifice. Such valves are called Air-to-open valves. If the air pressure varies from 20 to 100 kPa the plug is moved from a fully open to fully closed position.

- **Hydraulic actuators**

Hydraulic valve is used when a large amount of force is required to operate a valve (for example, the main steam-stop valves), hydraulic actuators are normally used. Hydraulic actuators use fluid displacement to move a piston in a cylinder positioning the valve as needed for 0-100% fluid flow. Although hydraulic actuators come in many designs, piston types are most common. A typical piston-type Hydraulic Actuator is shown in Fig.3

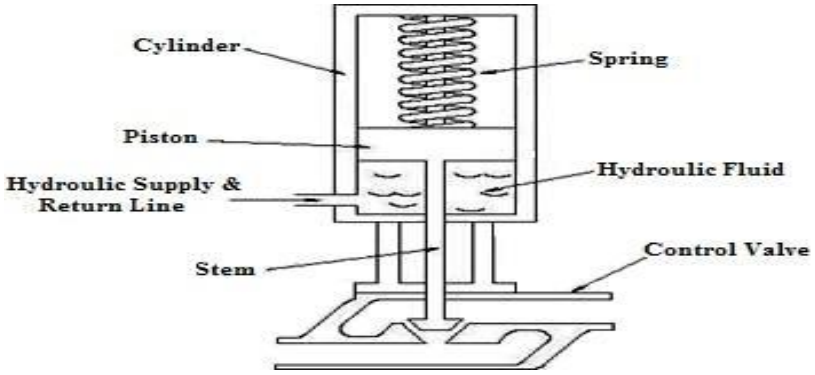


Fig. 3

- **Electronic Solenoid Actuators**

Solenoid actuators are used on small valves and employ an electromagnet to move the stem which allows the valve to either be fully open or fully closed. A typical

electric solenoid actuator is shown in Fig. 30.5. It consists of a coil, armature, spring, and stem.

Major advantage of solenoid actuators is their quick operation. They are much easier to install than pneumatic or hydraulic actuators. However, solenoid actuators have two disadvantages. First, they have only two positions: Fully open and fully closed. Second, they don't produce much force, so they usually only operate relatively small valves.

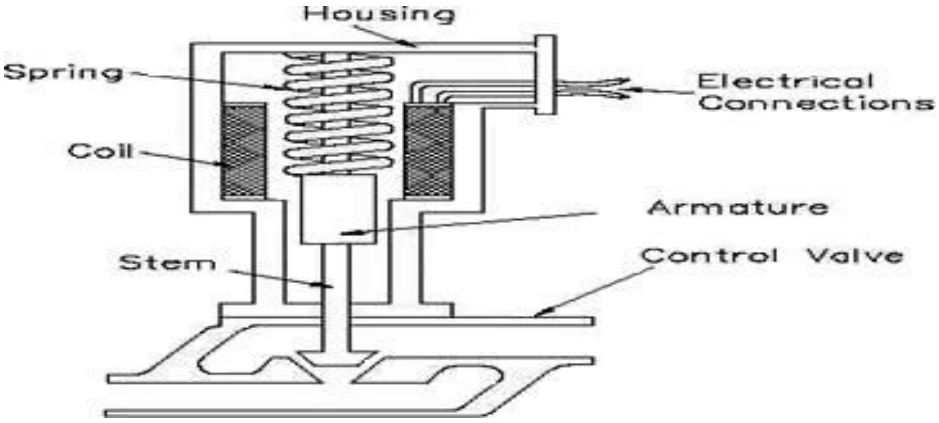
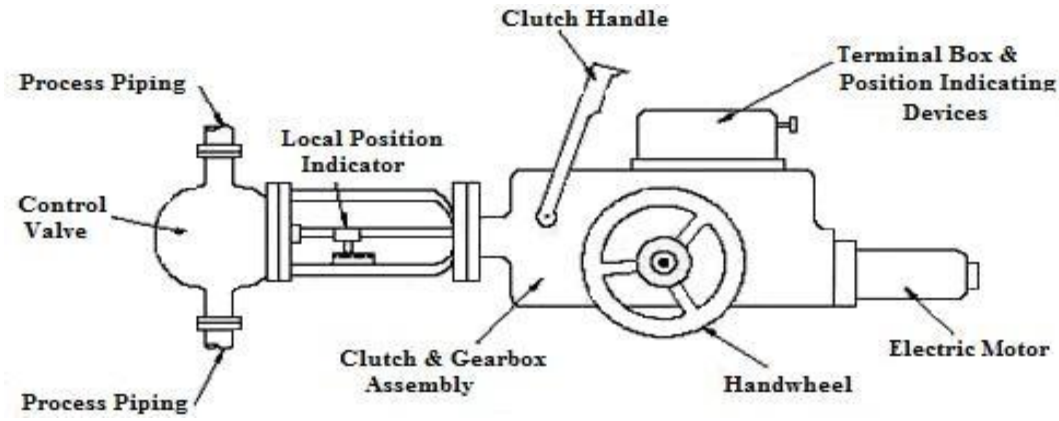


Fig.4

- **Electric motor actuators**

An electric motor is composed of a rotating center, called the rotor and a stationary outside, and called the stator. Electric motor actuators vary widely in their design and applications. Some electric motor actuators are designed to operate in only two positions (fully open or fully closed). Other electric motors can be positioned between the two positions. A typical electric motor actuator is shown in Fig. . Its major parts include an electric motor, clutch and gear box assembly, manual hand wheel, and stem connected to a valve.



- **pH & Conductivity measurements:**

Water is used in a large volume in various applications like for cooling of oils, hot metals, making steam in Power plants etc. PH & Conductivity analysis is very important for ensuring the water quality. To check the PH balance and maintaining the softness of water is the prior things to do.

12.4 History of Process Control and Automation

1. Manual Control
2. Hard Wired Logic Control
3. Electronic Control Using Logic Gates
4. Discrete process control
5. Programmable Logic Controller
6. Distributed Digital Controller

Manual Control

In this all the actions related to process control and automation are taken by the operators. One of the major drawbacks of this method is likely human errors and consequently its effect on quality of final product. The manual control has its own limitations with regard to mass production techniques and hence this method cannot provide the consumer with quality goods at an affordable price.

Hard Wired Logic Control

This was considered to be the first step towards automation. Here the contactor and relays together with timers and counters were used in achieving the desired level of automation.
It had certain limitations as listed below:

1. Bulky and complex wiring
2. Involves lot of rework to implement changes in control logic.

Electronic Control Using Logic Gates

With the advent of electronics, the digital logic gates started replacing the relays and auxiliary contactors in the control circuits.
With incorporation of these changes, we got the benefits of:

1. reduced space requirements
2. energy saving
3. less maintenance and hence greater reliability
4. Even with electronics, the implementation of changes in the control logic as well as reducing the project lead time was not possible. However, this method of control and automation was also popular for quite some time.

Discrete process control & measurement

Discrete process control is based on Single loop controllers, Digital process indicators, Process Parameter recorders, Alarm annunciators etc. This type of system were/are in use before DCS came into existence. This type of process monitoring & control system required more space and large sized instrument panels. However all the parameters were visible at a time to the plant operators.

Programmable Logic Controller (PLC) & Distributed Digital Controller

With the coming of microprocessor and associated peripheral chips, the whole process of control and automation underwent a radical change.

Instead of achieving the desired control or automation through physical wiring of control devices, in PLC/DCS it is achieved through a program or software. As the desired logic control & PID control is achieved through a 'program', these controllers are referred to as Programmable Controllers.

What are the important advantages of PLC/DCS?

Reduced Space, Energy Saving, Ease of Maintenance, Economical, Greater Life and Reliability

Where Do We Use PLCs/DCSs ?

- In industry, there are many production tasks that are of highly repetitive in nature. Although repetitive and monotonous, each stage needs careful attention of operator to ensure good quality of final product.
- Many a times, close supervision of processes cause high fatigue on operator resulting in loss of track of process control.
- Sometimes it is hazardous also as in the case of potentially explosive chemical processes.
- Under all such conditions we can use PLCs effectively in totally eliminating the possibilities of human error.

In short, wherever sequential logic control and automation is desired the PLCs are best suited to meet the task. It includes simple interlocking functions to complicated analog signal processing.

Hardware (CPU, Power Supply, Digital and Analog I/O)

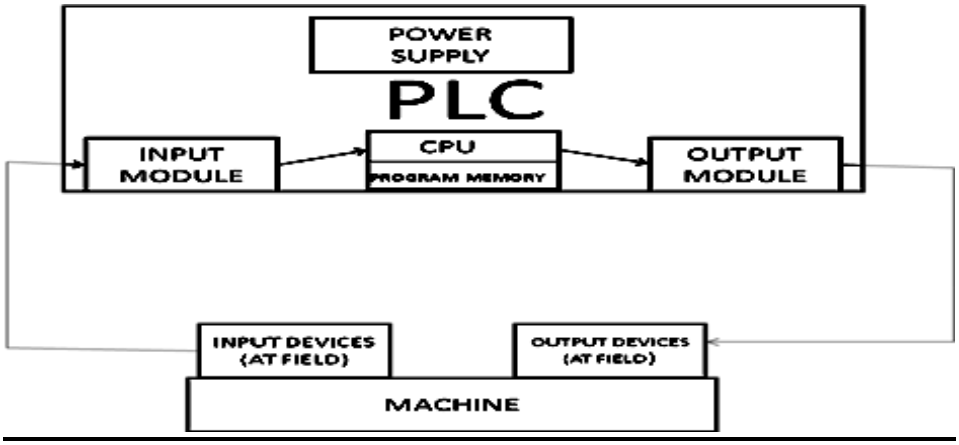
What Constitutes A PLC/DCS?

The PLC/DCS is basically a programmed interface between the field input elements like limit switches, sensors, transducers, push-buttons etc. and the final control elements like actuators, solenoid valves, dampers, drives, light emitting diodes (LED), hooters etc.

This interface called as PLC/DCS consists of the following:

1. Input Modules 2. CPU with processor and program memory
3. Output modules 4. Power supply Unit

Block schematic of a PLC/DCS



How PLC/DCS works?

1. Bringing input signal status to the internal memory of CPU

As the field signals are connected to input module, at the output of input module the field status converted into the voltage level required by the CPU is always available.

At the beginning of each cycle, the CPU brings in all the field input signals from input module and stores into its internal memory as process image of input signal. This internal memory of CPU is called as PII, meaning Process Image Input.

The programmable controller operates cyclically meaning when complete program has been scanned, it starts again at the beginning of the program.

3. Processing of Signals using Program:

4.

Once the field input status is brought into the internal memory of CPU i.e. in PII, the execution of user program, statement by statement begins. Based in the user program the CPU performs logical and arithmetic operations on the data from PII.

3. Storing the Results of Processing in the internal memory:

The results of the user program scan are then stored in the internal memory of CPU. This internal memory is called Process output Image or PIQ.

5. Sending Process Output Image to Output Modules

At the end of the program run i.e. at the end of scanning cycle, the CPU transfers the signal states in the process image output to the output module that finally reaches to field controls or actuators.

Can PLCs/DCSs be connected with other devices?

PLCs/DCSs also can be connected with computers or other intelligent devices. In fact, most PLCs/DCSs, from the small to the very large, can be directly connected to a computer or part of a multi drop host computer network. This combination of computer and controller maximizes the capabilities of the PLC/DCS, for control and data acquisition, as well as the computer, for data processing, documentation, and operator interface.

Messages / Data transmission in a PLC/DCS network : Data/Messages are exchanged between PLCs/DCSs over a network. A LAN's (Local Area Network) access method prevents the occurrence of more than one message on the network at a time. There are two common access methods.

i) Collision detection is where the nodes "listen" to the network and transmit only if there are no other messages on the network. If two nodes transmit simultaneously, the collision is detected and both nodes retransmit until their messages get through properly.

ii) Token passing allows each node to transmit only if it's in possession of a special electronic message called a token. The token is passed from node to node, allowing each an opportunity to transmit without interference. Tokens usually have a time limit to prevent a single node from tying up the token for a long period of time.

Programmable Logic Controller (PLC)

PLC were earlier developed to replace the hardware relay logic, timers and counters employed for electrical circuits. But with the development of very powerful CPU all the functions of process controllers , recorders, alarms process diagnostic etc, were added to the PLC systems making a very thin line between PLC and DCS systems.

Distributed Control System (DCS)

DCS were earlier developed to replace process monitors, Single loop controllers, process recorders alarm annunciators etc.

A distributed control system (DCS) refers to a control system usually of a manufacturing system, process or any kind of dynamic system, in which the controller elements are not central in location (like the brain) but are distributed throughout the system with each component sub-system controlled by one or more controllers. The entire system of controllers is connected by networks for communication and monitoring. DCS is a very broad term used in a variety of industries, to monitor and control distributed equipment.

PLC is used where SPEED of OPERATION is an important factor whereas DCS is used to control a single plant with certain speed but it can handle more complex loops and large inputs and outputs. DCS is also used where high level of redundancy / security / fault diagnostic features are needed.

SCADA:

Full form of SCADA is Supervisory Control and Data Acquisition. The main functions of SCADA are:

- Collecting the analogue data like current, voltage, frequency, pf, MW, MVA, MVAR, etc and digital status like CB ON/OFF, Fault Trip relay operation etc. and transferring these data from Remote Terminal Units (RTUs) to Master Control Station for entire network (analogue values and digital status) for further monitoring, control and analysis. These data are called AI and DI data.
- Switching ON/OFF different circuit breakers at unmanned substations at a remote location, if required by generating digital output i.e. DO commands.
- Facilitating load balancing and ensuring system stability when the CPP is islanded from the grid with its full generation. The same is accomplished through a definitive program running in the servers at the master control station.

DAS:

DAS is Data acquisition System for collecting Process information on real time basis and displaying those information after processing in desired format/useful format to the plant operators, process engineers, maintenance engineers and plant managers.

Process alarms and events are recoded with time stamping and displayed to the operator for taking timely action. Paperless recorders are also a scaled down version of data acquisition system. Many of the mathematical functions like totalizing, averaging, adding, multiplying etc. are included in most of the DAS models.

Many of instrumentation functions like noise filtering, scaling, linearizing, compensation, alarm setting etc. are included in DAS systems.

However DAS does not include process control, rather it is only a monitoring system for process parameters.

- **Level -2 Automation System**

  Level-2 automation is used for complex processes to optimize the process based on software modelling.

  The level-2 system also generates plans and schedules for the production and process. Level-2 system takes all the inputs from level-1 system and generates output and set points for the operator as well as for level-1 system.

  There are two types of software model i.e.

  - Off line advisory model - In this type of model the level-2 system gives advice to the operator based on calculation fortuning the process.
  - On line model - In the on-line model the level-2 system directly manipulates the set points of level-1 controller based on calculations from the model.

- **General makes of PLC/DCS Systems installed in SAIL Units:**

1. Siemens
2. Schneider
3. ABB
4. GE Fanuc
5. Rockwell/Allen Bradley
6. Emerson
7. Yokogawa
8. Honeywell
9. Toshiba
