GENERAL PLANT OPERATIONS ENGINEERING

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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/ore handling plant/ore bedding and blending plant 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 –

1. Unloading& stacking of raw materials
2. Screening of iron ore lump & fluxes
3. Crushing & screening of coke/flux for base mix/sinter mix preparation

4. 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 (Raw Materials Division, SAIL) 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 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 interplant 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 :

Every attempt is being made to utilize low-grade iron ores, fines and industrial wastes. A huge amount of fine is generated during mechanized mining operation, which cannot be directly charged into blast furnace. The proportion of these fines is further increased due to narrow size distribution specification of iron ore required by blast furnace operators. For better utilization of low-grade ores, it is advised to beneficiate it after crushing and grinding. Such operations yield concentrate in finer form In addition to these fines there are good deposits of blue dust, which mostly remain unused due to its fineness

These fines can be either used after agglomerations or utilized for direct reduction processes or production of powder metal products. Depending upon the size gradation of the ore fines the agglomeration can be done by sintering, pelletization, briquetting and nodulizing methods. Agglomeration generally refers to the process of forming a physically larger body from a number of smaller bodies.

Thus, the major objectives of agglomeration processes are:

(i) Economize mineral use by utilizing finer fraction of the minerals.
(ii) Energy conservation by preparing the burden so as to increase the efficiency of reduction process and decrease the coke rate.
(iii) Environment improvement by utilizing the waste in-plant fines.

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^{0}C. Many times cement is added and pellet can be divided into

(a) Acidic Pellets &
(b) Basic Pellets

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:

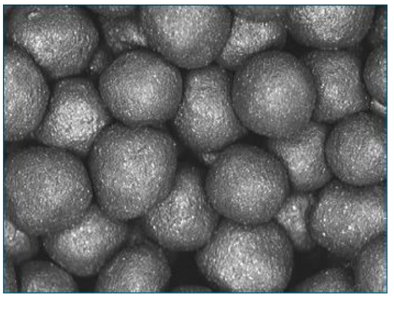
The chemical analysis is to a degree controllable in the concentration processing within limits dictated by economics. In reality no LOI makes them cost effective.

• 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

Pellet - Blast Furnace Grade: Chemical Quality (Typical)

Parameter	Specification
Fe	65% min
SiO2+Al2 O3	5% max
Al2 O3	0.60% max
Na2O	0.05% max
K20	0.05% max
TiO2	0.10% max
Mn	0.10% max
P	0.04% max
S	0.02% max
V	0.05% max

Basicity	
$(CaO+MgO)/(SiO_2+Al_2O_3)$	0.40

Moisture (free moisture loss at 105^0C)
4% max (fair season) 6% max (monsoon)

Screen Analysis	Specification
+16mm	5%max
-16mm ,+9mm	85%min
-9mm,+6.35mm	7.00%max
-5mm	5%max
Tumbler test (ASTM)	
Tumble index (+6.35 mm)	94.00 % min
Abrasion index (+ 0.6 mm)	5.00 % max

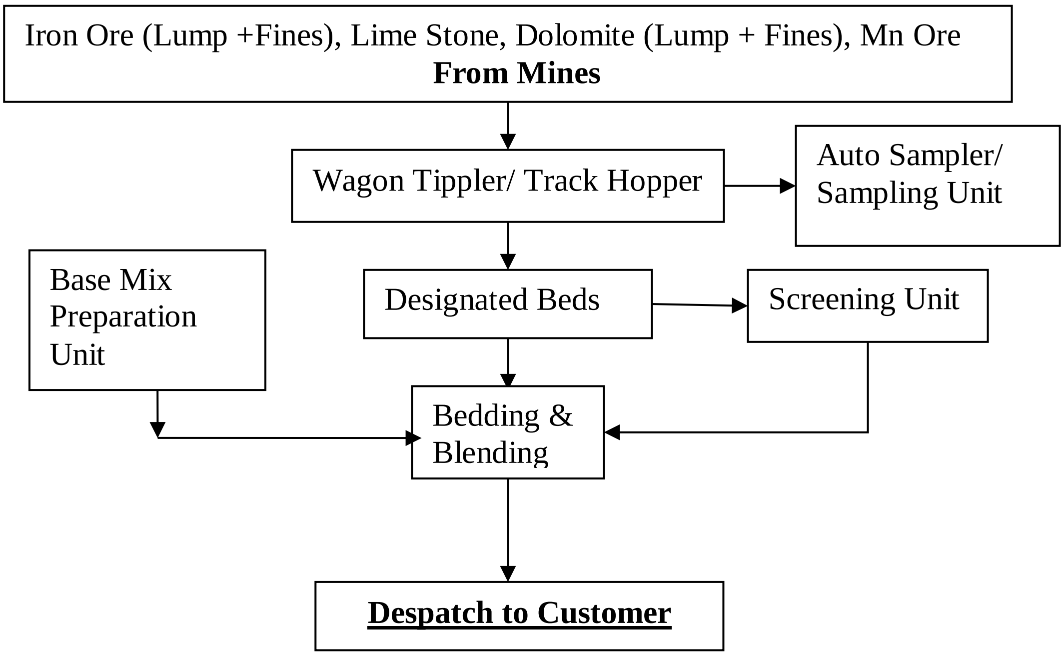
	Specification
Swelling	20% max.
Compression Strength	250 KG/PELLET min
Porosity	25.00 % min
Reducibility	60% min

Right quality raw material is the 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 Lump	Fe SiO_2 Al_2O_3 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 Al_2O_3 62-63% 2.3 – 3.6% 2.8 – 3.3%	+10mm= 5% Max - 1mm= 30 % max
3.	Lime Stone (BF) grade.	CaO MgO SiO_2 43 - 50% 2.25-5% 3.5-6.5%	-5mm= 5% max +40mm= 5% max
4.	Dolomite (BF) grade.	CaO MgO SiO_2 30% 18% 5%	-5mm= 5% max +50mm= 5% max
5.	Lime Stone(SMS) grade(Jaisalmer), Imported(Dubai & Oman)	CaO MgO SiO_2 52% 1% 1.5 % (max.)	-40mm= 7% max +80mm= 3% max (30-60mm)
6.	Dolomite(SMS) grade	CaO MgO SiO_2 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%, SiO_2-12-15% Moisture- 10-15% (max.)	< 15mm

1.4 Process Flow Diagram of RMHP/OHP/OBBP



1.5 Material Handling Equipments

Major equipments 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.
3.	Track Hopper	For manual unloading of wagons
4.	Stackers/ Stacker- cum - Reclaimer (SCR)	For stacking material and bed formation
5.	Barrel / Bucket wheel /SCR	For reclaiming materials 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 /customer.

Logistics:

For smooth operation, the planning of Raw Material requirement for the set target is of prime importance. Raw material requirement plan is to be made ready and communicated to the concerned agencies well in advance to avoid any setback for the process.
The different agencies which are involved in this process are -

-RMHP/OHP/OBBP
-Traffic and Raw Material Department
-Raw Materials Division (RMD)
-Production Planning Control (PPC)
-Finance
- Materials Management (Purchase)
-Railways, etc,

Indian Railway acts as a linkage between mines and steel plant as major mode of Raw Material transport.

Inside the plant, Traffic Department (of the Plant) plays the major role for foreign wagons (Railways) rakes movement and the processed/waste material movement by the plant wagons. 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, Quartzite etc, unloaded in wagon tippler or track hopper is being conveyed through series of belt conveyors to the designated bed and stacked there with the help of stackers/ SCR. 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 and the effect becomes constant after 580 layers.

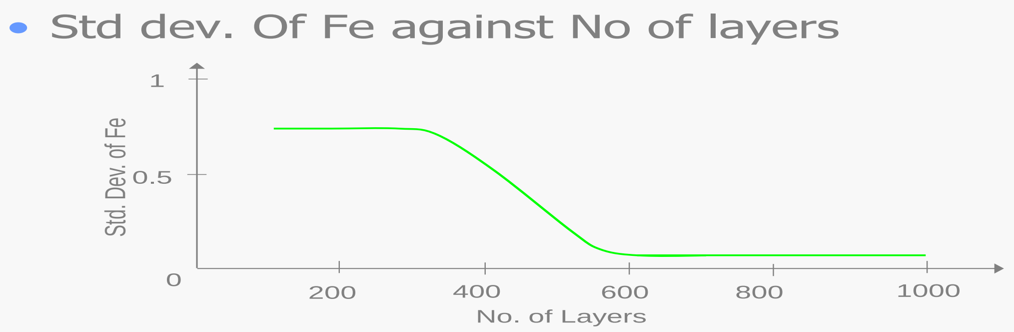


Fig.:Change of Homogeneity of co-efficient with no. of layers after Blending

Iron Ore Lump Screening:

Screening of Iron Ore Lump is necessary because Iron Ore Lump 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 Lump screening section and then stacked in the designated Iron Ore Lump beds, from which this screened ore is supplied to blast furnace.

Screened Iron Ore Lump also called sized iron ore. Screening plays a very important role as size of material is very important as far as blast furnace operation is concerned. Incoming Iron Ore Lump contains -10 mm fraction as high as 15 to 20 %. To get rid of this -10 mm fraction, vibratory screen of 10 X 10 mm mesh size is used.

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, return sinter etc, mixed at certain proportion. Before mixing, above said materials are stored in individual bunkers, also called proportioning bins. Prior to stacking, required ratio is to be set for Iron Ore Fines, flux, coke fines, return sinter etc., so that prepared base mix should satisfy the requirement of sintering plant.

Panoramic view of RMHP/OHP/OBBP

Panoramic view of RMHP/OHP/OBBP

Iron Ore Fines:

Iron Ore Fines is the base material for base mix preparation. Nearly 70-80 % Iron Ore Fines is used in base mix preparation. Fe content in Iron Ore Fines is around 62-64%.

Flux:

Flux is a mixture of 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. Nearly 12-16% flux used in base mix preparation. Hammer crushers are used for crushing Limestone and 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, 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%. Nearly 5-6% crushed coke used in base mix preparation.

Plant Return & Metallurgical Waste:

Plant Return or BOF (LD) slag is used as a replacement of Blast Furnace grade Lime Stone. Nearly 3.5 – 4 % BOF slag is used for base mix preparation. Metallurgical Waste such as mill scale, flue dust, sludge, spillage also used in base mix preparation @ 1%.

1.6 Customers of RMHP

Sl. No.	Customer	Product/ Material
1.	Blast Furnace	Size Ore (Screen Iron Ore Lump) & Quartzite.
2.	Sinter Plant	Base Mix/Sinter mix, crushed limestone & dolomite (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:

- Centralized Raw Material facility
- Mechanized & faster unloading facilities
- Facility for sizing of materials for base mix preparation.
- Minimizing undersize in iron ore lump by means of screening
- Consistency in chemical & physical properties by means of bedding & blending.
- Input quality over a time period is known.
- Base mix preparation for Sinter Plants
- Supply prepared Raw Materials to Units
- Utilization of metallurgical waste.

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 of prime important. To take care of surrounding area Dust Extraction & Dust Suppression system is installed. In some plants dry fog dust suppression (DFDS) system is also in use. Housekeeping is a major challenge for smooth operation in this department and requires special attention. Spillage materials are collected & reused by effective housekeeping. Scrap conveyor belts are regularly collected and disposed at designated place for proper disposal. This helps in maintaining personal and equipment health and safety. It makes the surrounding 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 in next page:

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.

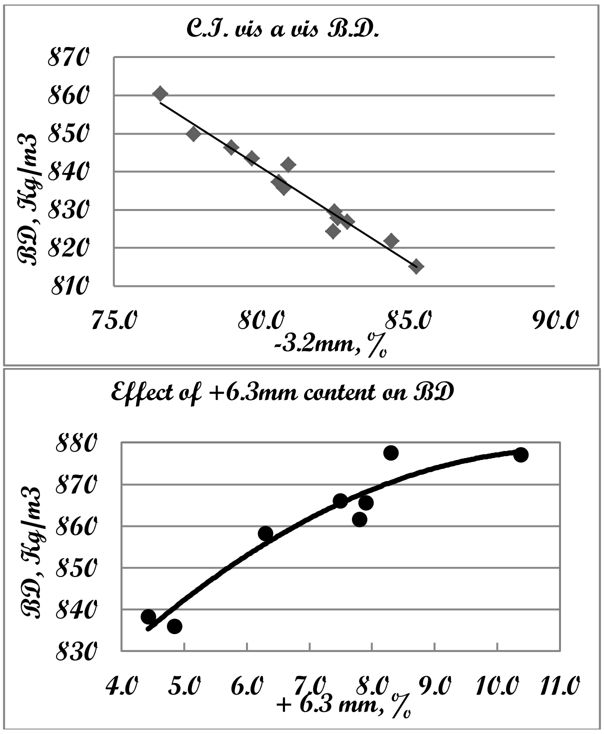


Fig : Bulk density variation with Crushing Index and +6.3 mm content in coal charge

<u>Importance of Blending:</u>

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.

<u>COAL BLEND QUALITY:</u>

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.

<u>Major Equipments:</u>

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°C. 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/Nm³ ± 50mg, Hydrogen Sulphide- 200 mg/Nm³ ± 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:

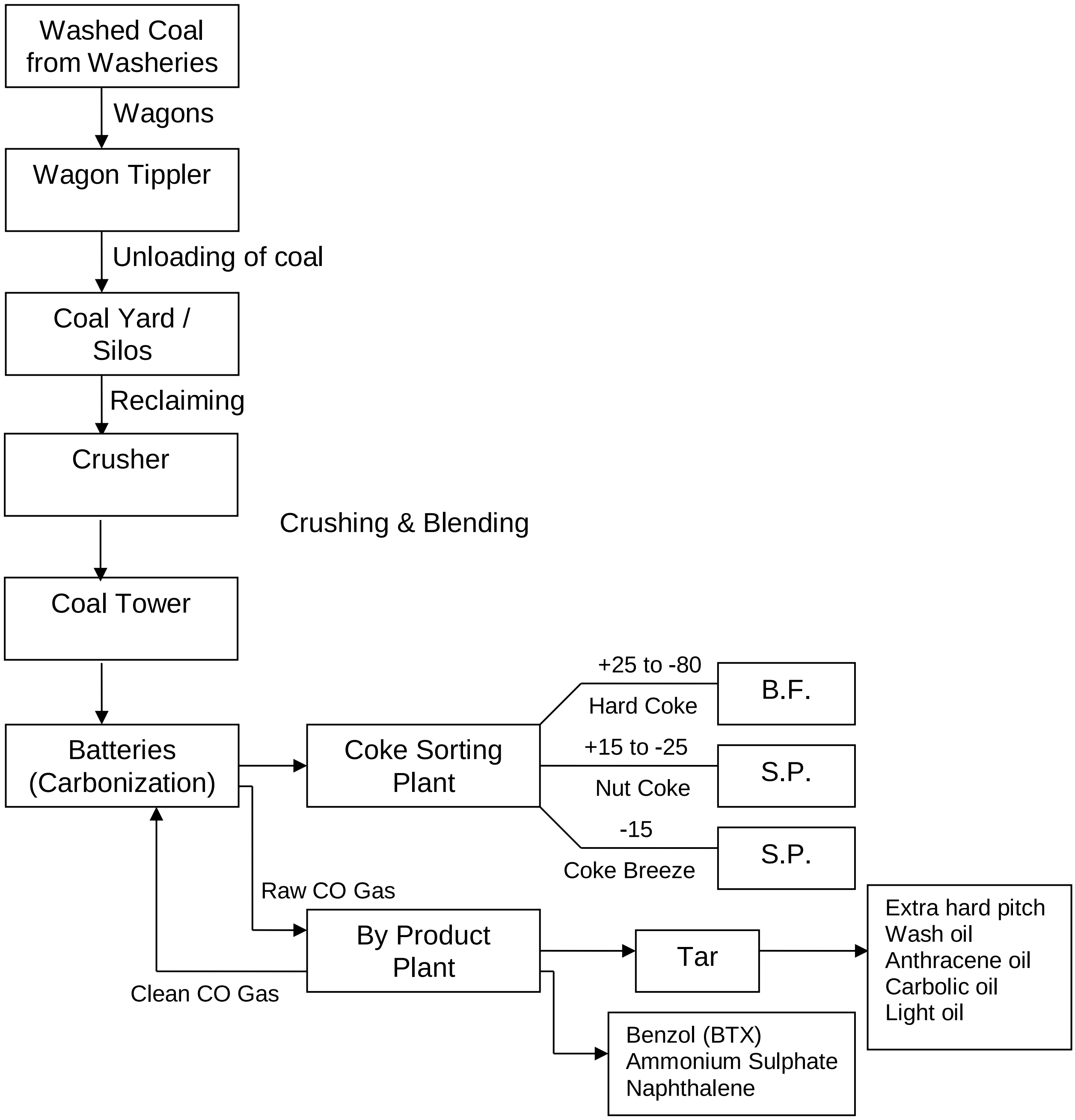
Ammonia	:	50 ppm
Phenol	:	1 ppm
Cyanide	:	0.2 ppm
Tar & Oil	:	10 ppm

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



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 OHSAS - 18001 (Occupational Health and Safety Assessment Series)

OHSAS 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 OHSAS 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 plants agglomerate 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 charged directly 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 material, they are mixed with Iron ore fines and agglomerated into lumps by a process known as SINTERING.

Sintering is the process for agglomeration of fine mineral particles into a Porous and lumpy mass by incipient fusion caused by heat produced by combustion of solid fuel within the mass itself.

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. Millscale+fines
8. B.O.F.Slag /L D Slag
9. BF Return fines+ Sinter R/fines

3.2 Raw material proportioning

The scheme for preparation of charge first envisages blending of raw materials in raw materials yard to obtain consistency in the chemical composition and size fraction of raw materials. After this raw materials are received in raw material receiving bins. Preliminary proportion is done at the receiving bins and then the raw materials are transported to stock bins where final and accurate proportioning is done. Normally constituents proportioned are Iron ore fines, Flue dust , ,Mill scale, Lime stone fines, Dolomite fines, LD dust and Return sinter (as Re-circulating load). It can be seen that sinter plant can make adequate use of almost all the valuable metallurgical wastes arising in an integrated steel plant thus paving the way for valuable conservation of minerals and techno-economic benefits..

An accurate proportioning is envisaged to be done at the stock bins. Here the constituents proportioned may consists of :-

- Ore fines comprising mixture of ore fines and mill scales.
- Flux consisting of mixture of lime stone and dolomite in desired ratio to obtain optimum MgO and CaO contents in the sinter.
- Crushed Coke fines
- Return sinter as re-circulating load (BF sinter return & in plant sinter)

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

Ore fines	:	750-800 kg	Coke: 65- 80 kg	Mill scale + fines: 16Kg
Lime stone	:	86 -110kg	B.O.F. Sludge: 02kg	B.O.F. Slag : 20Kg
Dolomite	:	80-100 kg	Burnt Lime: 04 to 40 kg	
Sinter return	:	25 to 32 % (BF sinter return + In plant sinter return)		

Note- All above mentioned data varies in different plants under SAIL unit.

3.3 Sintering process

Preparation of charge mix

Preparation of charge mix mainly consists of crushing of fluxes, solid fuels, proper sizing of them and mixing with iron Ore fines in a certain ratio to prepare base mix. Experience of operation of sinter plants has demonstrated that the fluxes mainly lime stone & dolomite fines should be crushed to obtain 90% minimum(-3mm fraction).Such finely crushed fluxes result in the formation of strong sinter due to absence of free lime.

As in the case of fluxes, careful preparation of coke breeze to the extent of 85% minimum (-3mm fraction) is an essential pre-requisite for producing high quality sinter. Normally for crushing of coke breeze, Roll crushers /rod mills are used which ensures better and consistent crushing and also preferred due to easy maintenance.

Finally these finely crushed coke and fluxes are mixed with ore fines(called as a BASE MIX) in required proportion in balling/ nodulising drum where atomized water is added .The purpose of balling/nodulising drum are homogenizing of base mix and formation of balls. This base mix (now called green mix) is then loaded on moving sinter machine pallets through belt conveyors and segregation plates. The purpose of segregation plate is to segregate the base mix such that coarser particles falls in the bottom of sinter machine, medium particles in middle portion and smaller particles at the top by rolling effect.

Before loading base mix on sinter machine, a layer of return sinter(namely hearth layer) is loaded on pallets forming the bottom most portion of the charge just above the pallet grates. This hearth layers helps in preventing burning of grate bars apart from getting optimum under grate suction.

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 and 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 that the 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 where as 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 the charge 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, screened, cooled and dispatched to Blast furnace. The ideal size of sinter required in blast furnace is in between 5mm to 40mm. The other sizes are screened & returned back to sinter bin(Called inplant returnfines).

Thermal change in the sinter bed during sintering

Typical change in the sinter bed during sintering is taking place as :

Wet zone is the bottom of the sinter bed and sintered zone is the surface of sintering bed. Between surface and bottom, temperature distribution during sintering is indicated. From this temperature changes, reaction zone can be divided as shown in following table.

Zones

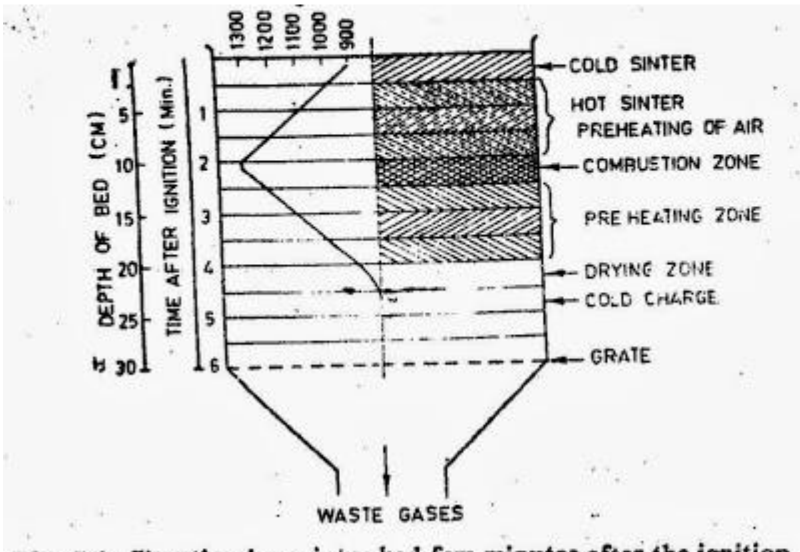


Fig. 7·1. Situation in a sinter bed few minutes after the ignition of the top layer.

Classification of reaction zone of sintering bed:

Reaction Zone	Temperature	Remark
1&2 Wet zone	Constant Temp. (Increase 2-3 degree C	Wet sinter raw mix
3 Drying zone	Increase 100 degree C	Charging material is dried.
4 Preheating zone	Increase temp. due to coke combustion	
5 Combustion zone	Combustion of coke, rapid temp. Increase, reduction of Fe3O4	No bonding, coke comb. and partial reduction
6 Oxidation zone-A	Increase oxidation temp. of Fe3O4	Soft bonded sinter
7 Equilibrium zone	Constant equilibrium temp. of Fe3O4 and Fe2O3	
8 Oxidation zone-B	Oxidation of Fe2O3	Hardened sinter
9 Cooling zone	Decrease temp.	Hardened sinter
10 Sintered zone	Constant temp.	Cooled sinter with small cracks.

Wet zone and drying zone

Vaporization in the wet zone is only 10% of the moisture. In the drying zone, there is a rapid vaporization due to the hot gas from the pre-heating zone. After passing drying zone, hot gas loses its sensible heat due to the vaporization of moisture. Gas temperature in the wet zone is maintained because when the temperature in wet zone is increased, as the equilibrium temperature, the vaporized temperature is increase and the heat loss per unit time is increased and vaporize temperature is decrease. The temperature of the wet zone is about 60 degree Celsius and this temperature has no relation between gas volume and temperature. Only drying zone is affected. The thickness of the drying zone is changed by the supply of heat and maximum thickness of this drying zone is only 5 mm.

Preheating zone

In this zone, coke breeze temperature will be increased to igniting temperature by hot gas coming from combustion zone. Ignition temperature of coke breeze is about 600 degree Celsius. Thickness of this preheating zone is also few millimeter. Instead of limestone, there is a case of slaked lime or burnt lime. In this case, pores of raw mix is increased and this characteristic is not changed during drying.

Combustion zone

In this zone, coke is ignited and heat is produced same as other combustible elements such as sulphur and graphite. This zone has a reduction atmosphere and reduction of Fe_2O_3 occur. The thickness of this zone changes due to volume of coke and the suction air volume. In this zone, raw mix is heated at certain temperature by the combustion heat of coke and suction air and also supply the heat to the bottom area.

Oxidizing zone-A

After combustion of fuel, atmosphere become oxidizing and forms oxidizing zone and Fe_3O_4 becomes Fe_2O_3 with 100 kcal/kg oxidation heat. Due to continuous oxidation, temperature is increased and oxidization is reduced. The thickness of this zone is decided by fuel quantity and suction air volume.

Equilibrium zone

The factor to occur the equilibrium zone, combustion zone speed should be faster than cooling zone speed. In this zone, Fe_2O_3 and Fe_3O_4 equilibrium occur and oxidation of Fe_3O_4 is not occur.

Oxidizing zone-B

When cooling of sinter is started by excess suction air, oxidizing of Fe_3O_4 to Fe_2O_3 started. Some oxidizing heat occurs due to oxidation of Fe_3O_4 to Fe_2O_3 . Cooling of sintered ore become slow.

Cooling zone

After combustion of coke, cooling zone occur.

Sinter zone

After cooling, temperature of sinter decrease and become same temperature with suction air.

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 the charge 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, screened, cooled and dispatched to Blast furnace. The ideal size of sinter required in blast furnace is in between 5mm to 40mm. The -5mm sizes are screened & returned back to sinter bin.(-5mm size sinter called as in plant return)

Chemical reactions in sintering process:

Sinter is produced as a combined result of locally limited melting ,grain boundary diffusion and re-crystallisation of iron oxide during sintering.The basic metallurgical reaction takes place in sintering zone.

1. $C+O_2$---CO_2 + 4220calories
2. $CO_2 + C$ --- $2CO$ + 53140 calories
3. $3Fe_2O_3$+ CO ---- $2Fe_3O_4$ + CO_2 + 8870 calories

Fe_3O_4 + CO ---- $3FeO$ + CO_2 - 4990 calories

<u>Factors affecting sintering process</u>

<u>Quality of Input raw materials</u>

Quality of Iron ore fines :

- ✓ : +10 mm should be nil
- ✓ : -1mm should be 30% maximum
- ✓ : Alumina(Al_2O_3) 2.5% maximum
- ✓ : Silica (Si_2O_3) 2.5% 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 in generation of –5mm fraction & also resulting in chute jamming.(Due to high Alumina in B/Mix. With increase of SiO_2 level in Iron ore fines ,glassy phase in sinter increases and causes brittleness in sinter.

<u>Quality of Flux</u>

- ➢ : -3mm fraction should be 90% minimum(Crushing index)
- ➢ : less crushing index results in free lime, causing weak sinter

<u>Quality of Coke</u>

- ➢ : -3mm fraction should be 85 % minimum(Crushing index of coke)
- ➢ : +5mm fraction should be nil
- ➢ : Increase in 5mm fraction decreases the productivity and causes sticker formation in sinter machine.
- ➢ : Increase in less than 0.5 mm particle size in coke causes increase in coke consumption during sintering

Moisture :

Moisture in the form of water is added in the base mix in balling/nodulising drums. Water acts as binder of base mix. Addition of water in base mix plays an important role in 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.

<u>Ignition furnace temperature:</u>

Ignition of sinter mix is carried out through ignition hearth where a temperature of 1150 to 1350 degree Celsius 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 2100kcal/m3. Higher hearth temperature results in fusing of sinter at top layer. This reduces the bed permeability, hence low productivity. Low heat temperature results in improper ignition. 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 plant under SAIL unit.

Coke rate :

Coke acts as a solid fuel in base mix in the sintering process. It is normally 6% of total charge. Higher coke rate will fuse the top layer, thereby decreases the bed permeability. Sticker formation will increase. Low coke rate will result in incomplete sintering.

Machine speed :

Speed of sinter machine can be varied as per the condition of sintering process. BTP (Burn 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 degree Celsius (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 sintering process is called 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 approximately by using crushers. Normalising of finished crushed sinter is then done on coolers by means of air blowers (forced draught fans); so that coolers discharge end temperature is about 80 degree centigrade. For effective cooling, bigger size of sinter should be on bottom portion & smaller size should be on top.

Finally various fractions of sinter are screened out.-5mm fraction of sinter returns back to bunkers. 10 to 20 mm 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

3.4 Quality Parameters of Sinter (Subject to Requirement of BF) Plant

	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- SiO_2) %	3.4 to 6	DTI	70% MIN
4.	As per BF Requirement		RDI	30% MAX
5.	SiO_2 %	4.8 to 5.2	+ 10 mm	65 % min.
6.	Al_2O_3 %	3.0	+40 mm	9 % max.
7.	Basicity.	1.6 to 1.9	- 5 mm	6 % max.

Note- Quality parameters of sinter vary in different plants under SAIL unit.

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 serves to predict the sinter's degradation behavior in the lower part of the blast furnace stack.

<u>Advantages of using Sinter</u>

1. Agglomeration of fines into hard, strong and irregular porous lumps, gives better bed permeability.
2. Utilizes the solid wastes of steel industry

3 To utilize the coke breeze generated in coke screening 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.

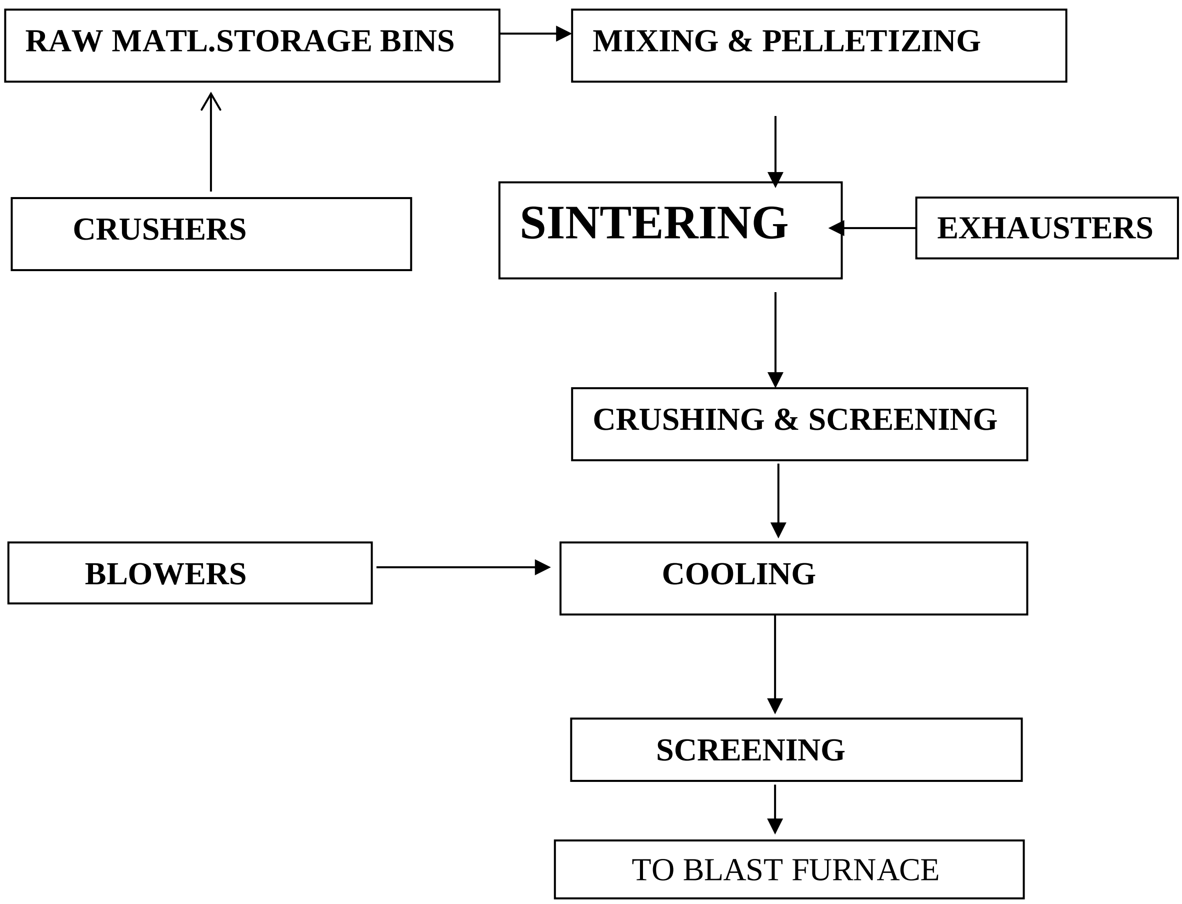
5 Increase of sinter percentage in Blast Furnace burden, increases the permeability, hence reduction and heating rate of burden increases, so the productivity also increases. Coke rate is also reduced in Blast furnace.

6 Minimal fraction of total mass of impurities, Viz. sulphur, phosphorous, zinc, alkali is reduced.

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.

3.5 Process Flow Diagram of Sinter Plant

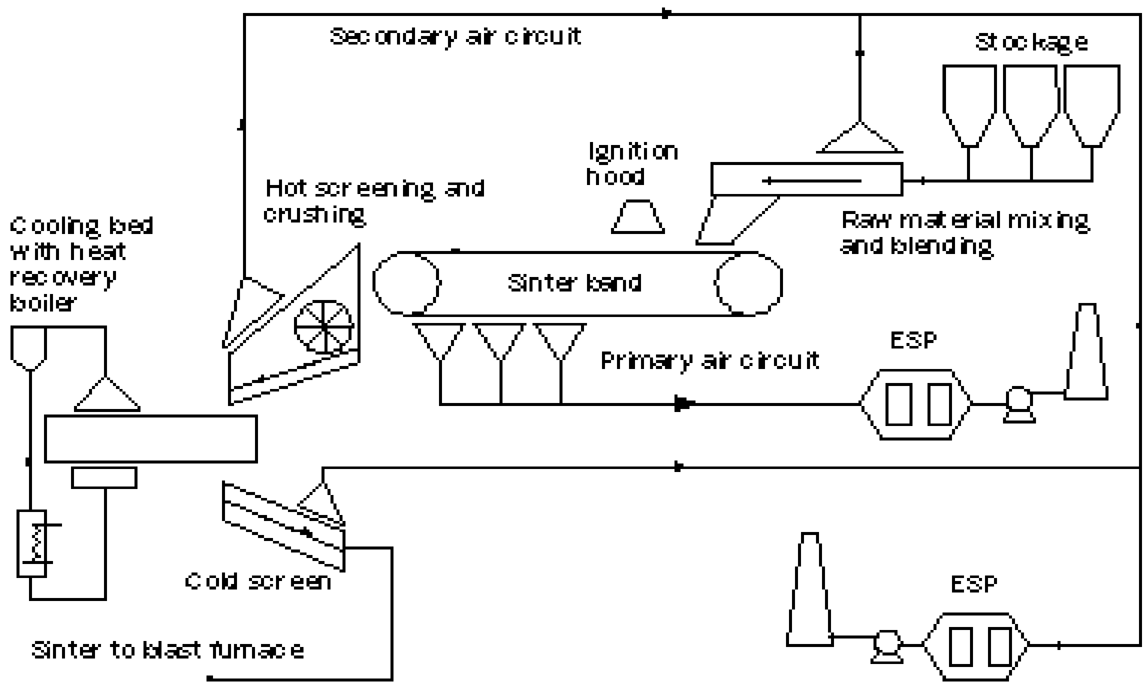


Some critical terms/parameters used/monitored in sinter plant

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.**

Sintering Plant Layout for Reference :

Figure 1
Taranto Ilva sintering plant



3.6 Main Areas & Equipments

Main Areas	Equipments	Functions
Sinter making & Cooling bldg.	Balling drums Sinter pallets Screens Crushers Coolers	To mix & pelletize Sintering takes on it Screens out diff. sizes Crushes sinter cake Cools/ Normalise sinter
Exhausters	High capacity fans Battery cyclones ESP	To suck air below grates To clean Exhaust air To clean Exhaust air
Proportioning Bins	Electronic feeders Conveyors Bunkers	For adjusting feeding Transport 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 as possible & 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 to considerable 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.

3.7 Safety Hazards at Sinter Plant

1. Dust pollution

As lots of finer particles are used in sintering, there is a Lot of dust pollution. Efficient running of ventilation is a Must. Use of dust mask is essential. Chimney Stack Emission should be below 30 mg/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 any where in exhauster results in high level of noise.Air compressor , chiiler unit,hammer crusher, coke crusher are also high noise generating areas in Sinter plant.Use of Ear plug is essential.

<u>OHSAS - 18001 (Occupational Health and Safety Assessment Series)</u>

OHSAS 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 OHSAS 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.

5-S SYSTEM (WORK PLACE MANAGEMENT):

5 S system is an integrated concept originated by the Japanese for proper work place management. Takashi 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.

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 Meghahatuburu Kiriburu	Barsua Kalta Meghahatuburu Kiriburu	Bolani GuaMeghahatuburu	Gua Bolani Meghahatuburu	Kiriburu Meghahatuburu 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^{o}C
	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.

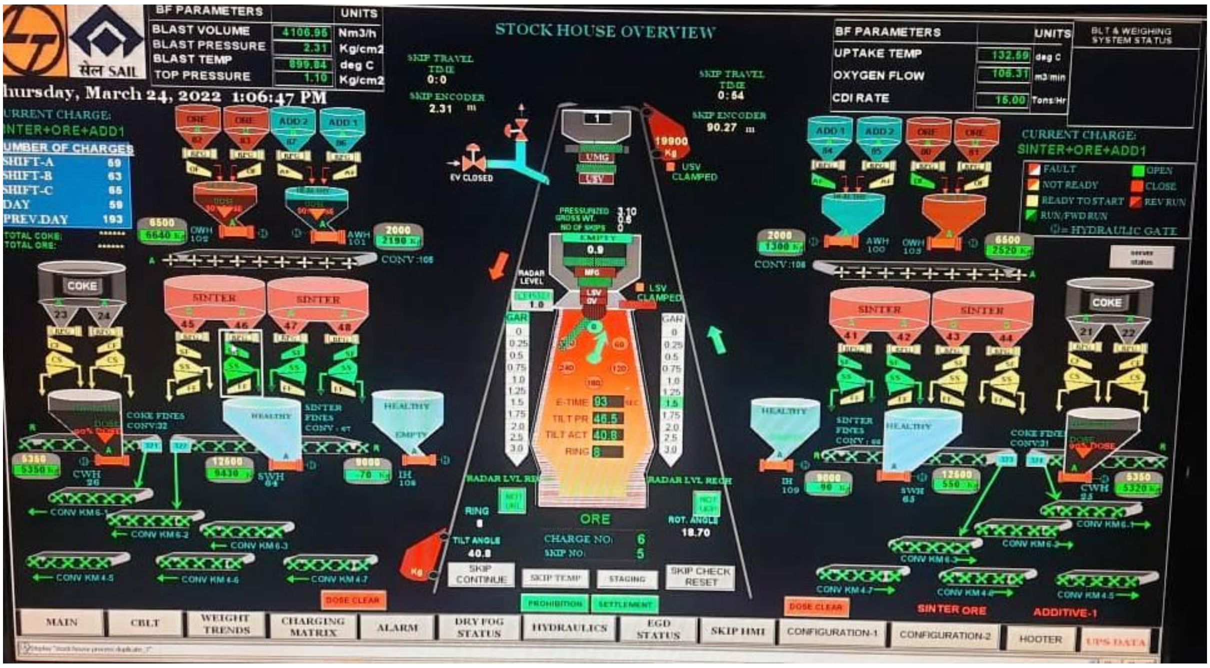
Raw materials from the ore yard are charged by suitable means into the respective bunkers. Alternately in some plants iron ore is received in a wagon Tripler, stack in to piles, and reclaimed using reclaimers.

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.

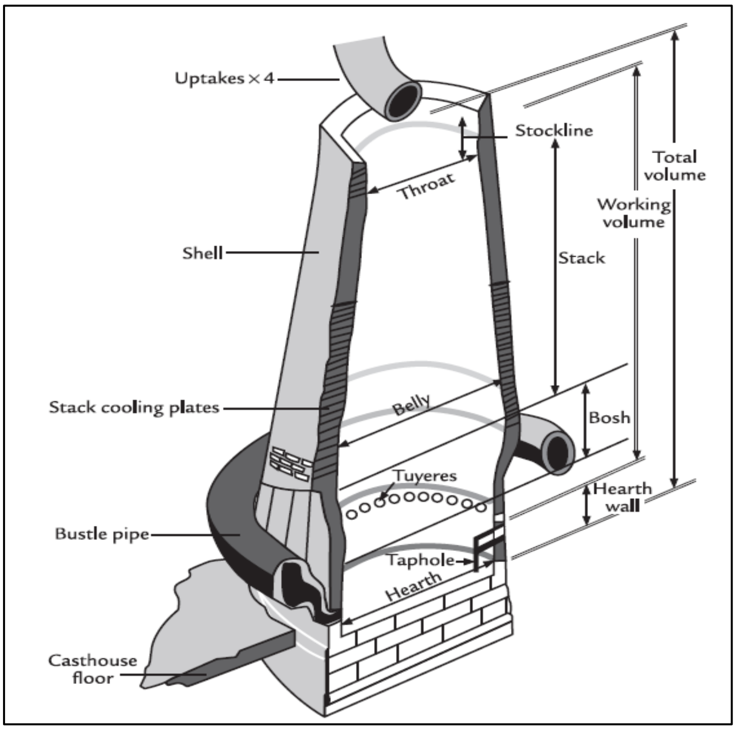
4.3 Blast Furnace and accessories

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

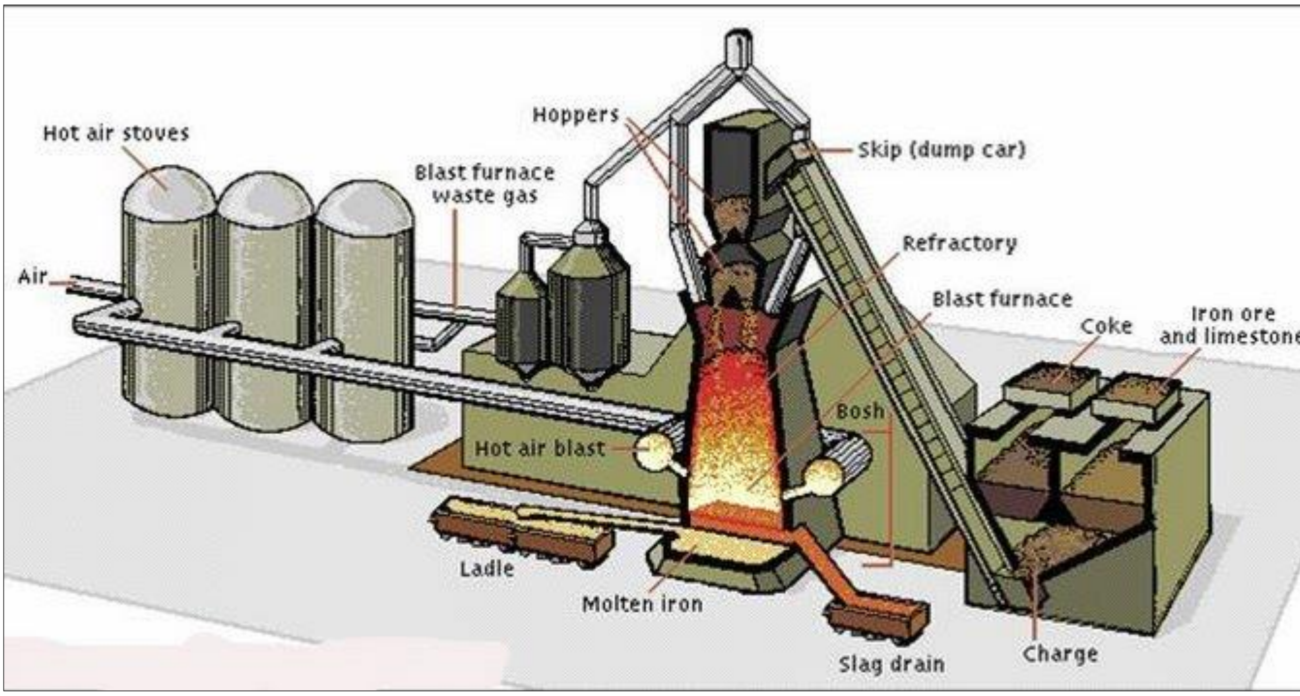
The sections from top down are:

- 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.

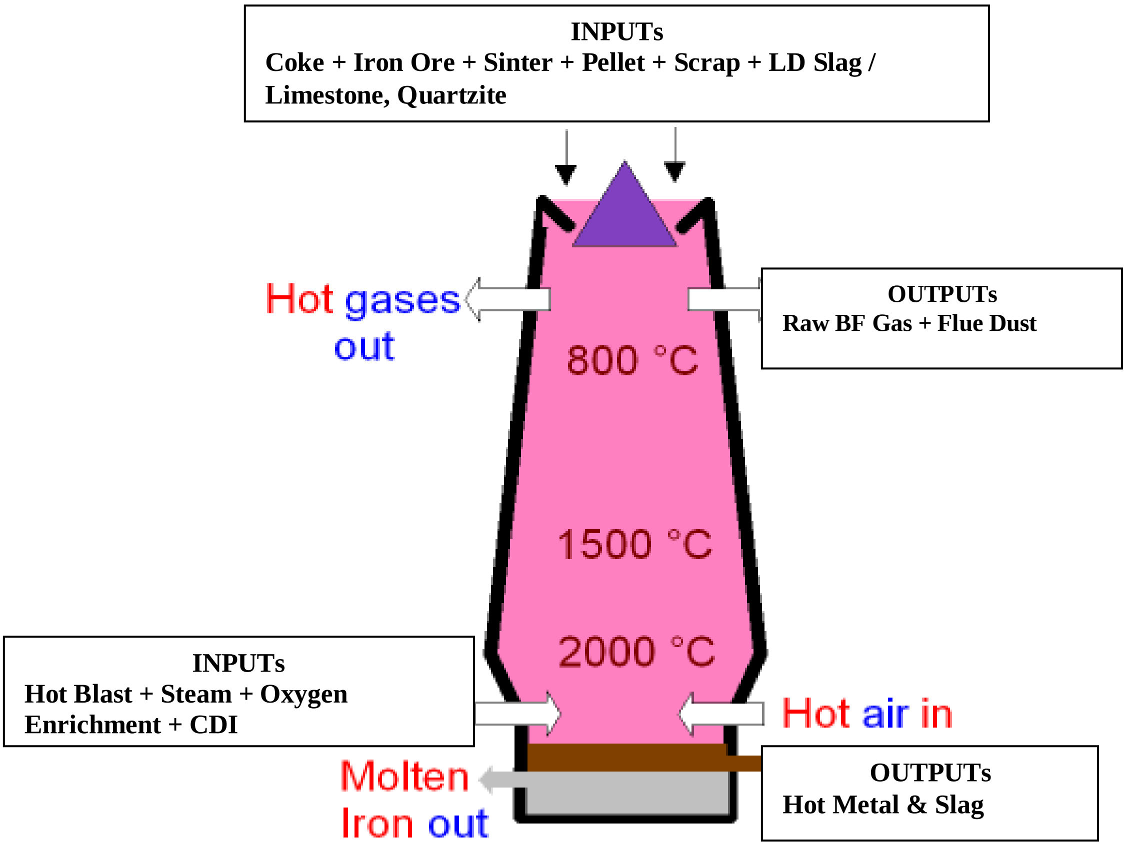
- The hearth, where the hot metal and slag is collected and is cast via the tap holes.



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.Theascending reducing gas(CO and H_2) comes in contact with the iron ore thusreduction (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:-

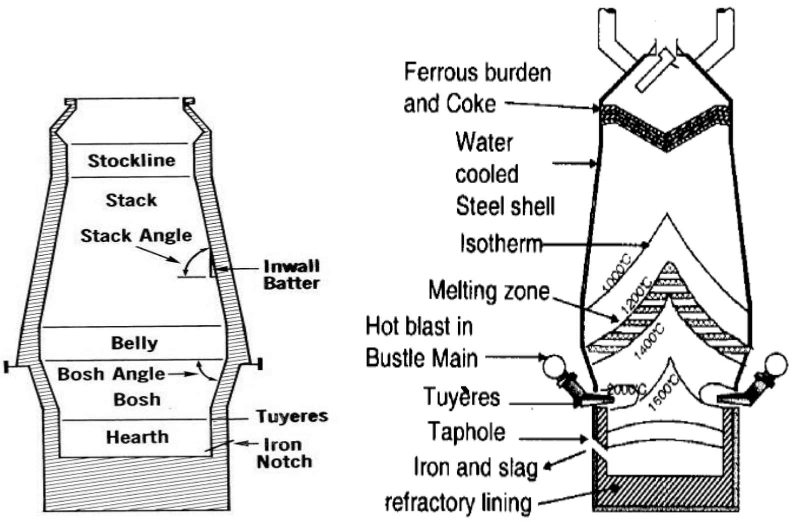
1. Hot Metal in the liquid condition.
2. Slag, in the liquid condition having less density thusfloats at the top of metal.

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.

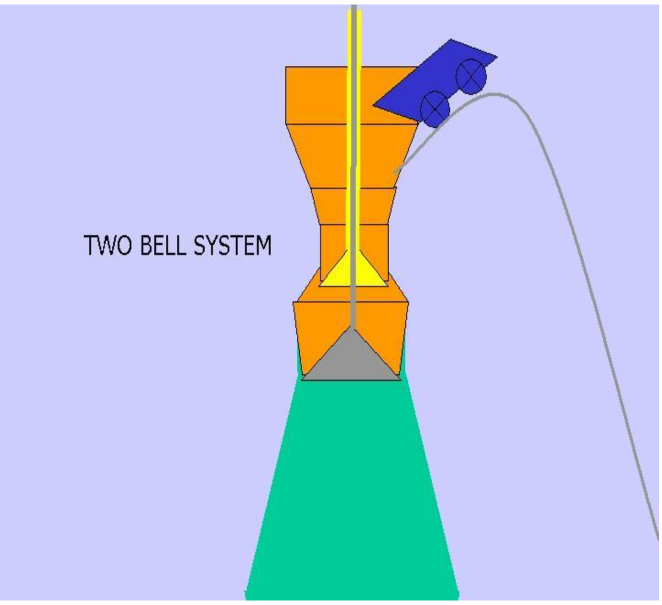


Fig-1. Double Bell

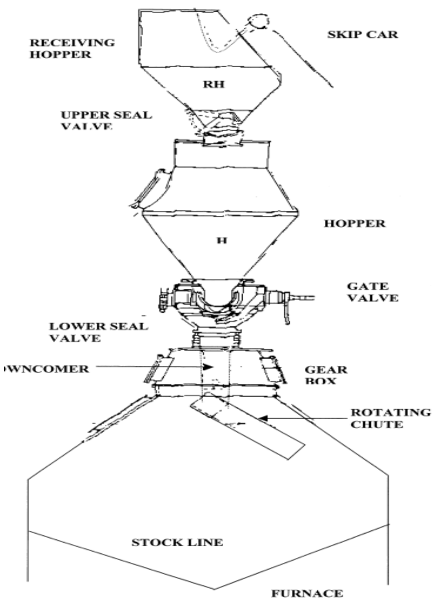


Fig-2 BLT systems

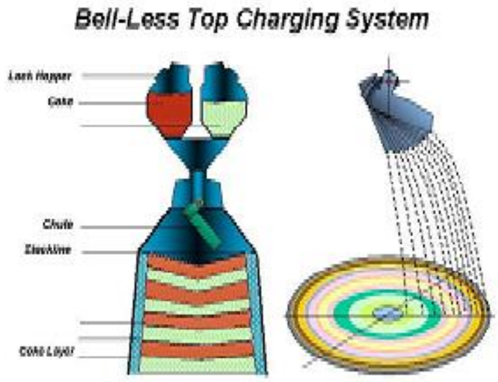


Fig-3 Rotary Charging Unit (RCU)   **Fig-4 BLTCharging**

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 eparated from mould chain by knockout arrangement.

<u>EQUIPMENTS of PCM</u>

- 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:

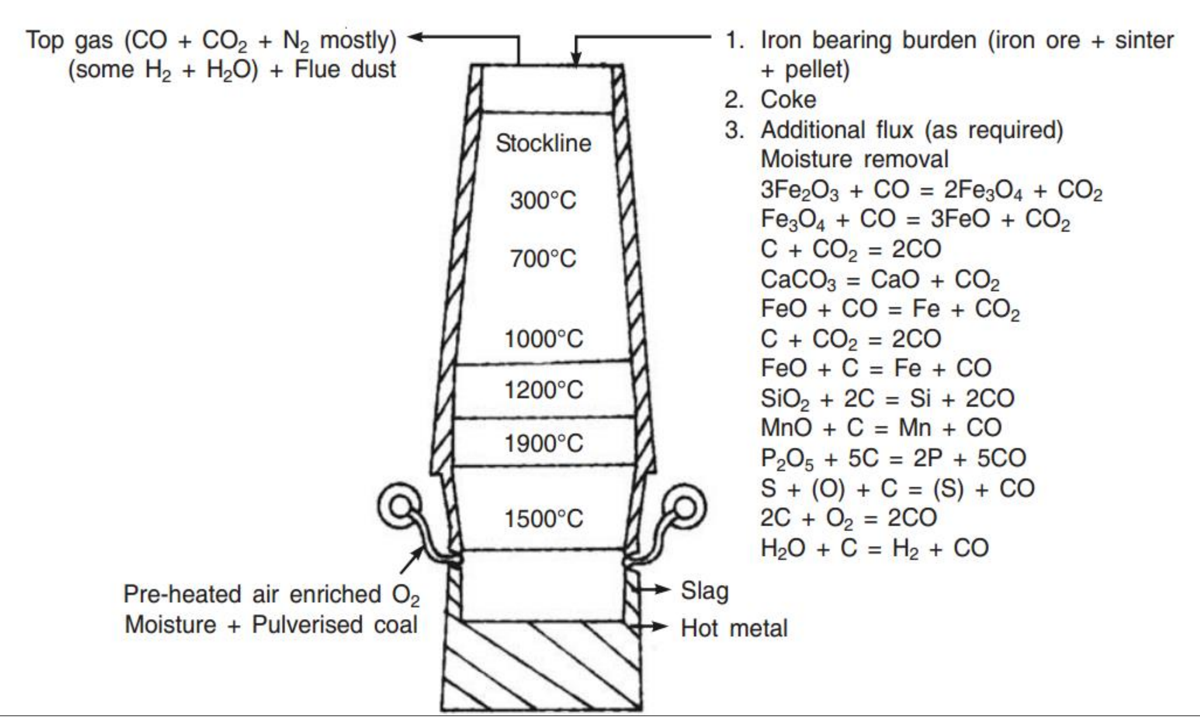
The other product BF gas contains lot of dust in it and it is cleaned in dust catcher, ventury washer and scrubber and finally in electro static precipitator. This activity is done under the supervision of energy management department. The cleaned BF gas is sent to the gas network and is used as a fuel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

  $3Fe_2O_3 + CO = 2\,Fe_3O_4 + CO_2$

  $Fe_3O_4 + CO = 3FeO + CO_2$

  $FeO + CO = Fe + CO_2$
- Carbon Deposition
- Decomposition of Carbonates
- Decomposition of Hydrates Water
- Gas Shift Reaction

  $CO + H_2O = CO_2 + H_2$

MIDDLE STACK ZONE

- Indirect/Direct Reduction

  $FeO + CO = Fe + CO_2$

  $CO_2 + C = 2CO$

  $FeO + C = Fe + CO$
- 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

  $C + O_2 = CO_2 + 94450$ cal

  $CO_2 + C = 2CO - 41000$ cal (solution loss reaction)

- 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:

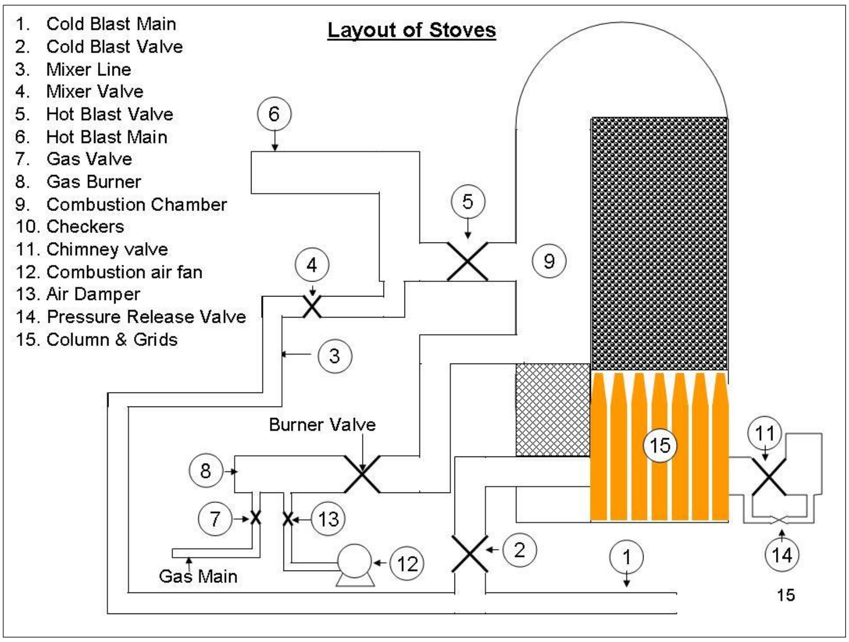
- Channelling
- Scaffolding
- Hanging
- Slipping
- Choking of Hearth
- Chilling of Hearth
- Burning of Tuyeres
- Coke rush through tap-hole.

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 of CHSGP 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

Techno-economics:

Productivity: the amount of hot metal produced per cubic meter of the furnace volume in a day, tonnes/m^3/day (either on working volume or useful volume basis)

Fuel rate: The amount of fuel required to produce one tone of hot metal, kg/thm. It includes coke rate + aux. fuel rate + nut coke rate (added in sinter).Carbon rate is more appropriate measure as carbon content of the fuel varies from time to time.

- 1% reduction in coke ash reduces the coke rate by 8 – 10 kg/thm(reduction of coke rate gives an overall saving of 0.5 % of the total energy consumption of steel plant)
- 1% reduction in gangue of iron ore results in coke saving of 1.5 %.
- 100 °C increase in HBT (Hot Blast Temperature) results in coke saving of 2 – 3 %.

Energy consumption for an iron making:-

Energy Consumption	Area Wise Energy Consumption
Coke Making	18 – 19 %
Iron Making & Sinter Making	49 – 50 %
Steel Making	8 – 9 %

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

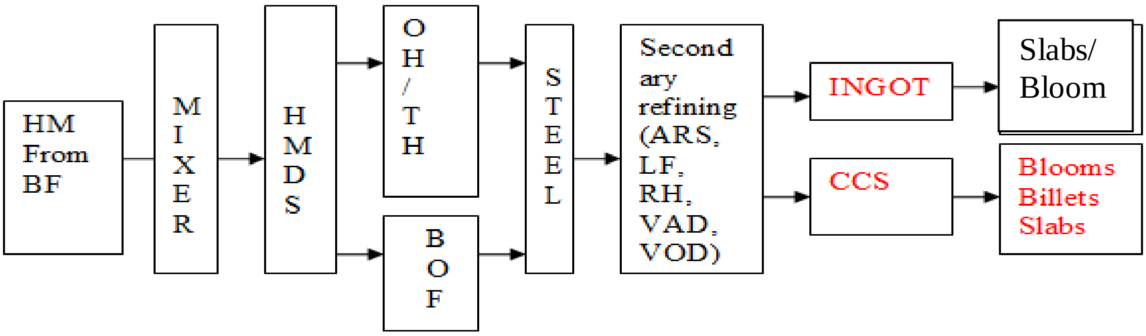
1. Don't allow any unauthorized person on stove platform.
2. Don't allow any one in Cast House area of blast furnace without safety appliances.
3. During any gas leakages don't allow anyone in the Cast House area & stove platform.
4. Don't Operate lift without proper knowledge of Mech./Elect. Operation 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.

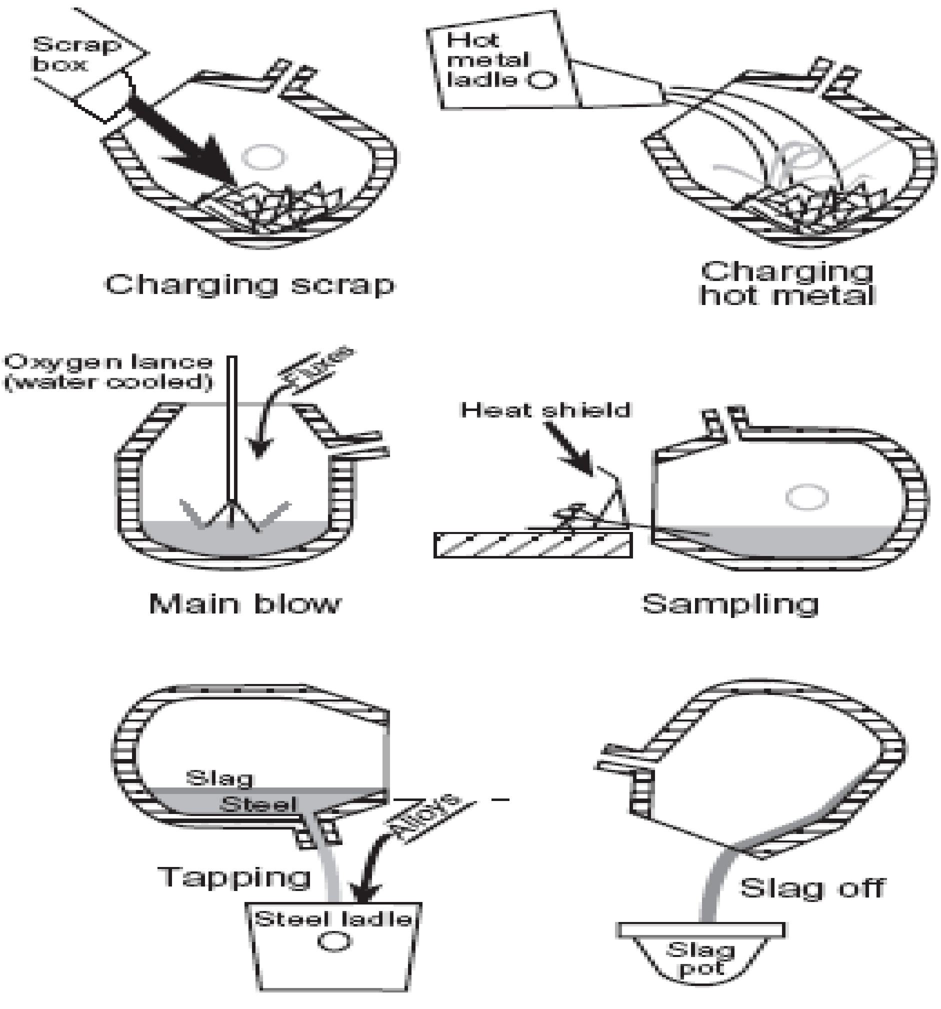
Activities in the furnace can basically be divided into two parts. Activities during cold period and activities during hot period run parallel at the same time for one of the two hearths in such a way that if one hearth is in cold period other will be in hot period. Cold period includes the time given 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



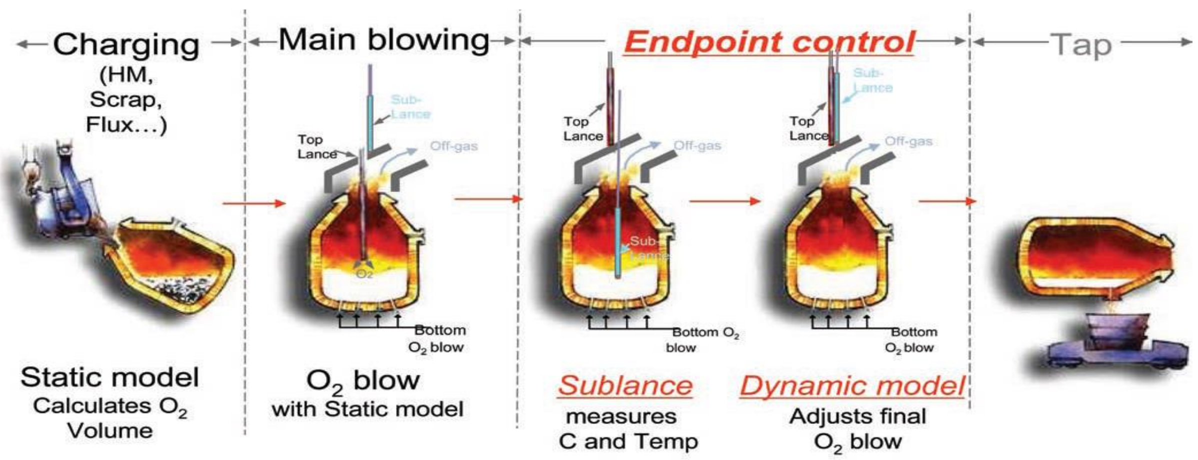
Basic Oxygen Furnace is commonly known as BOF process or LD process. It is named so because this process was developed in LINZ and DONAWITZ, two cities in Austria. The process is also called basic because of refractory type used for lining the vessel to withstand the high temperature of molten metal.

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 hot metal 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-Mn etc 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 blowing means 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.**

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, Mn etc 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.

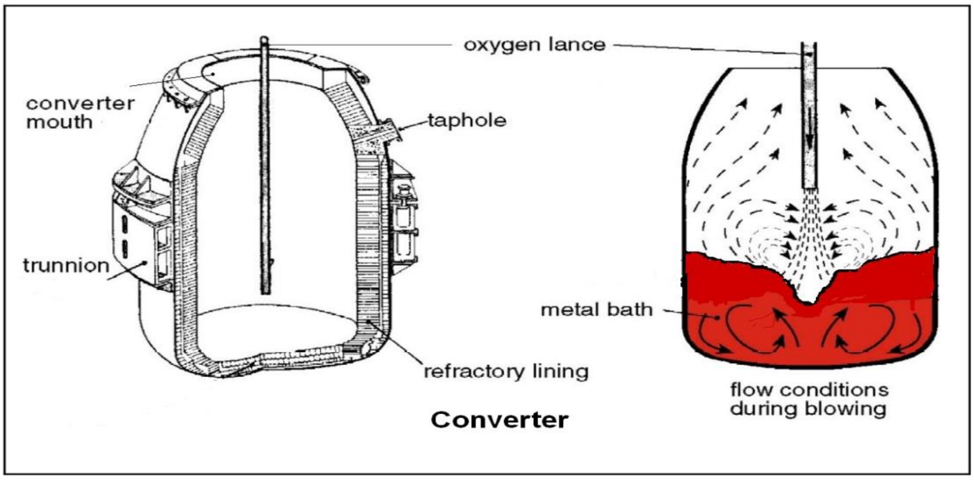
    - **Mixer:** The bricks used here are normally high alumina and magnesite bricks .

    - **Ladles:** The small vessel which carry Hot 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 the LD 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 be dumped.
- 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).

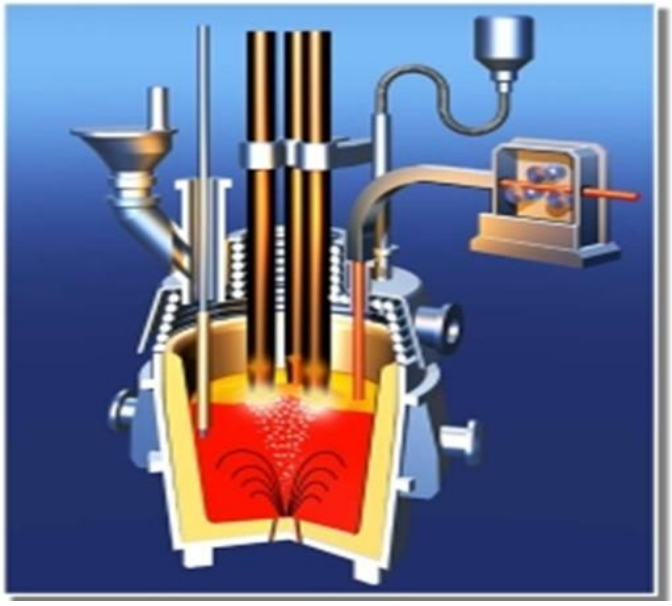
b. Ladle heating systems

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:

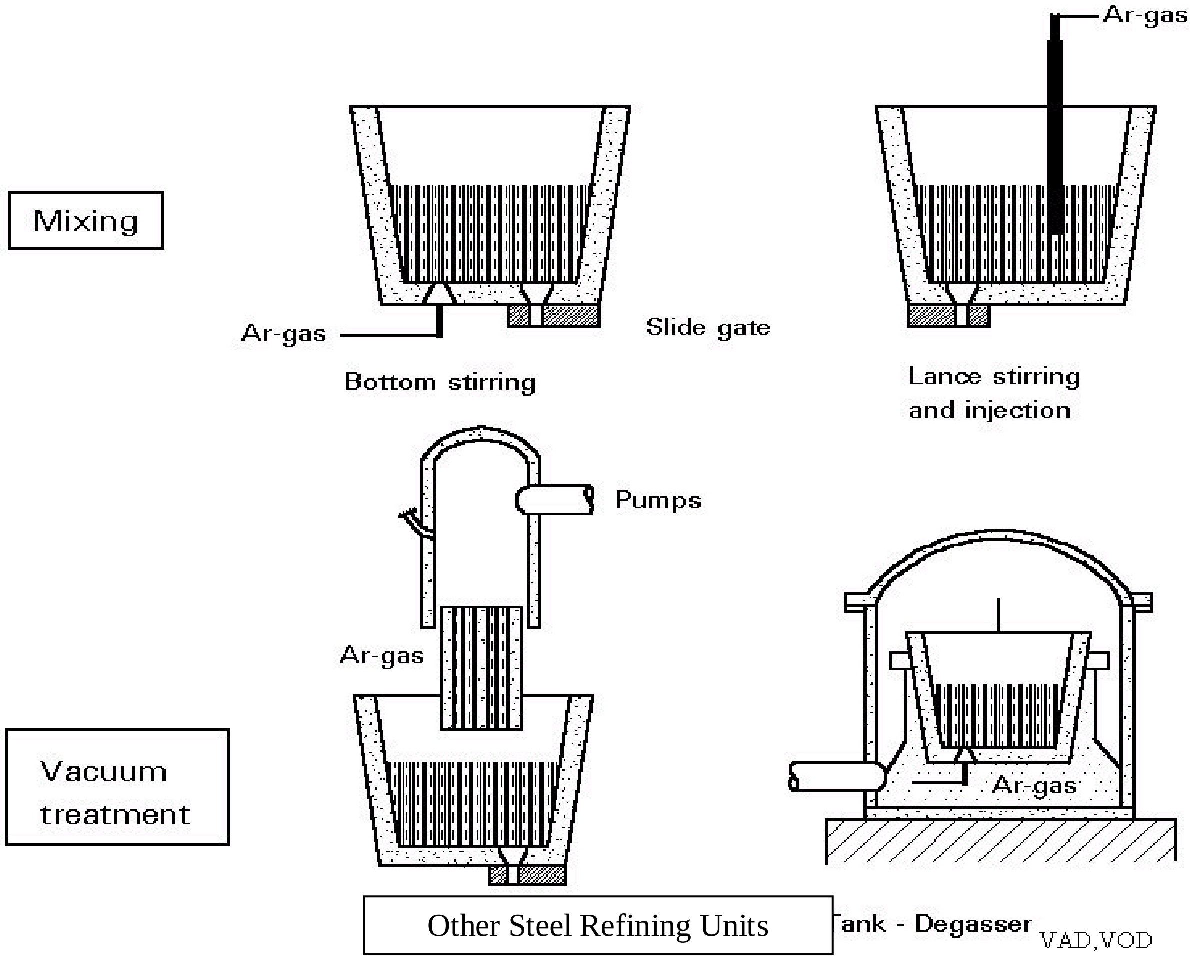
- reduction of the hydrogen content to less than 2 ppm
- considerable decarburisation of steel to less than 30 ppm when oxygen is blown by a lance (RH - OB)
  alloy addition under vacuum
- homogeneous steel composition, high degree of cleanliness from deoxidation products

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

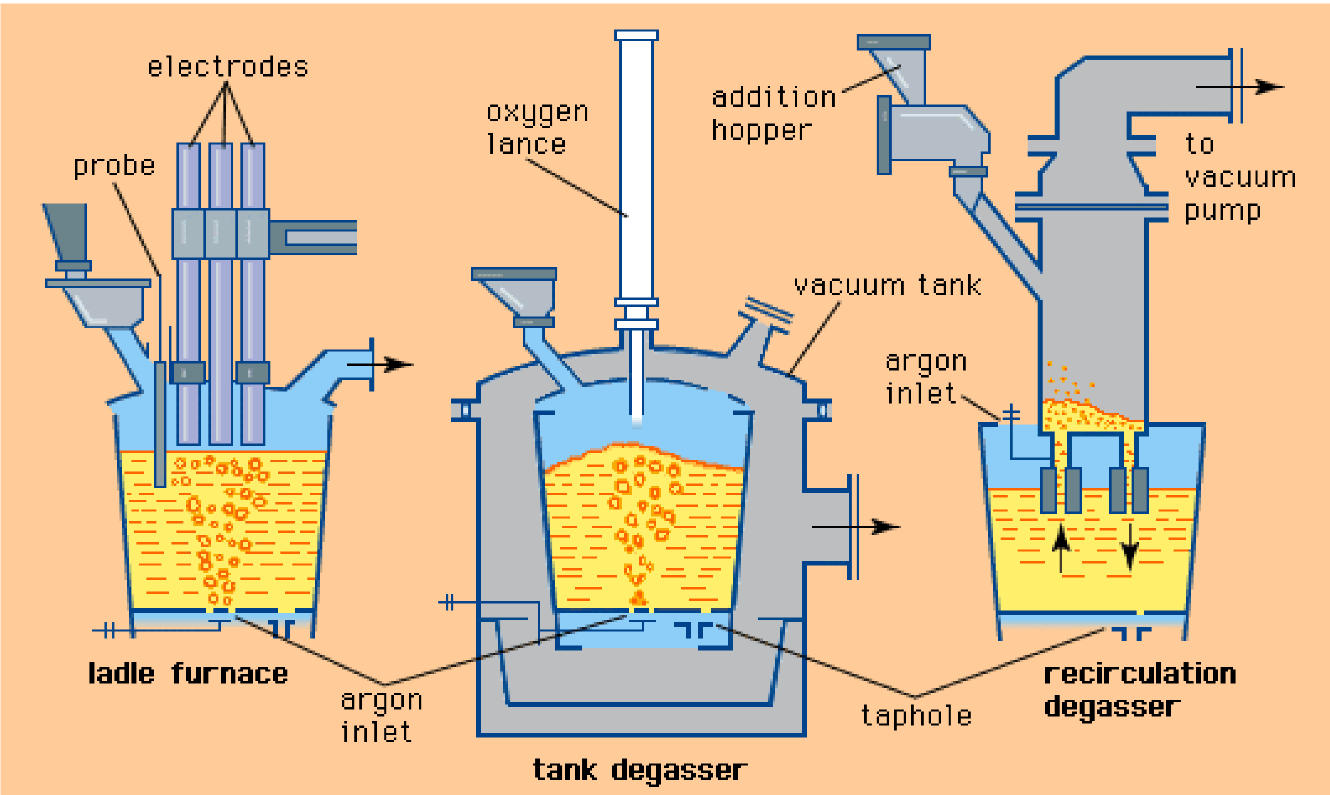
Ferro alloy addition facility for trimming addition

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



Metallurgical Principles

( ) 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 sulphide carrying capacity 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.

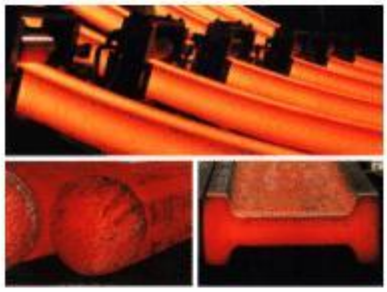
Nitrogen removal

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



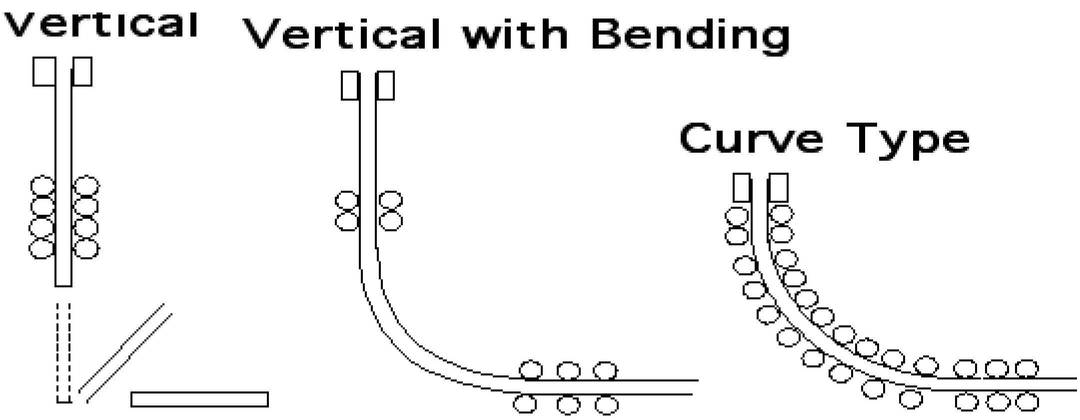
Background

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

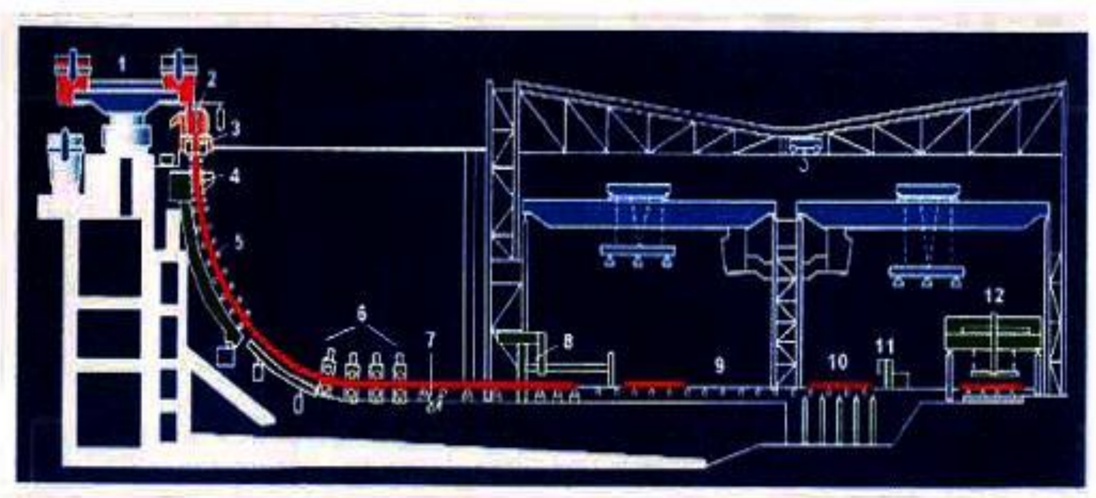
- **Molten steel is continuously poured into a water cooled Cu mould that is open at the top and bottom.**
- **The steel gradually cools and begins to set solid in the mould. The rate at which molten steel is poured into the top is matched with the rate at which the solid steel is pulled out at bottom.**
- **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.

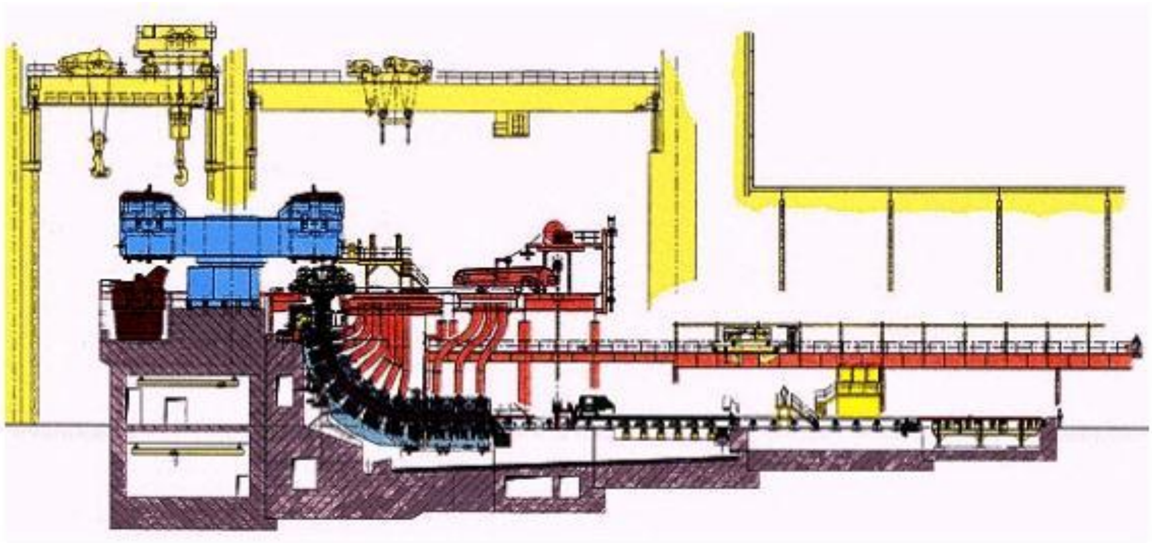


Figure 3 -Slab Caster Layout

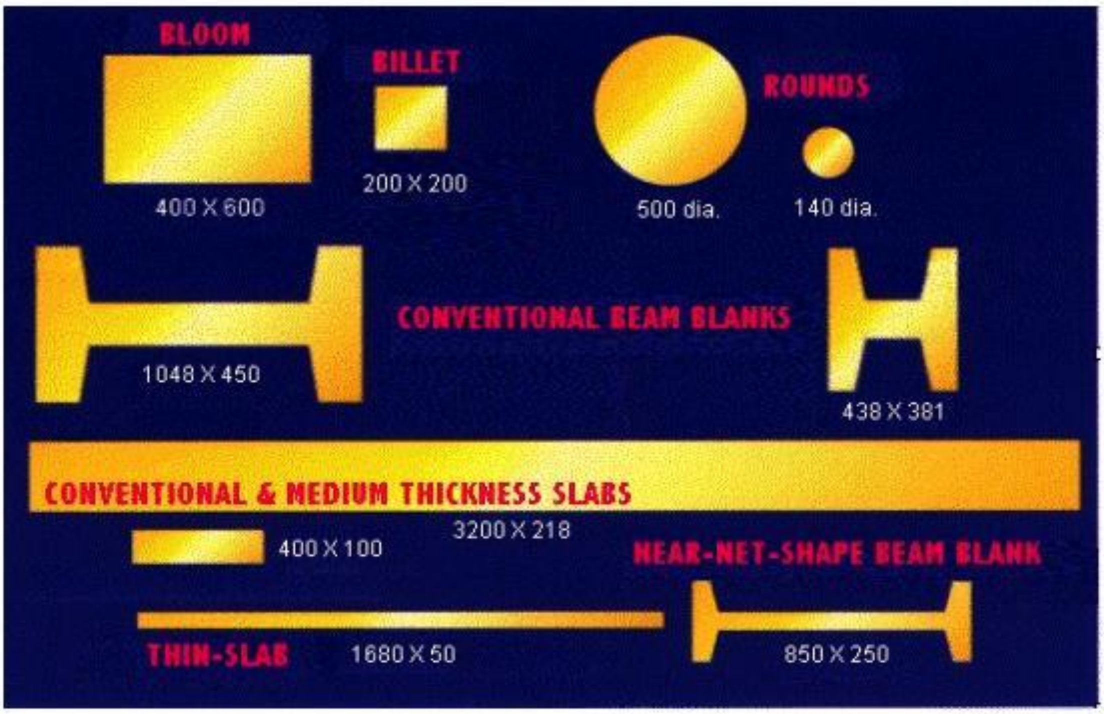


Figure 4 - Continuous Cast Shapes (sizes in millimeters)

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.

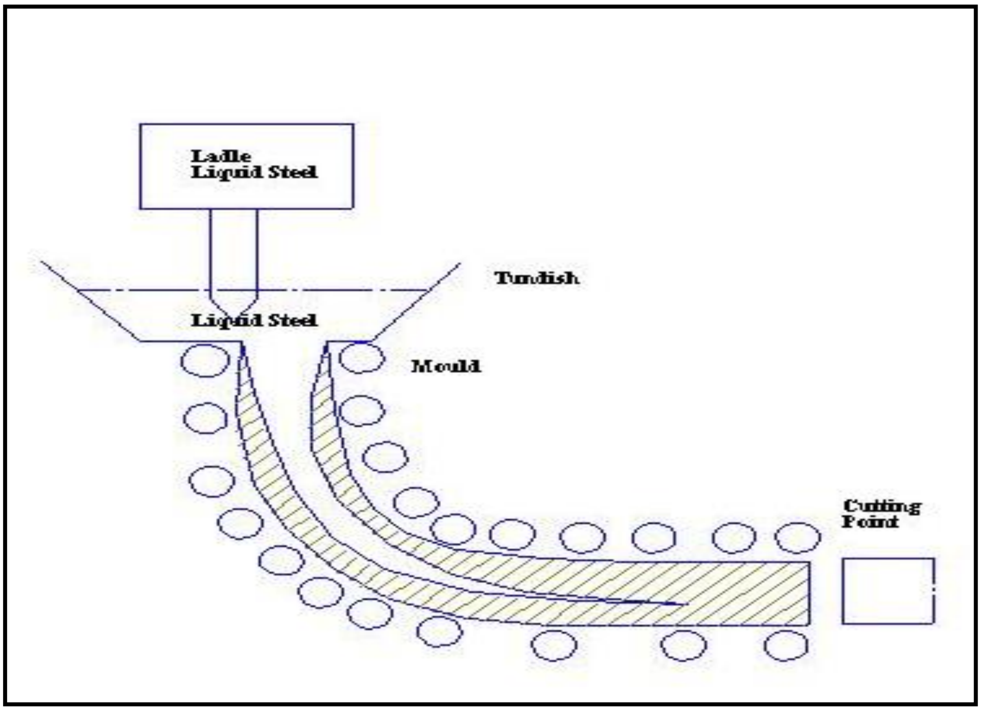
Tundish is a device through which continuity of the casting is maintained. There are two types of casting practices are in use namely cold tundish and hot tundish practices. Liquid steel comes from the ladle into the tundish and in turn the tundish feeds the liquid steel into the mould through different 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:

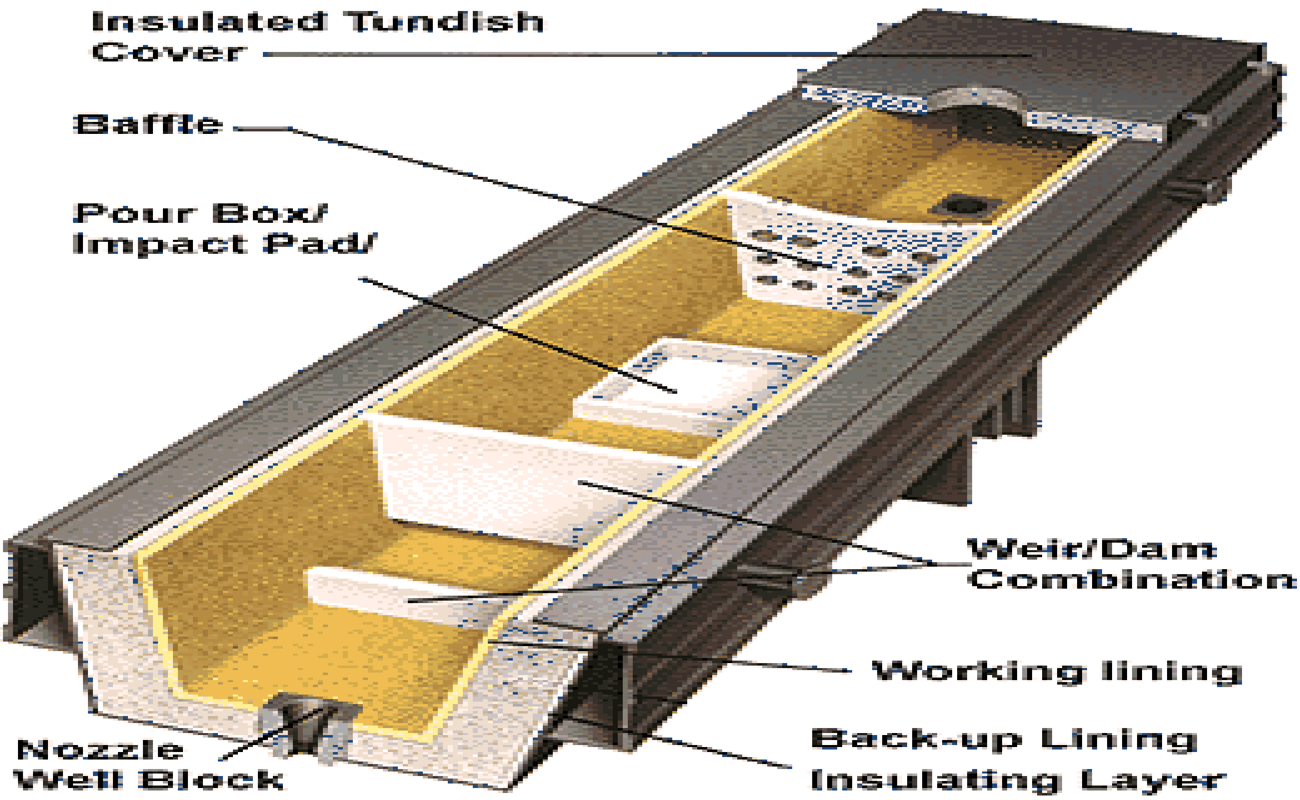
- A tundish, located above the mould to feed liquid steel to the mould at a regulated rate
- A primary cooling zone or water-cooled copper mould through which the steel is fed from the tundish, to generate a solidified outer shell sufficiently strong enough to maintain the strand shape as it passes into 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:

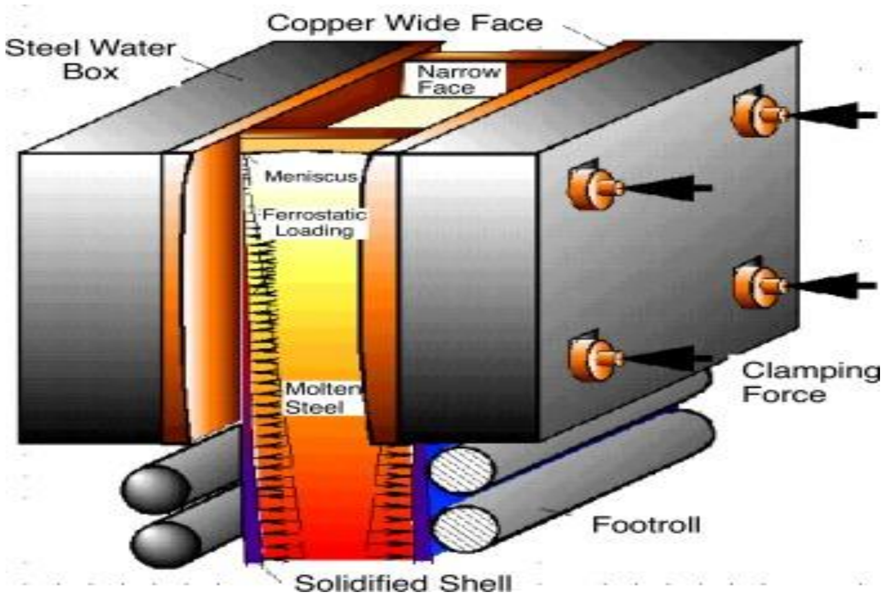
- Affects the stream flow pattern in mould.
- Reduces the pouring rate.
- May lead to premature changing of SENs and termination of casting operation.
- Steel quality may be affected.

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

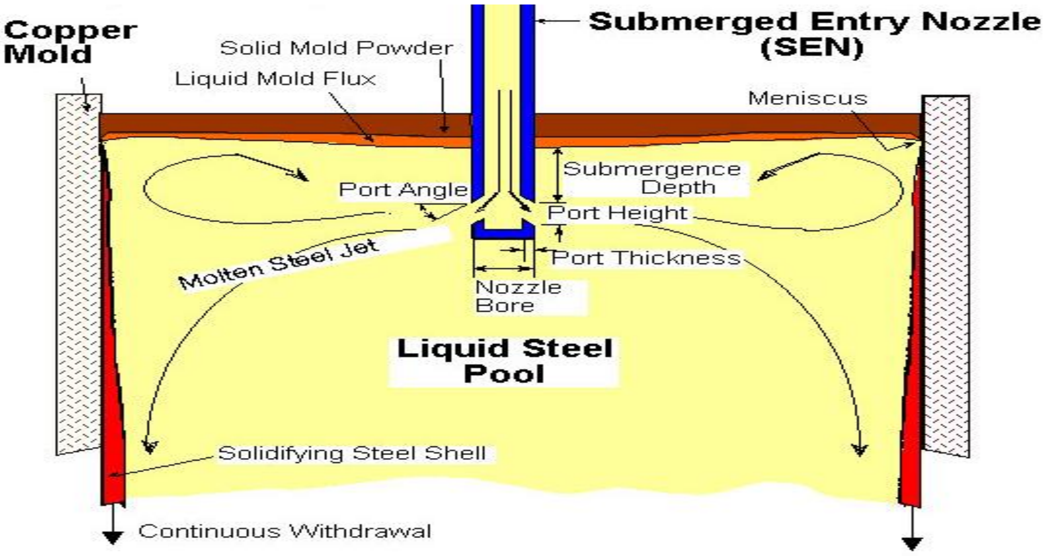
The main function of the mould is to establish a solid shell sufficient in strength to contain its liquid core upon entry into the secondary spray cooling zone.



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.

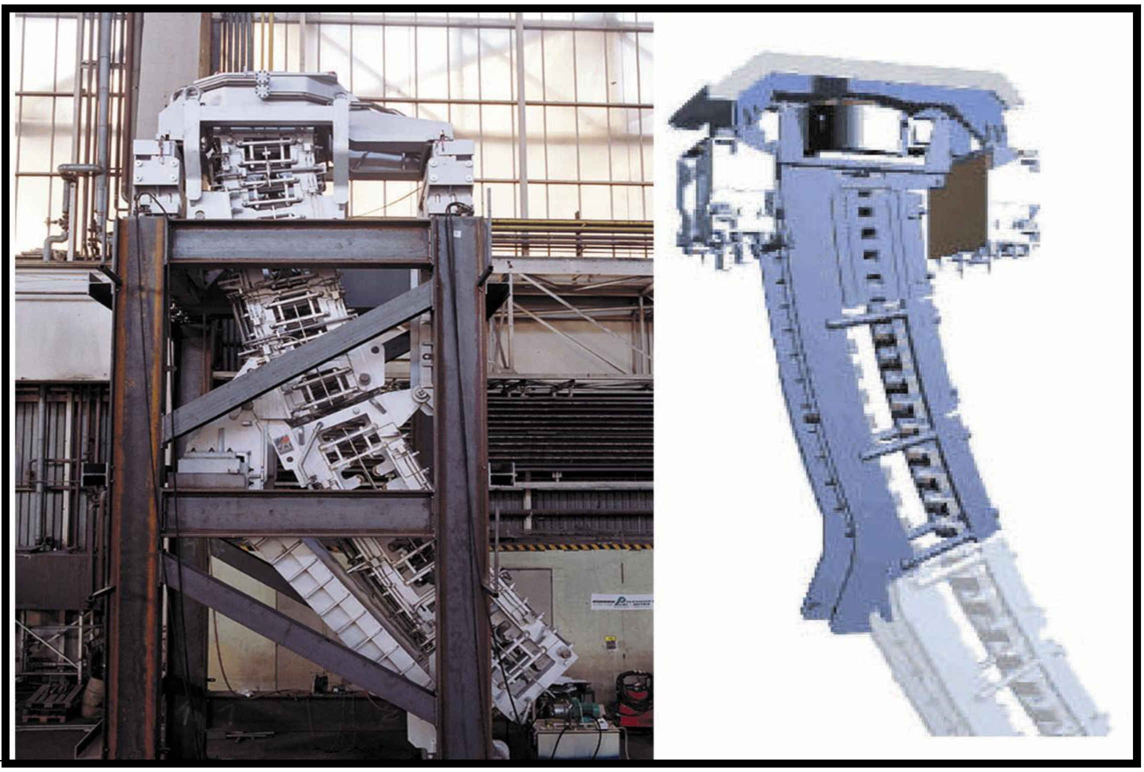
Mould Flux

- 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.

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.

Chapter – 6.0

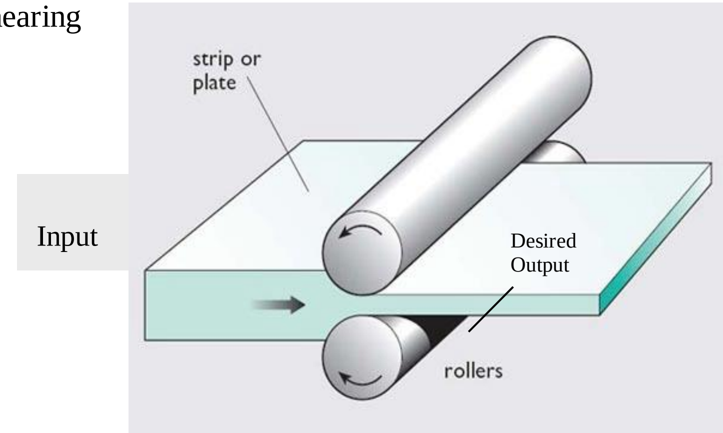
ROLLING MILLS

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

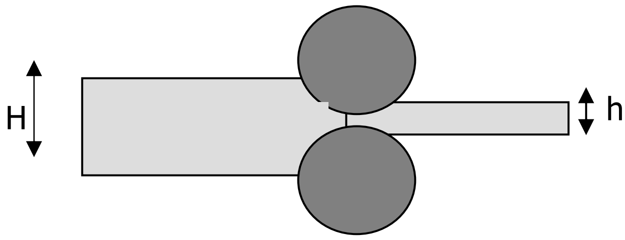
Basic Definitions



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.

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

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.

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

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= $\frac{\text{Output}}{\text{Input}}$x100

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:. Hot rolling is a metalworking process in which metal is heated above the recrystallization temperature to plastically deform it in the working or rolling operation.
This process is used to create shapes with the desired geometrical dimensions and material properties while maintaining the same volume of metal. The hot metal is passed between two rolls to flatten it, lengthen it, reduce the cross-sectional area and obtain a uniform thickness. Hot-rolled steel is the most common product of the hot rolling process, and is widely used in the metal industry either as an end product or as raw material for subsequent operations. Hot rolling breaks the grain structures and destroys the boundaries, giving rise to the formation of new structures with strong boundaries having uniform grain structures.

Hot rolling improves:

- Toughness and strength
- Ductility
- Resistance to vibration and shock
- Formability
- Weldability

Hot-rolled steel products are classified into four groups:

- Flat
- Long
- Seamless
- Specialty

Typical applications of hot-rolled steel are:

- Automotive structural parts such as frames
- Tabular products such as pipe and gas cylinders
- Machine structures such as saws and springs
- Agriculture equipment
- Metal buildings
- Guard rails

Cold Rolling: Metal forming process in which the shape and structure of steel is altered through drawing, extruding, hammering, pressing, rolling, spinning, and/or stretching at temperatures below the steel's recrystallization point (usually room temperature).

Cold rolling is a technique where a metal strip or sheet is passed between two rollers and then squeezed and compressed. The level of strain present determines the properties and hardness of the finished material.

This process is widely used for surface finish and high-quality dimensional accuracy, which can help prevent material damage and corrosion

The typical applications of cold rolling are in the production of:

- Filing cabinets
- Metal furniture
- Computer cabinets
- Water heaters
- Exhaust pipes
- Steel drums

Through cold rolling of steel, the strength and hardness of the material is enhanced significantly, which in turn improves the corrosion resistance of metal in many ways. This is brought about by the addition of more tension and energy to the product.

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.

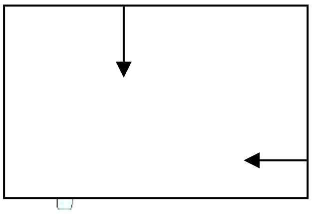
The difference between the two is the temperature at which they are processed. Hot Roll is processed above the re-crystallization temperature. Its grains reform after the rolling process and it is left in a stress-free state. Cold Roll is processed below the re-crystallization temperature. Its grains remain flattened and elongated, leaving the material in an anisotropic state and full of cold work.

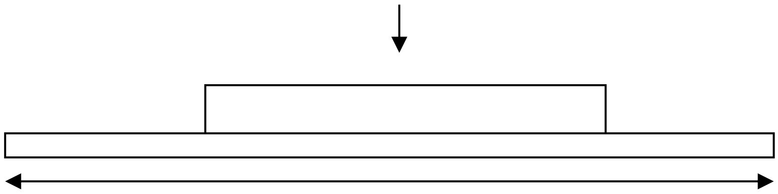
FACTORS	HOT ROLLED CHARACTERISTICS	COLD ROLLED CHARACTERISTICS
Layout Orientation	The material characteristics is identical in all directions	Care must be exercised in layout. The grains of the material are deformed during the rolling process and stay deformed. The material will be stronger with the grain than against the grain.
Price	Less Expensive	More Expensive
Strength	Weaker	Stronger
Weldability	Excellent for welding	Weldable, but the material will take on the properties of hot roll wherever it is welded
Machinability	Experiences no warping when machined	The removal of too many residual stresses during machining will throw the material out of equilibrium and cause deflection and wrapping
Dimensional tolerances of stock	Fair. Deviations from the stated size are present due to surface scale and thermal shrinkage	Good. It is not as accurate as ground stock, but better than Hot Roll.
Surface Finish	Fair to Poor The surface of the material will be covered with carbon scale	Good. Not as good as ground stock, but much better than Hot Roll.

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**.





Flat products

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

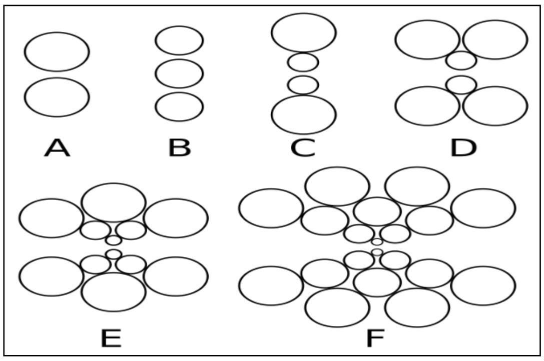
- Hot rolled carbon and Stainless steel flat products
- Cold rolled stainless steel sheets and coils

Visvesvaraya Iron and Steel Plant, Bhadrawati

- Semis, Bars

<u>Different configuration of rolls used in rolling mills</u>

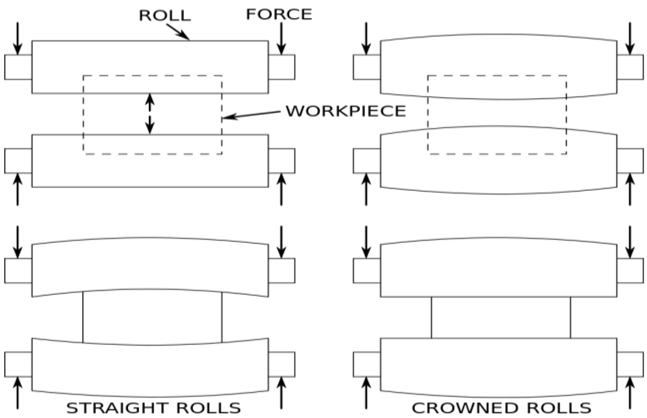
Mills are designed in different types of configurations, with the most basic being a two-high non-reversing, which means there are two rolls that only turn in one direction. The two-high reversing mill has rolls that can rotate in both directions, but the disadvantage is that the rolls must be stopped, reversed, and then brought back up to rolling speed between each pass. To resolve this, the three-high mill was invented, which uses three rolls that rotate in one direction; the metal is fed through two of the rolls and then returned through the other pair. The disadvantage to this system is the workpiece must be lifted and lowered using an elevator. All of these mills are usually used for primary rolling and the roll diameters range from 60 to 140 cm (24 to 55 in).

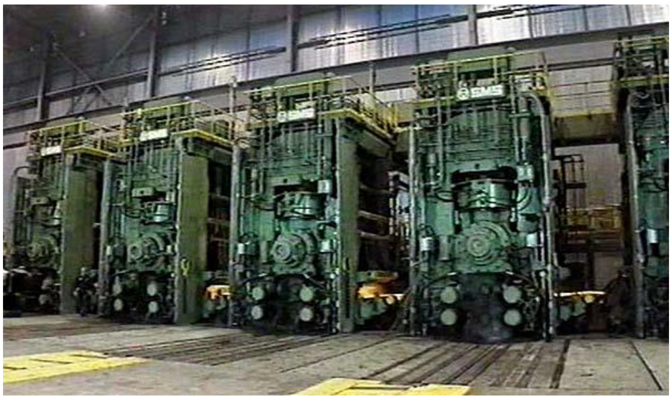


Various rolling configurations. Key: A. 2-high B. 3-high C. 4-high D. 6-high E. 12-high cluster & F. 20-highSendzimir Mill cluster

To minimize the roll diameter a four-high or cluster mill is used. A small roll diameter is advantageous because less roll is in contact with the material, which results in a lower force and power requirement. The problem with a small roll is a reduction of stiffness, which is overcome using backup rolls. These backup rolls are larger and contact the back side of the smaller rolls. A four-high mill has four rolls, two small and two large. A cluster mill has more than 4 rolls, usually in three tiers. These types of mills are commonly used to hot roll wide plates, most cold rolling applications, and to roll foils.

Roll deflection during rolling





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

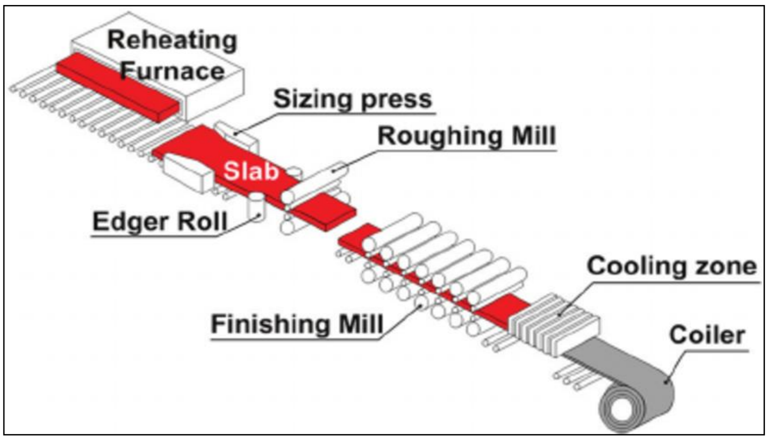
In the reheating furnaces the Input materials are heated to a specified temperature and soaked for given time depending upon size of input slab and their metallurgical requirements for which it is planned to be rolled. Ideally, it is aimed to equalize the surface and the core temperatures of the slab. 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.

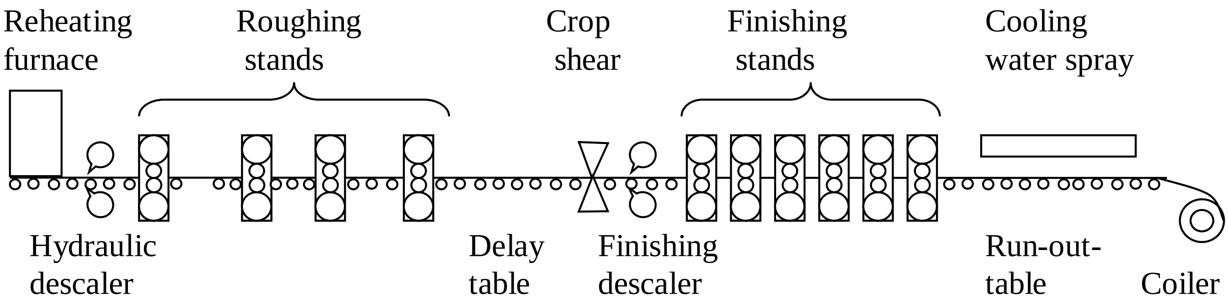
Types of Reheating Furnaces:

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:

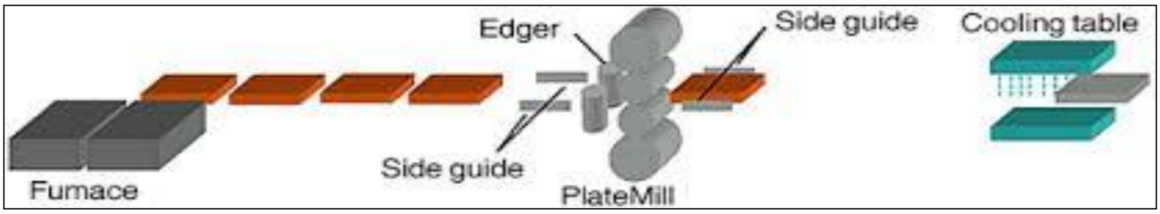
Finishing Stands of Hot strip mill normally have 5-7 stands in 4-high construction (combination of work rolls and back up rolls). These stands are in tandem and strip passes through them on continuous basis. Roll force, roll gap can be controlled through different mechanisms such as roll bending, pair 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:

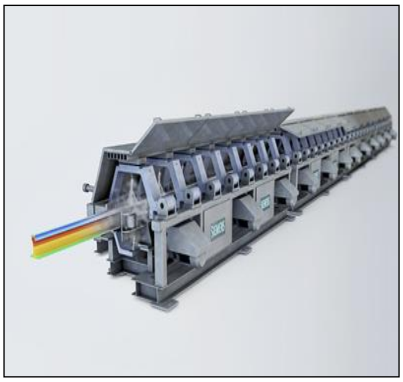
Roll change schedule has to be strictly adhered to and roll cooling conditions need to be monitored continuously. Shape and dimensional tolerances also depend on the above mentioned conditions.

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:

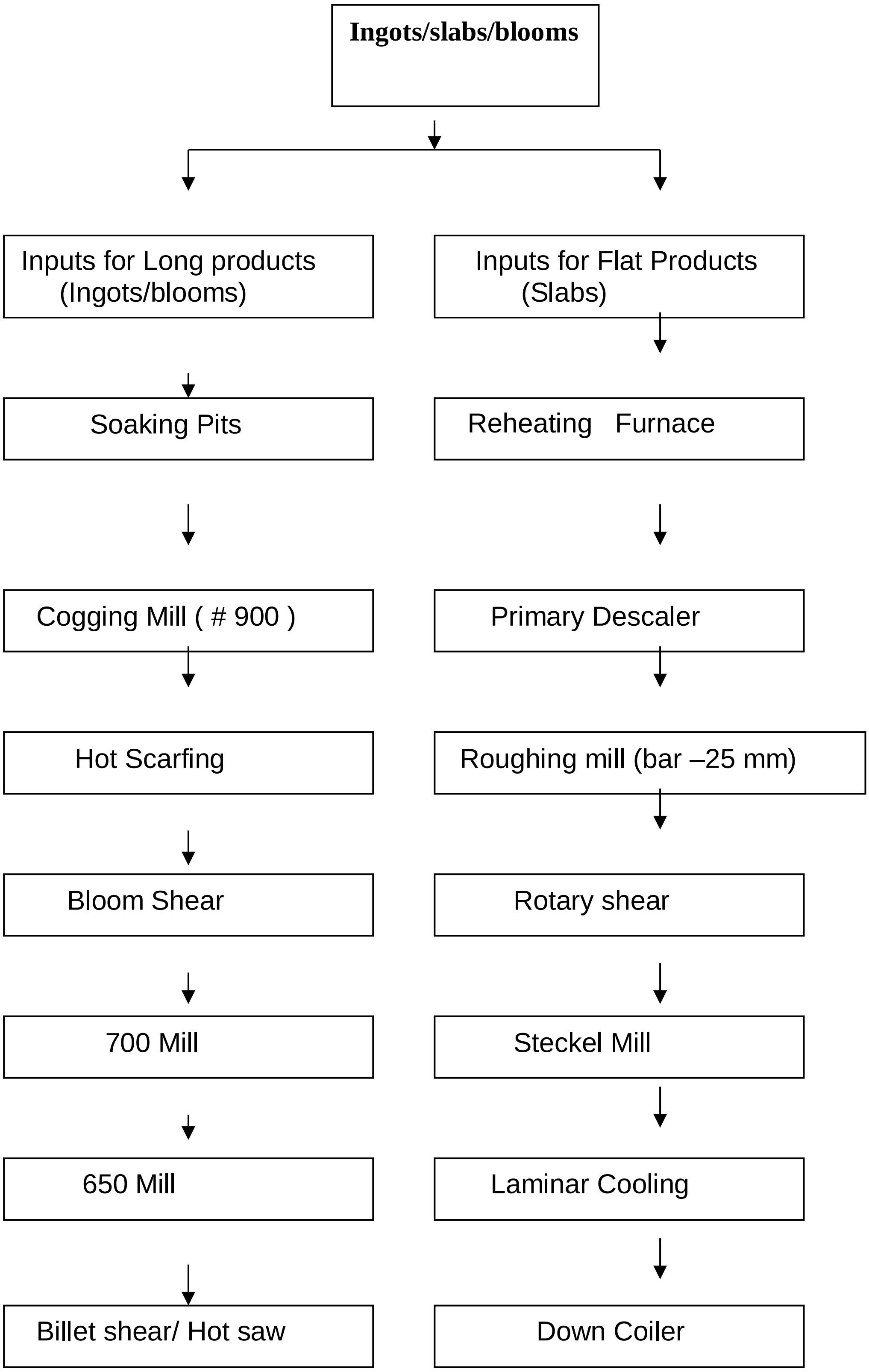
a) **Rolling defects:** Defects induced during the rolling process are classified as rolling defects.
b) **Steel defects:** Defects resulting from steel making practices and getting carried forward during the process of rolling to the end product may be classified as steel defects.

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.

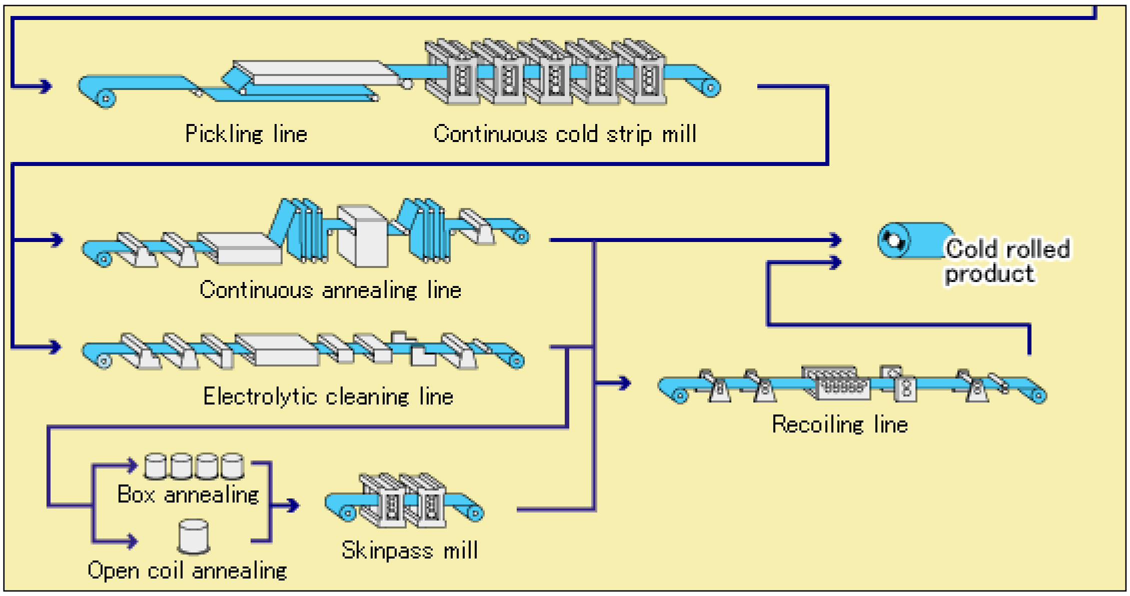
SPECIAL PLATE PLANT (SPP)

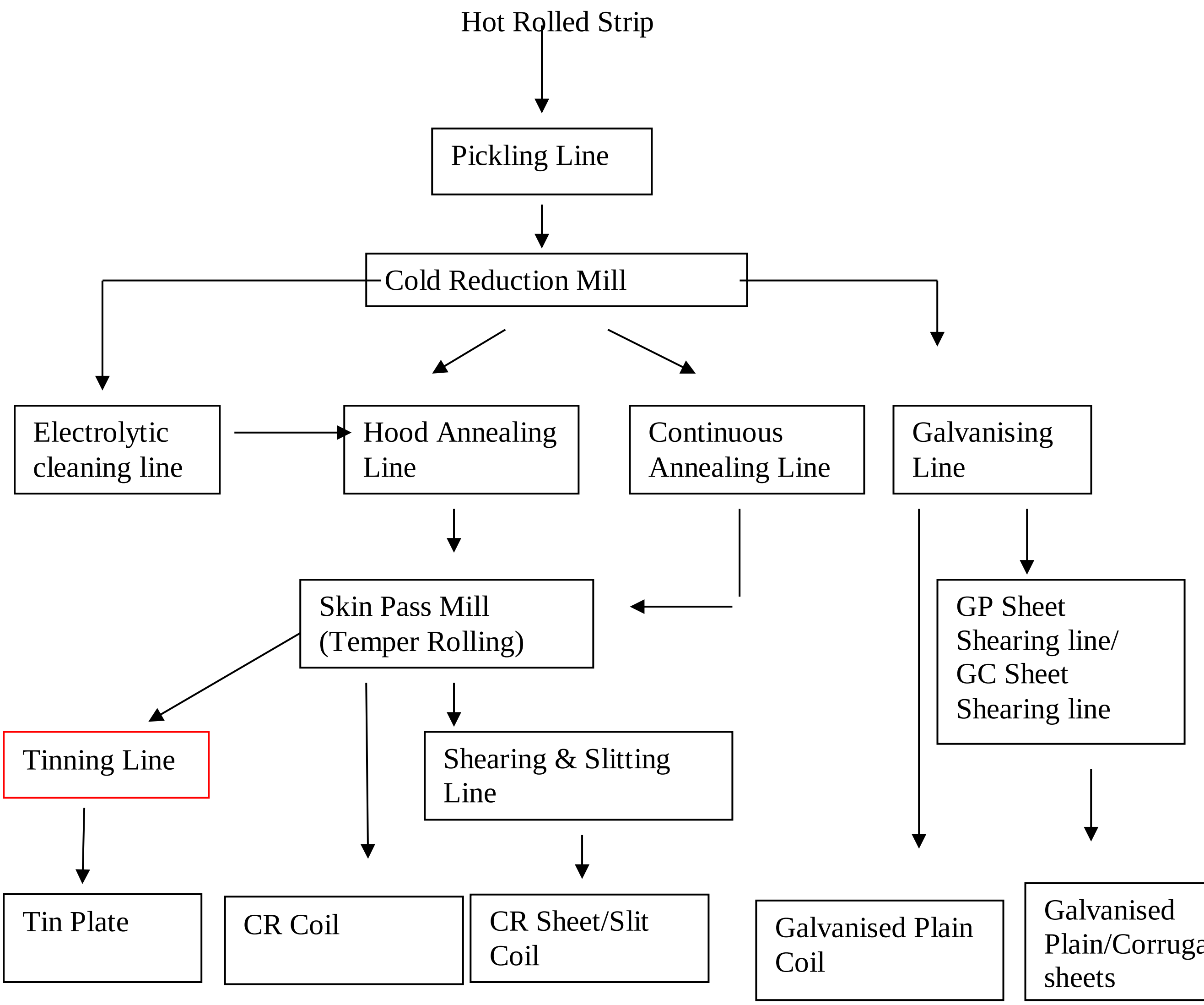
Special Plate Plant (SPP) of Rourkela Steel Plant caters to the needs of Defence & Space requirements. Special Plate Plants is **the only unit in India** producing various grades of quenched and tempered special steel plates, Armour Plates & Components for Defence in larger dimensions. All these steels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

6.8 Cold Rolling

<u>COLD ROLLING MILL (CRM)</u>

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;

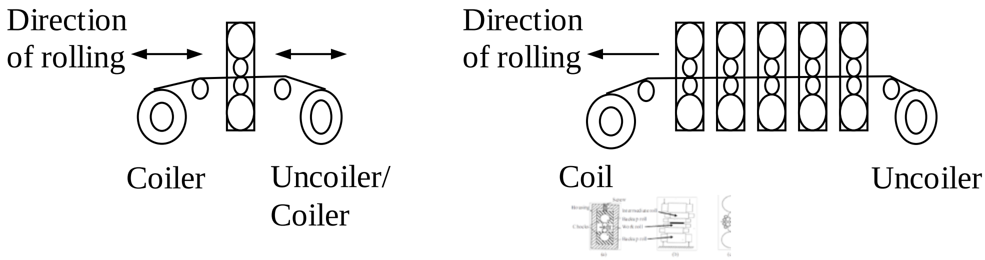
or

- 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.

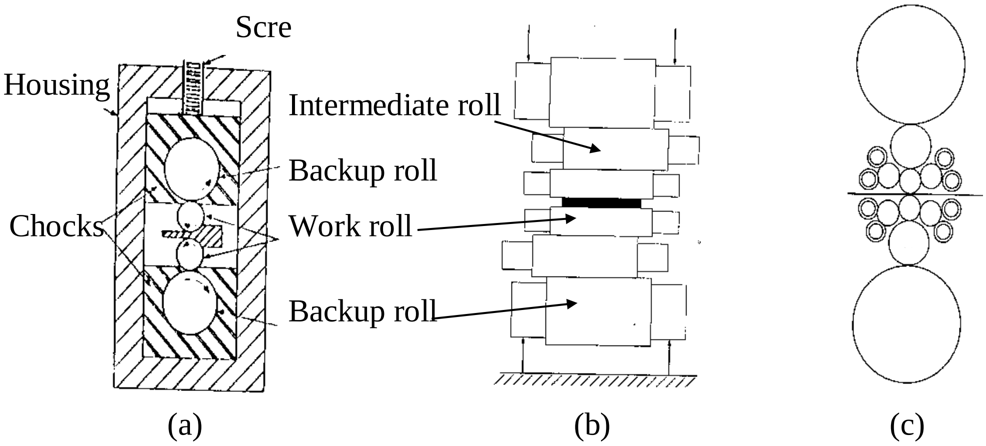


(a) (b)

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 of 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.

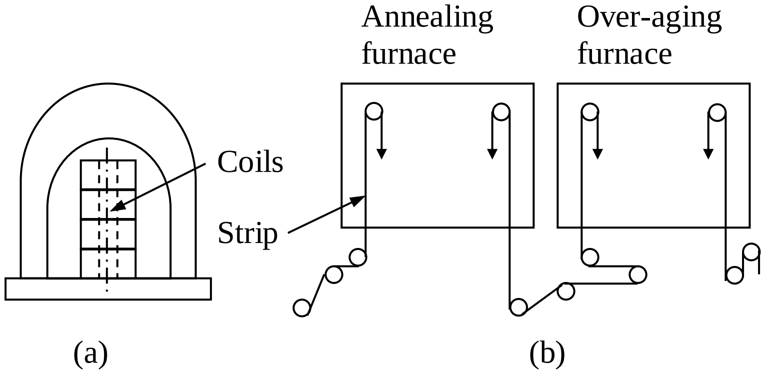


Figure: Schematics of (a) Batch Annealing and (b) Continuous Annealing

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 into 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. Online inspection is done in most of the cases.

CR SLITTER

In slitter CR coils are slitted lengthwise 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 Galvanizing 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.

6.10 Introduction to Pipe Plants and Silicon Steel Plant

PIPE PLANTS (PPs)

Rourkela Steel Plant has two Pipe making mills

ELECTRICAL RESISTANCE WELDING PIPE PLANT (ERWPP)

The ERWPP in RSP is modernized in the year 2005 with high frequency welder and is named as HFW pipe plant. It is designed to produce IS ,ASTM and API grades pipes up to grade API-5L-X70 of diameter ranging from $8^5/_8$" to 18''(219.1 mm to 457.2mm) Outside diameter with wall thickness from 4.8 mm to 12.7 mm. The IS grade pipes are used for transportation of water, slurry, sewerage ,ash etc.IS 4270 grades pipes produced at ERWPP are used for structural jobs, deep wells etc. ASTM grades pipes are also produced to cater few orders. **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 both IS and API grade 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.

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 and SW pipe plant. This input material is formed to a tubular shape by gradual deformation and then welded by the combination of heat and pressure in ERW pipe plant .The HR coils are formed in spiral form and welded with filler material in SW pipe plant.

SILICON STEEL MILL

Electrical steel is an iron alloy which may have from zero to 6.5% silicon (Si:5Fe). Commercial alloys usually have silicon content up to 3.2% (higher concentrations usually provoke brittleness during cold rolling). Manganese and aluminum can be added up to 0.5%.

Silicon significantly increases the electrical resistivity of the steel, which decreases the induced eddy currents and narrows the hysteresis loop of the material, thus lowering the core loss. However, the grain structure hardens and embrittles the metal, which adversely affects the workability of the material, especially when rolling it. When alloying, the concentration levels of carbon, sulfur, oxygen and nitrogen must be kept low, as these elements indicate the presence of carbides, sulfides, oxides and nitrides. These compounds, even in particles as small as one micrometer in diameter, increase hysteresis losses while also decreasing magnetic permeability. The presence of carbon has a more detrimental effect than sulfur or oxygen. Carbon also causes magnetic aging when it slowly leaves the solid solution and precipitates as carbides, thus resulting in an increase in power loss over time. For these reasons, the carbon level is kept to 0.005% or lower. The carbon level can be reduced by annealing the steel in a decarburizing atmosphere, such as hydrogen.

The silicon mill Complex is designed to produce of Cold Rolled Non-Oriented electrical grade Silicon Steel of various sizes and grades in the form of Coils as well as Sheets.

6.11 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”.

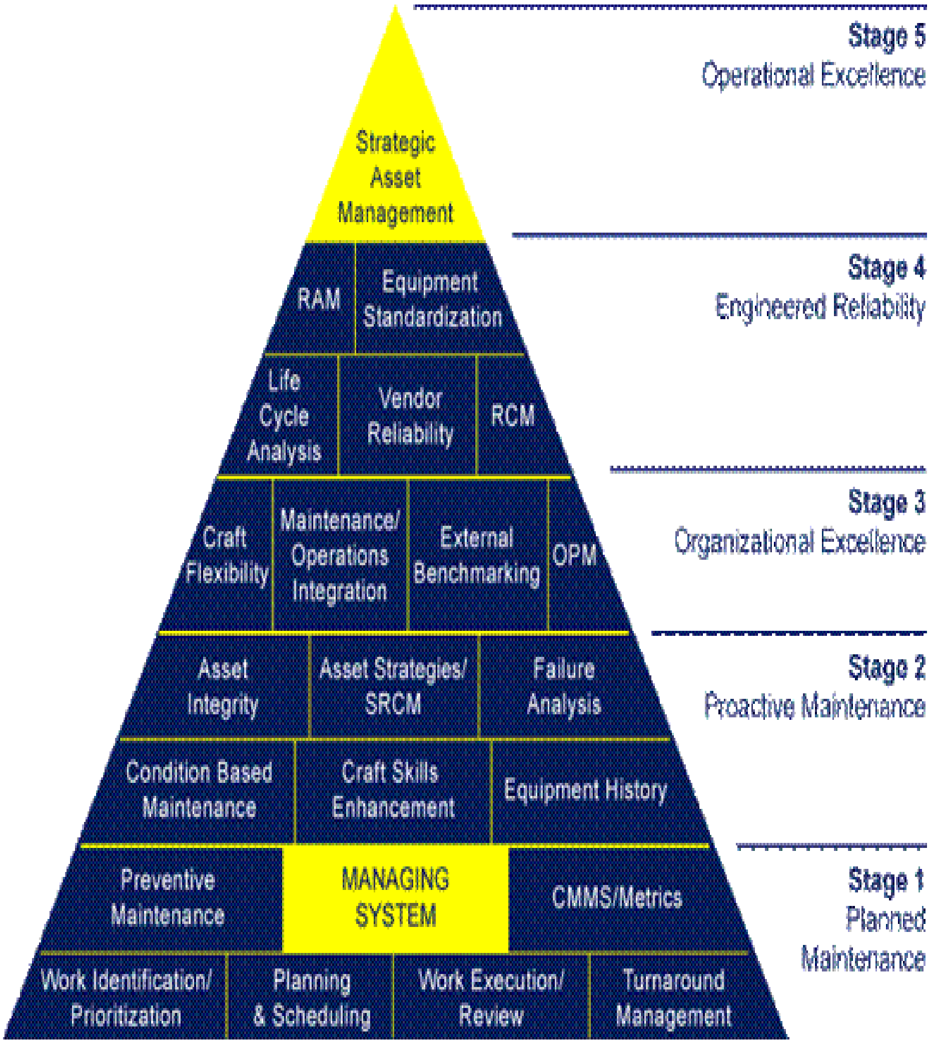


Figure 1: Asset Healthcare

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

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 have time to turn equipment over to maintenance as scheduled.
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 excellence means having the lowest cost of items available.
7. Pressure is on individuals to do better. No gauges or tools of "better" exist.

Asset Management Excellence Model

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 lagging indicator goals (e.g. monthly production), and have unique leading indictor goals that support activities (e.g. % of PMs performed to schedule).
6. Purchasing and inventory management's highest goal is parts service level and mean time between failure for purchased parts.
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^{0}C and 100^{0}C. Some special greases may withstand a temperature above 100^{0}C 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^{0}C. For every 10^{0}C 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

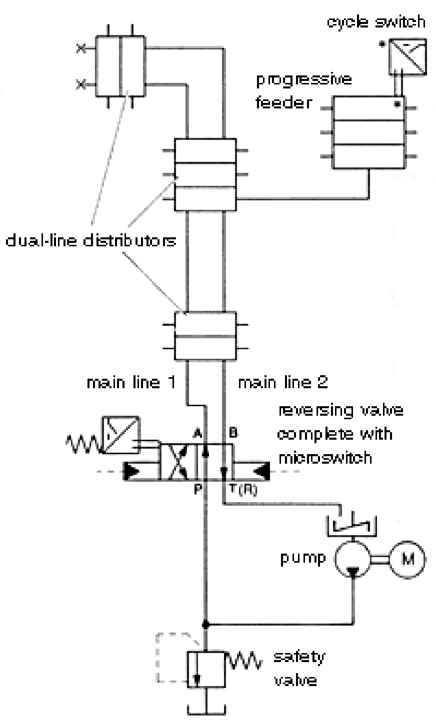
Single Line Lubrication System

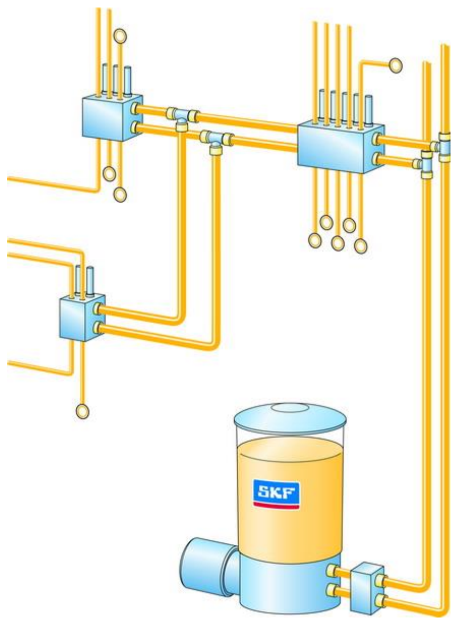
Single line lubrication systems have a motor operated pump, pumping pressurized lubricant into pipelines to lubricating points through single line metering devices or distributors. From the distributors, the lubricants pass through one lubricating point to another progressively; that is only after one 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.





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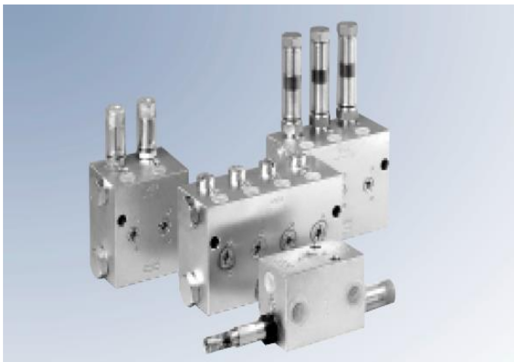
A typical dual line system flow diagram

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

End-of-line Pressure Unit 632-36501-1



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.

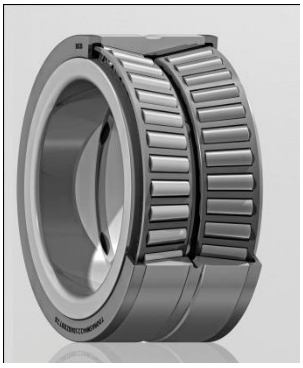
THRUST BALL BEARINGS

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.

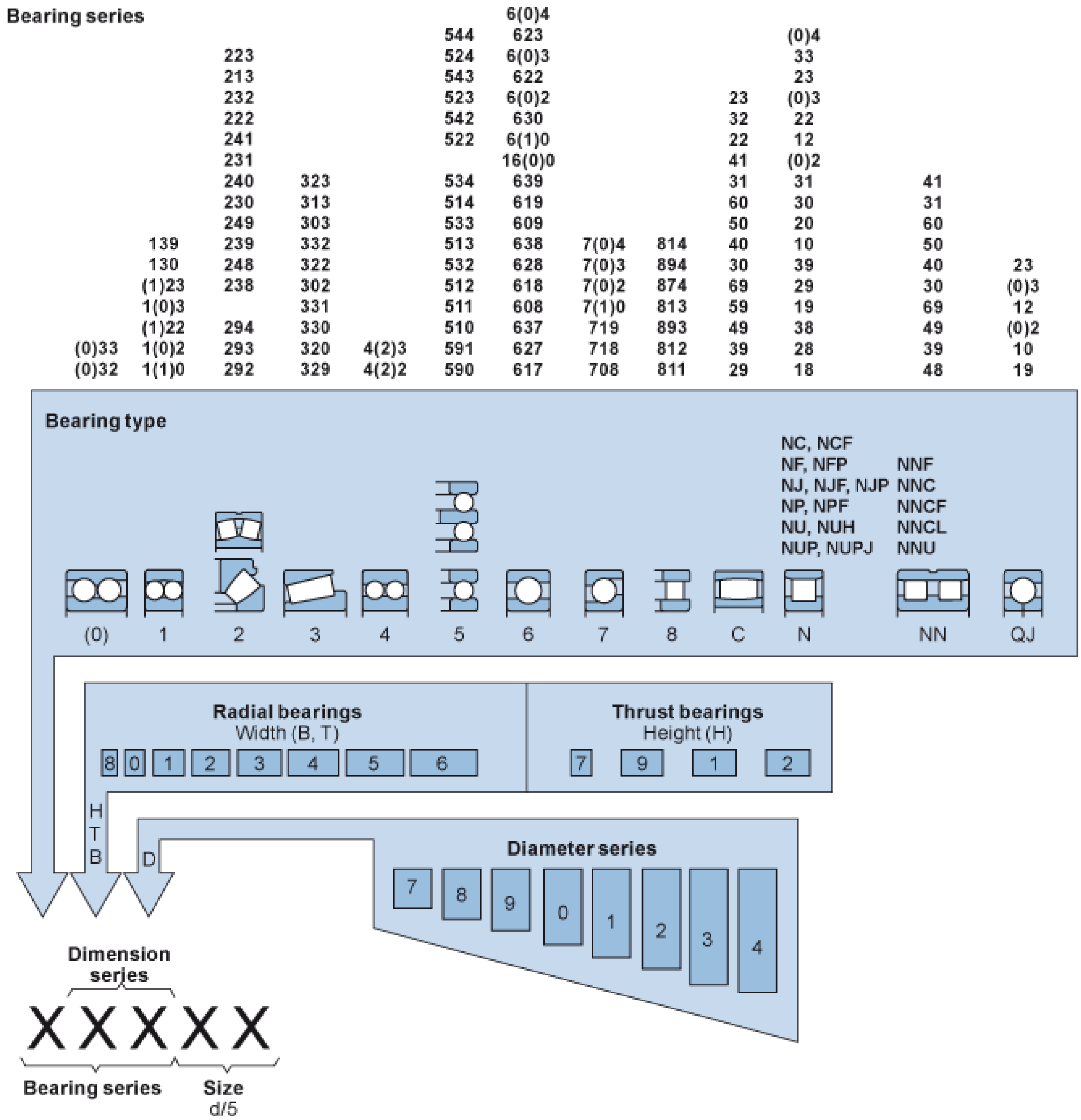
Four row taper roller bearings are used in rolling mills rolls.

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.

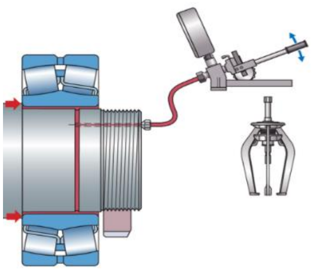
Hot oil baths have traditionally been used to heat bearings, but are no longer recommended except when unavoidable. In addition to health and safety considerations, the environmental issues about oil disposal are also involved.

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:

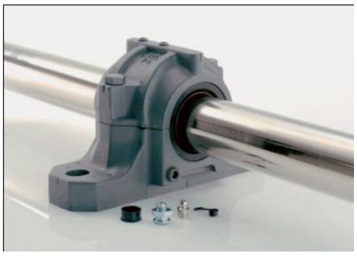
Keep bearings in their original unopened packages until immediately prior to mounting to prevent the ingress of contaminants and corrosion. Bearings are coated with a rust-inhibiting compound and suitably packaged before distribution. For open bearings, the preservative provides protection against corrosion 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.

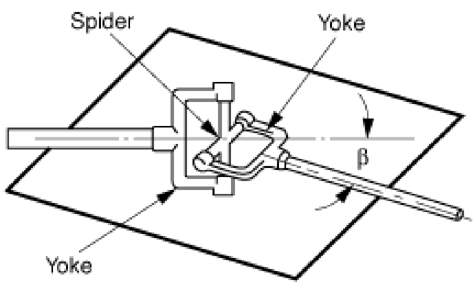


Figure 1 - Single Universal Joint

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:

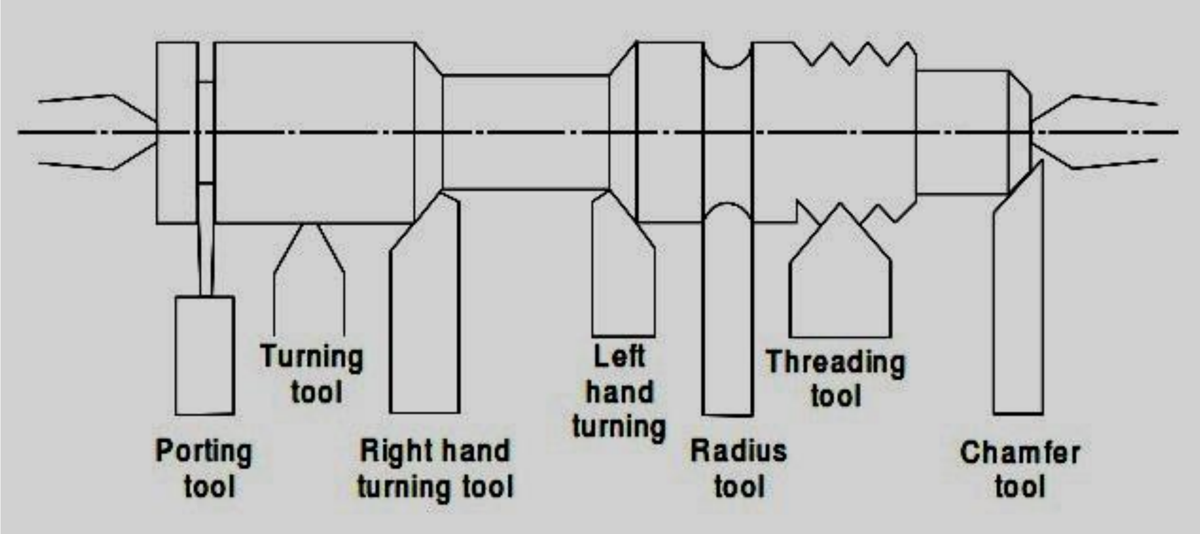
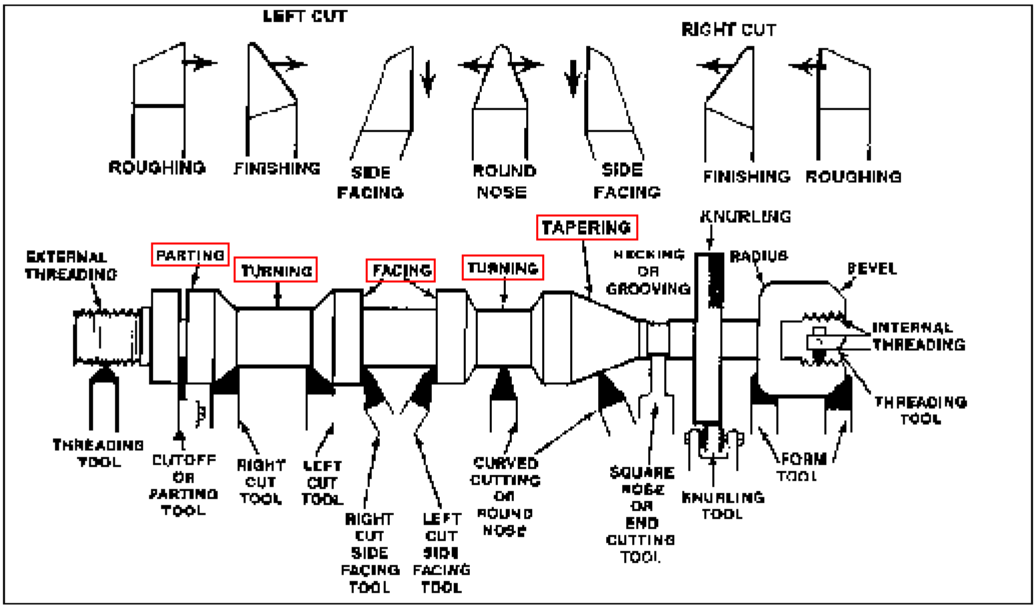


Fig. Lathe operation



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.

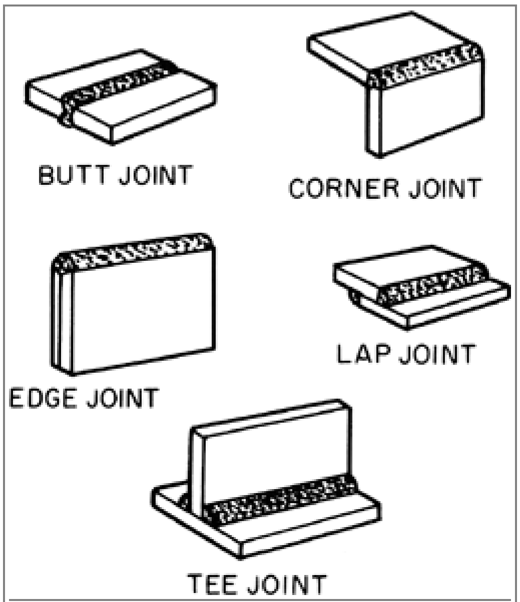
(a) **Butt joint**. In this joint type, the parts lie in the same plane and are joined at their edges.

(b**) Corner joint**. The parts in a corner joint form a right angle and are joined at the corner of the angle.

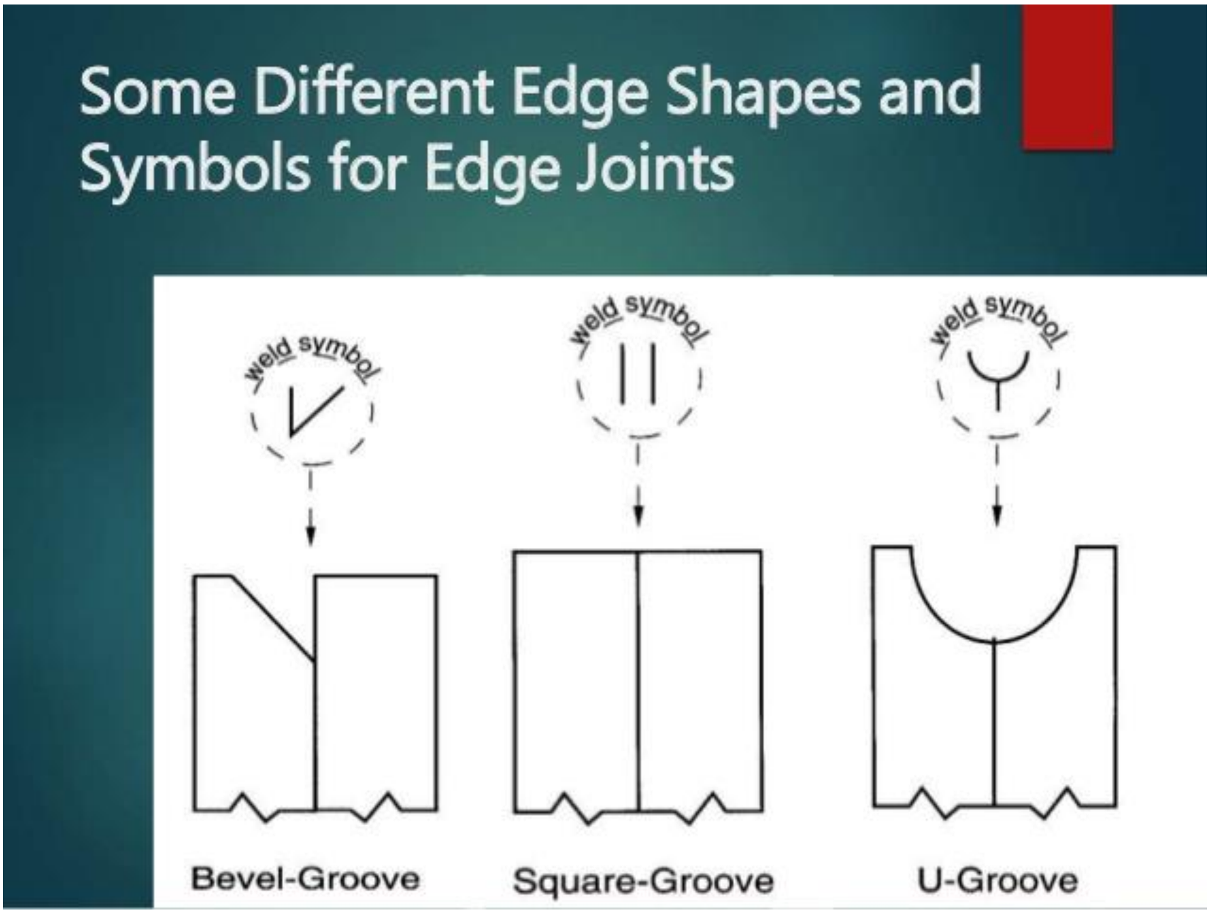
(c) **Lap joint**. This joint consists of two overlapping parts.

(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).



welded joints



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.

DONTS

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

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. However water as a medium for Hydraulics is rarely used in present day applications.

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 turbulent flow.

Flow rate is the measure of volume of liquid passing through a given point in unit time. It is generally measured in lpm (liters per minute) or gpm (gallons per minute). 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. It is basically a reflection of the resistance caused to the flow of the fluid. Pressure means or measured as the force exerted per unit area, generally measured in psi, or kg/ cm^2, or bar or MPa (1 Mega Pascal =10 bar)

Atmospheric Pressure

At sea level the whole column of atmospheric air exerts a weight or force of 14.7 pounds for every square inch of the surface area i.e. a pressure of 14.7psi or 1.03kg/cm^2. This is called atmospheric pressure.

1 Atmospheric Pressure = 1.03 Kg/cm^2= 1 bar =14.7 psi

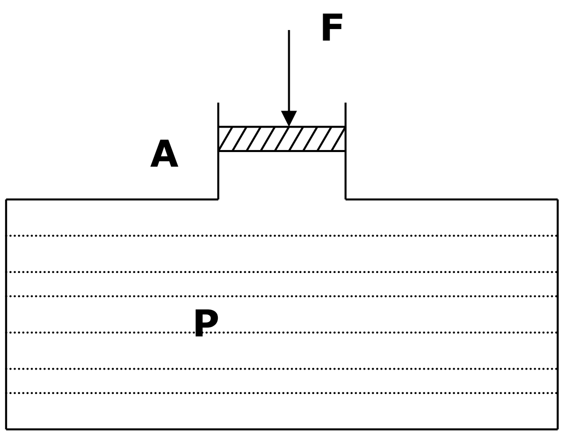
Flow & Pressure are inter-related. Flow is responsible for causing the motion of piston in a cylinder. It is the movement of hydraulic fluid caused by a difference in pressure at two points. When we open the kitchen tap the pressure difference (between the water tank at height and tap) pushes the water 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.
11. Flow takes the path of least resistance.
12. Flow always takes place from higher pressure to lower pressure.
13. Resistance in series flow adds up.
14. Rate of flow is directly proportional to the pressure difference.
15. As a the diameter of the pipe increases the pressure drop decreases.

Pascal's Law

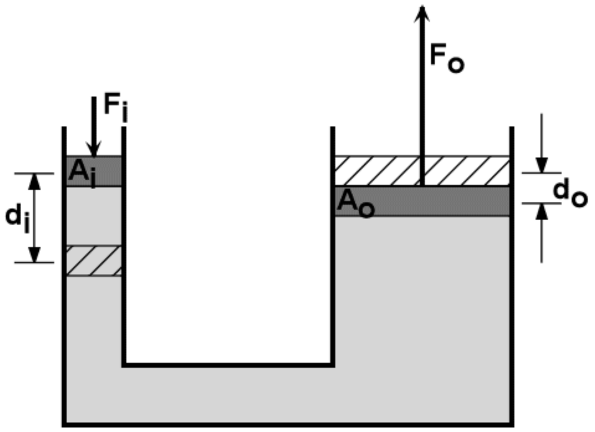
PRESSURE APPLIED ON A CONFINED FLUID IS TRANSMITTED UNDIMINISHED IN ALL DIRECTIONS AND ACTS WITH EQUAL FORCE ON EQUAL AREAS AND AT RIGHT ANGLES TO THEM (If a force F is applied on a piston of area A, (over a confined fluid) then it gives a pressure P = F/A. This pressure will be uniform in the entire confined fluid at rest.



$$P = F / A$$

Hydraulic Press (BRAMAH PRESS)
Since pressure in the confined fluid is uniform throughout and by applying this pressure on large areas large forces can be developed. This is the starting point for development of Hydraulics (see the fig below).

If two cylindrical chambers which are connected and fitted with pistons of area Ai, A_o and if a Force Fi acts on piston of area Ai, it develops a pressure P in the confined fluid. This pressure will be uniform in the entire fluid in double cylinder arrangement, and develops a force $F_o = P \times A_o$. Hence forces will be proportional to the area of the pistons. There is no energy creation and work done will be same by both the pistons. The displacements (lengths of travel of pistons di, d_o) will be inversely proportional to the areas of the pistons. (i.e. If the left side small piston travels a large distance, the right side big piston will travel only a small distance)



The length of piston travel is inversely proportional to area.

$\boxed{d_0/d_i = A_i/A_0}$

$\boxed{F_0/F_i = A_0/A_i}$

Work done Wi = Fi . di
Wo= Fo. do

Bernoulli's Principle
This is nothing but law of conservation of energy. If the flow rate is constant, the total energy at any point of continuous path of flowing fluid is same as at any other point. (Sum of motion energy, pressure energy, and potential energy is constant.).To know the pressure or flow velocity at any point in the circuit, this principle is used widely.

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 are 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. **In built Over load protection**- in case there is over load(pressure) 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 load holding devices for example 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, following some standard practices and keeping the system cool, will fulfill major portion of maintenance work. For these purposes 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
9. Heat is automatically carried away by the fluid
10. Minimum wear rates because components are lubricated by operating medium
11. Energy storage through accumulator, ideal for power failure requirements

RELATIVE DISADVANTAGES OF HYDRAULICS

i) Compressibility of hydraulic fluid needs to be considered. In the case of a fluid containing no air bubbles the volume reduces by 0.7% when the pressure is increased by 100 bar. Up to 150 bar the compressibility can be neglected but beyond that, especially when delivery rates are high, it can have an adverse effect on the functioning of the system. If there is any air trapped in the fluid it is more compressible and can give rise to disturbances such as noise, vibration and jerky motions at pressures as low as 50 bar.

ii) Fluid viscosity is sensitive to temperature and pressure. Viscosity decreases as the temperature increases. The viscosity-pressure behavior of hydraulic fluids is of importance when operating pressures are higher. Although the increase in viscosity can be low up to a pressure of 200 bar, it can double when the pressure reaches around 400 bar.

iii) Pressure and flow losses in pipes and control devices need to be considered meticulously while arriving at system pressure requirement of a hydraulic system

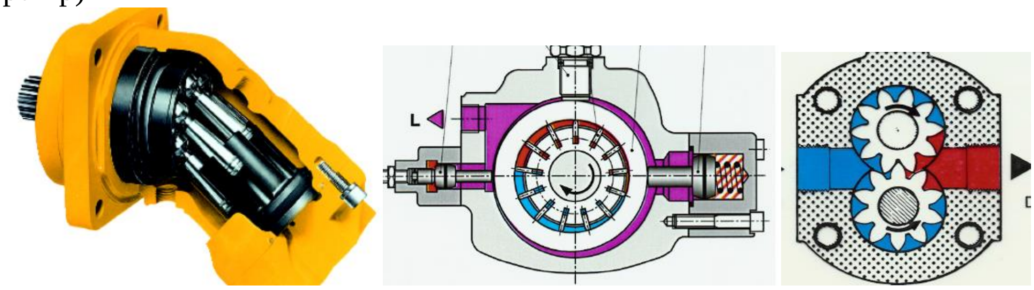
iv) Leakage problems need to be attended properly.

8.2 Components of Hydraulic System and their Functions

RESERVOIR: The tank which stores the working medium (oil), supplies to pump, 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 (preferably with interlock limit switch) 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 take care of minor mismatch between the tank and the pump and to take care of 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 (cubic cm per rev) when multiplied by speed of the electric motor driving the pump, gives Discharge of the pump (flow of the pump)



POSITIVE DISPLACEMENT PUMPS

Centrifugal pumps (non positive displacement type) are not generally used in hydraulic systems. In this type of pump, if delivery is closed, pressure will not build up beyond a particular limit. Safety valve is not required.

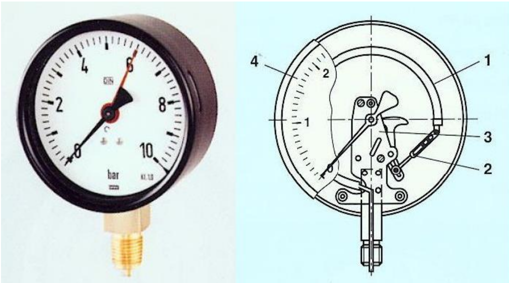
Most commonly used positive displacement pumps used in hydraulics are Gear, Piston and Vane types

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 delivery line is always followed by a check valve, relief valve (safety valve), pressure gauge, and shut off valve (These are required for pressure setting and isolating).

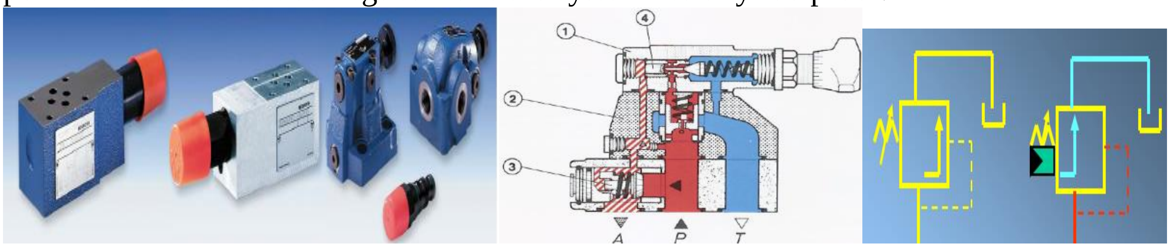
CHECK VALVE/NON-RETURN VALVE: It is a valve which allows flow in one direction only. Generally provided after the pump in most of the cases to take care of reverse rotation of pump, it is also used in many places of the circuit as a bypass etc. Check valve and non-return valve are same.

SOME CHECK VALVES

PRESSURE GAUGE: It is provided to know the pressure at any position at any instant of time and for setting of various valves, pressure switches etc. The pressure gauge with glycerin filled dial is preferred in the hydraulic system to take care of the damage to the gauge due to vibration and variations



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. It 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. This is provided at many points and at different settings to make the system literally foolproof.

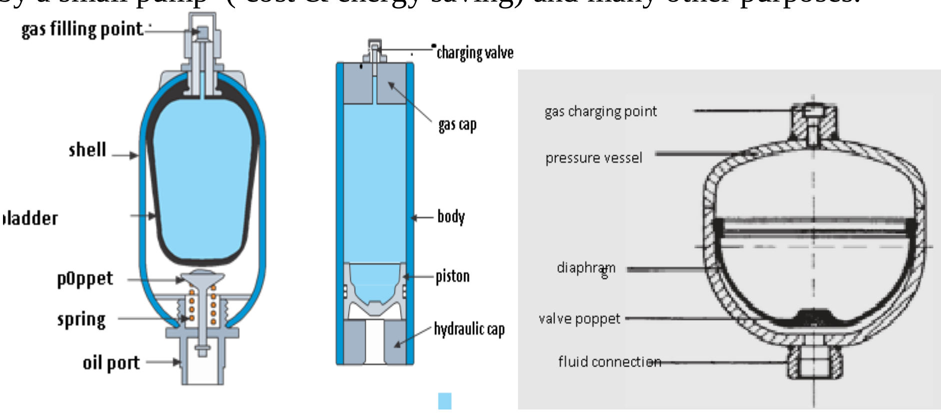


RELIEF VALVES

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 Hydraulic System 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.



ACCUMULATORS

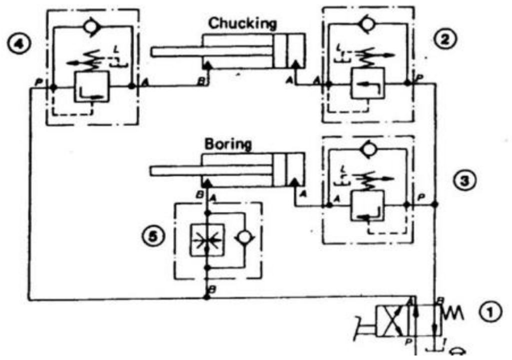
DIRECTIONAL CONRTOL VALVES: Distributor/Master valve / DC valve are all same. If a pump supplies oil directly to a cylinder, it is not possible or convenient to control the load or to change the direction of motion. Hence a DC valve is provided in between pump and the load cylinder to stop/start /reverse 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 the cylinder will travel in between the extremes only. You cannot stop the cylinder in between .There are many varieties of dc valves depending upon the requirements

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.

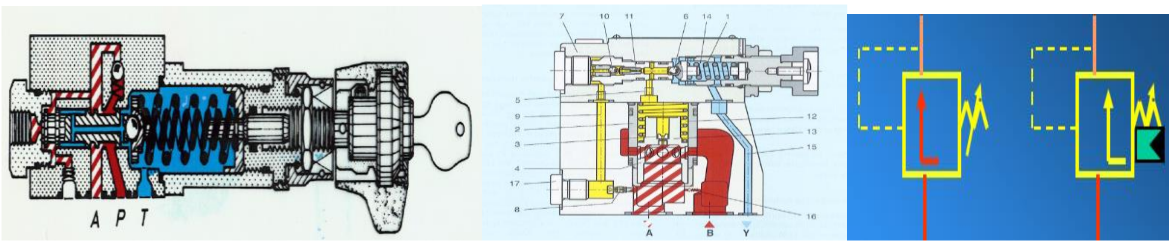
FLOW CONTROL VALVES

SEQUENCE VALVE: These valves are used to make multiple actuations, connected through a common system, work in a sequence of requirement. In other words these valves provide serial operations based on pressure setting. 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.



SEQUENCE VALVE APPLICATION

PRESSURE REDUCING VALVE: In some hydraulic systems many cylinders are working at same pressures ,but a few cylinders do not require full pressure and can work at a lower pressure .And since the system has to run with a common power pack which supplies a constant system 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 should never be confused. This valve is also known as Pressure Regulating valve.



PRESSURE REDUCING VALVE

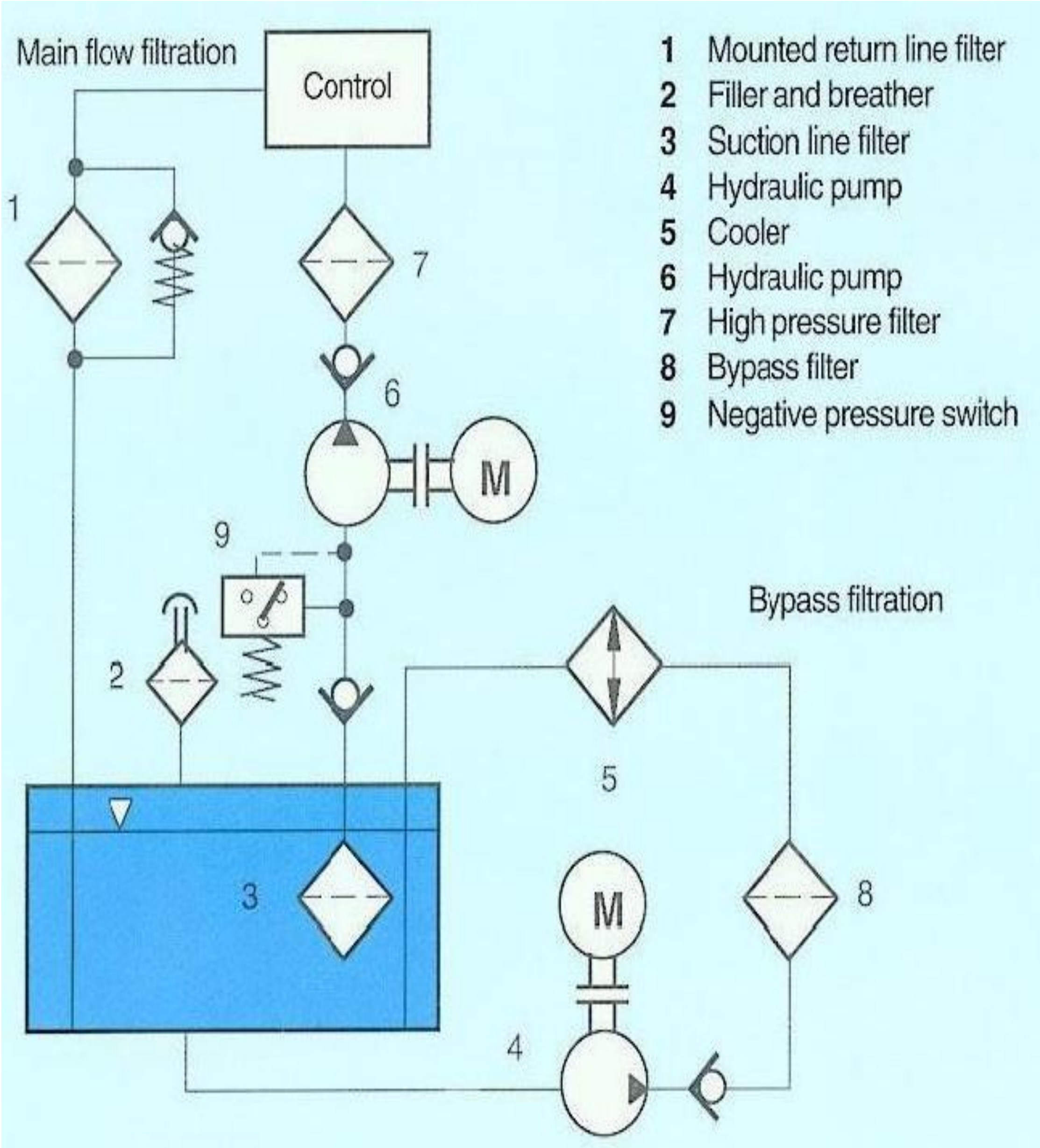
FILTERS: All hydraulic elements work under close tolerances and they are precision items with mirror surface finish .Contaminants and dust are the single largest enemy of the hydraulic system as they cause malfunctioning and jamming of valves and fast wear out of elements. The contaminants are internally 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.

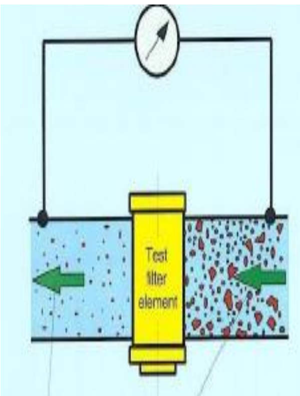
In a filter the hydraulic oil is allowed to pass through a porous medium (like paper, wire mesh, synthetic fiber etc) so that the dust particles and other contaminants are retained and only clean oil goes ahead into the system. Filtration can be either online or offline.

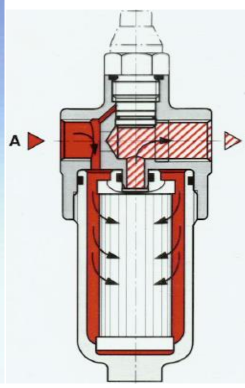
In online filtration the oil is passing through a strainer or a suction filter before it enters in the pump. After the pump the oil passes through the pressure filters and then after passing through the dc, flow control valve and actuators, before flowing back to the tank, the oil passes through the return filter

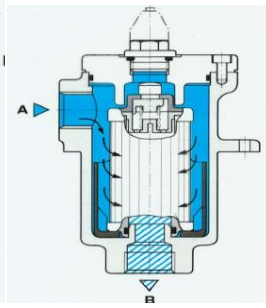
Offline filtration (mostly portable) systems are also used for up keeping the system depending on the criticality. Electrostatic Liquid cleaners are also used nowadays. These are very simple to operate and cheap. Generally Return line filters are provided with parallel bypass valves(check valve) to take care of clogging temporarily.

Location of filter in hydraulic system



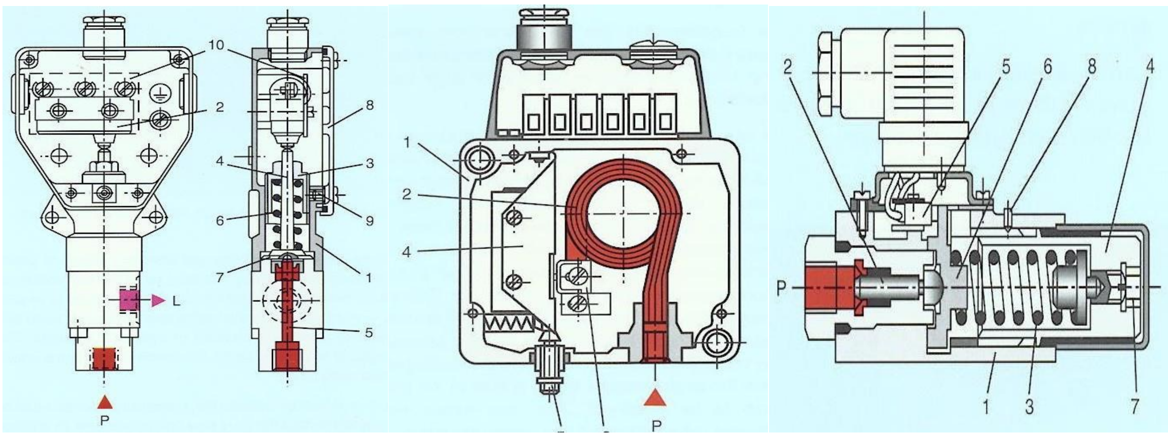






FILTERS

PRESSURE SWITCH: These are provided in the system for safety and efficient operation or for achieving a particular logic sequence. The pressure switch can be either plunger type or bourdon tube type. In plunger type pressure switch the hydraulic oil under pressure pushes small plunger which in turn makes/breaks an electrical contact. In the bourdon tube type pressure switch with the change in the pressure of the system the bourdon tube expands or contracts as in the pressure gauge thus making/ breaking contacts with the micro switch/ switches Contact Manometer is a pressure gauge with electrical contacts, which does almost the same job, but they are less reliable and less robust.



PRESSURE SWITCHES

LEVEL GAUGES AND 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.

LEVEL GAUGES AND SWITCHES

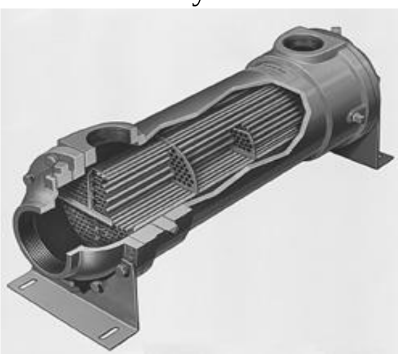
FILTERING-CUM-COOLING CIRCUIT: In hydraulics, more than 80% of problems are due to contaminated fluid. Thus, it is important to keep system fluid very clean. Particulate contamination and water contamination in hydraulic fluids can have serious adverse effects on the fluids' physical and chemical properties. 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).

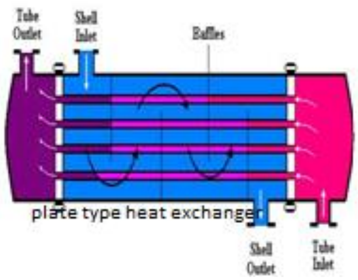
For the above reasons it is required to have a cooling cum filtering system which is nothing but a combination of pump, heat exchanger and the filter as a secondary system which runs parallel to the main system. Filters have already been discussed and in this part we will learn a bit about the heat exchangers

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. Heat Exchangers require periodical maintenance. 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.) Gasket type

In general the tube in shell type heat exchangers and plate type heat exchangers are most commonly used





HEAT EXCHANGERS

In shell and tube type heat exchangers the cooling fluid flows in the bunch of tubes placed inside the shell while the fluid to be cooled flows, in a reverse direction, in the shell, in the leftover gaps between the tubes.

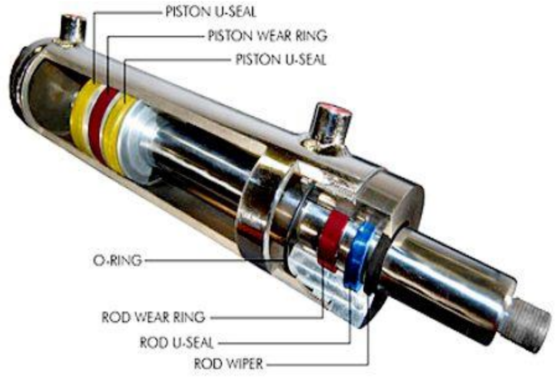
In the plate type heat exchangers the two fluids flow in the opposite direction in the honeycomb shaped recess between the plates which can either be separated by brazed plates or by gasket joints

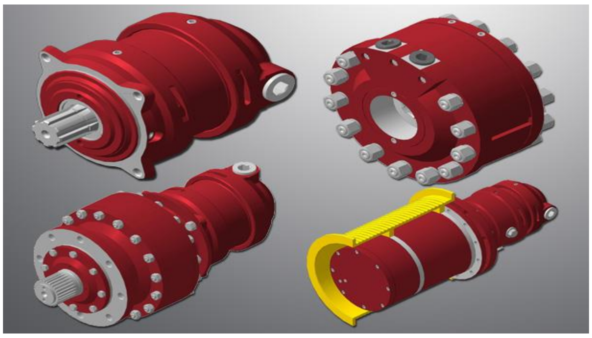
ACTUATORS: Generally the hydraulic cylinders and hydraulic motors are called actuators. These actuators do the actual job of lifting/lowering/pushing/rotating /holding etc. Hydraulic motor replaces many applications of electric motors along with the gear box due to many advantages like speed control, over load protection etc. Hydraulic motors are almost reverse to pumps. When these are supplied with 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 and consists of piston, piston rod, body, covers, seals, fasteners, eye etc. 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 and clamping devices in a goggle valve are generally single acting type.





CYLINDER **HYDRO MOTOR**

Hydromotors are used widely in mobile equipments for winch applications and wheel movement and nowadays very frequently used for the conveyor belt drive.

SEALS: The component which prevents the motion of the fluid in the undesired direction is called seal/packing. This can also be defined as the 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.

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. In higher temperature applications, Viton seals preferred. Seals should be handled delicately, and sharp tools should not be used.

PIPES, FITTINGS, CLAMPS: Generally pickled, flushed seamless carbon steel pipes are used in hydraulic systems. But nowadays the stainless steel piping is more preferred because of their resistance to the external conditions. 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 (polypropylene) are commonly used nowadays. While laying hose pipes, the layout should be smooth, and they should not crisscross/twist/entangle and rub each other.

PIPE CLAMPS

PIPE FITTINGS

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.

Fire resistant oil - i) HFA Type (5% oil in 95% water emulsion)
ii) HFB (60% oil in 40% water emulsion)
iii) HFC (60% glycol in 40% water). Offers highest degree of fire resistance
iv) HFD (anhydrous synthetic fluids)

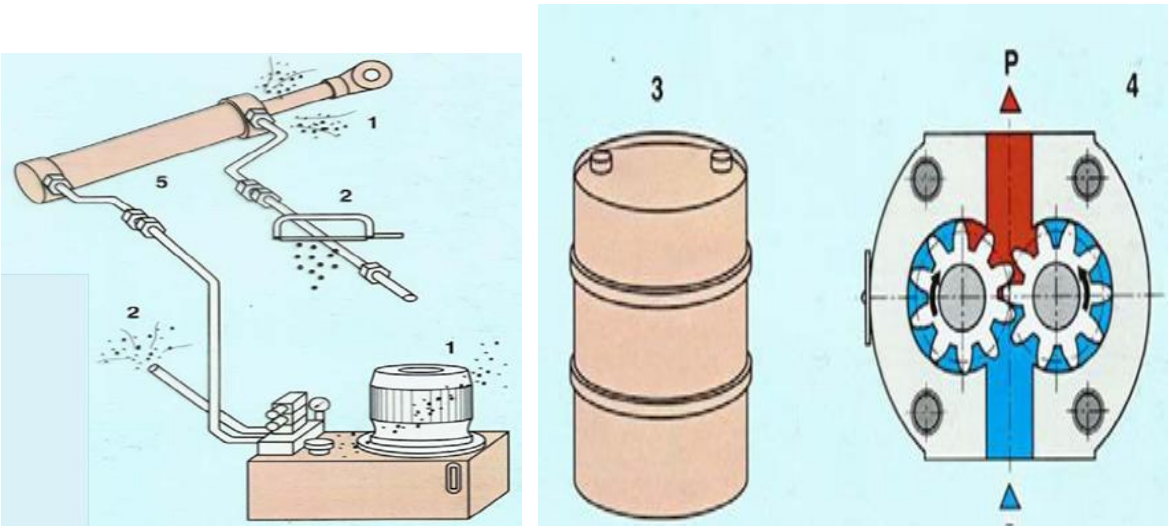
Following are the important properties which hydraulic fluid should possess:
a) Oxidation Stability b) Protection from Corrosion c) Anti Wear d) Viscosity &Viscosity Index (viscosity index should be high so that viscosity variation with temperature will be less), e) Demulsibility (ability to resist formation 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).

OIL CONTAMINATION CONTROL

Oil contamination is number one enemy of hydraulic system. Therefore, oil contamination control is the first requirement of any hydraulic system to get a trouble free smooth service. It enhances the life of different components. To keep oil clean is part of hydraulic system maintenance. It is just not possible to keep oil free from contamination in any industry due to various reasons. What we can do is to monitor oil contamination level regularly by cleanliness determination methods and take corrective steps including changing of filters. If situation does not improve, tank oil should also be changed as hydraulic valves especially proportional and servo valves are very dirt sensitive.

Sources of oil contamination

a) With the oil filled in the oil tank itself.
b) Due to wear and tear of internal parts of components such as pump, control valves, cylinders.
c) Due to wear of oil seals, o-rings.
d) Due to wear of inside of pipelines.
e) Due to generated debris after welding of metallic pipes.
f) Through piston rods of hydraulic cylinders.
g) Through ambient atmosphere.
h) Due to poor upkeep of filters and reconditioning system.
i) Due to use of cotton waste in revisioning or repairing of hydraulic components.



SOME CONTAMINANTS

Filters should be provided in oil filling line, reconditioning line, pressure line after pump with clogging indicator, pilot line and return line. Periodically pressure differences across filters should be monitored otherwise in case of high pressure difference filters wall may collapse and oil may pass without filtering or flow rate will reduce.
There are two methods of determination of oil cleanliness class: NAS1638 & ISO 4406.To decide oil cleanliness class required for different applications, the following table may be used as guide line-

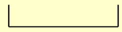
System type/Range of application	**Needed Cleanliness Class**	
According to standards	NAS 1638	ISO 4406
Heavy duty servo system, High pressure System with long service life	4-6	15/11
Proportional valve	7-8	16/13
Medium pressure system	7-9	18/14
Low pressure system	9-11	19/15

It is to be remembered that a fresh drum of oil is not the cleanest one. In fact it may be of class 10 or 11. So by replacing the oil is not the solution for making the system clean
<u>Ingress of water in the oil :-</u> Sometimes the heat exchanger may have internal leakage and owing to this water may get mixed with oil. Water in oil can cause serious problems for the system and can be evidently observed by the colour of the oil, which becomes whitish with foam. Because of the water in the oil the internal components get rusted. Water in hydraulic oil has a number of other negative effects. Water Depletes some additives and reacts with others to form corrosive by-products which attack some metals, reduces lubricating film-strength, which leaves critical surfaces vulnerable to wear and corrosion, reduces filterability and clogs filters

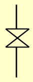
OIL LEAKAGE CONTROL
Oil is life blood of hydraulic system, hence leakages should be prevented. Major portion of mineral oil to be used in our country is imported for which we have to pay heavy price. Besides loss oil leakage may damage the soil and hence ground water and plant life. Consequently it damages animal life and human life also. Leakage in fire hazardous zones may result in fire which may damage property besides unnecessary production delay due to burning and damage of especially electrical wires and equipments. It is therefore necessary to control oil leakage to the extent possible. For this regular inspection followed by corrective measures such as tightening of loose connections and pipe supports, changing of even partially damaged oil-rings(o-rings), hoses and corroded steel pipes is necessary. Hydraulic hoses in fire hazardous zones should be periodically changed even though these are not damage

SOME BASIC SYMBOLS

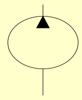
RESERVOIR / TANK



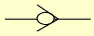
SHUT-OFF VALVE



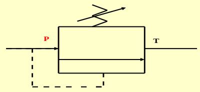
UNI-DIRECTIONAL FIXED DISPLACEMENT PUMP



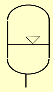
CHECK VALVE / NON-RETURN VALVE



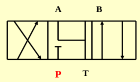
PRESSURE RELIEF VALVE



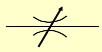
ACCUMULATOR GAS CHARGED



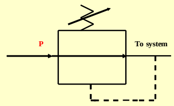
3 POSITION 4 WAY DIRECTIONAL CONTROL VALVE



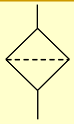
FLOW CONTROL VALVE
ADJUSTABLE, NON-COMPENSATED



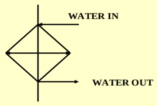
PRESSURE REDUCING VALVE



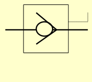
FILTER WITHOUT BY-PASS



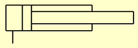
HEAT EXCHANGER / COOLER



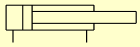
PILOT OPERATED CHECK VALVE / NON-RETURN VALVE



SINGLE ACTING CYLINDER

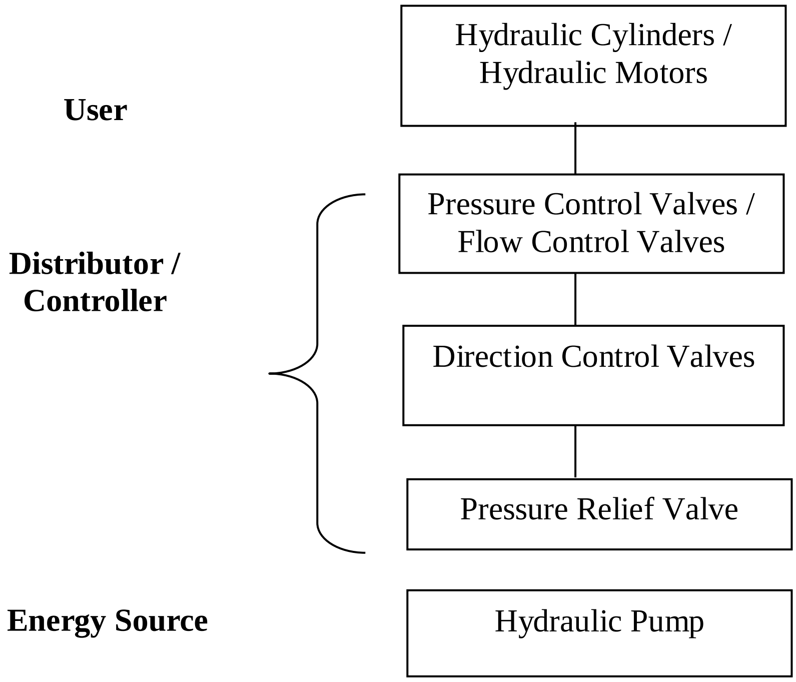


DOUBLE ACTING CYLINDER



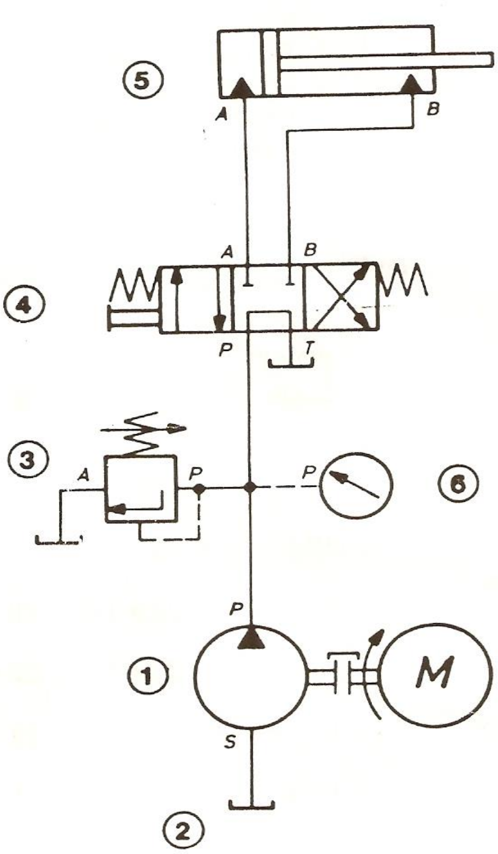
8.3 Block Diagram of Hydraulic System

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)

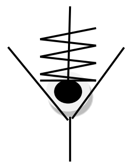
Here we have a hydraulic system in its most simple form. A pump 1 with fixed flow sucks fluid from a tank 2 and feeds it into the system connected to it. In zero position of the manually operated direction control valve the hydraulic fluid, circulates almost without pressure from the pump to the tank 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).

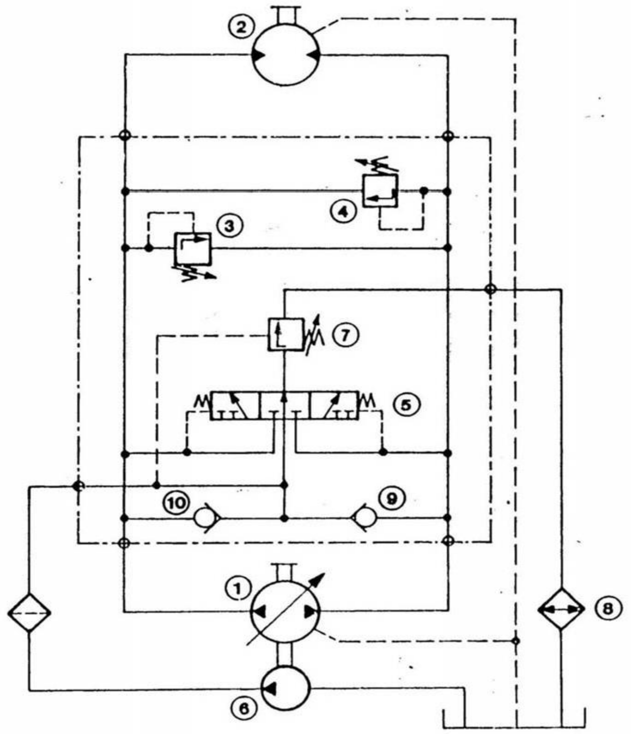
This is a typical circuit where check valve is not required.

Symbol of check valve



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 in 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 Reclaimers in Ore Handling Plants
7. Segments closing/ opening, Pinching Actions in CCS
8. Hydraulic Presses and Various Machine Tools etc.

SOME IMPORTANT TERMS

Cavitation

In any liquid flows, a localized condition within a liquid stream which occurs when the pressure is reduced to the vapour pressure of the liquid. Lots of vapour bubbles will form and these will be carried along with the flow and burst at some other point. This condition is highly harmful to the pump and all hydraulic elements. Generally this is taken care of at design stage that at any point of the hydraulics system the vapour pressure should not be so low to cause cavitation. The pump gives very high sound when under cavitation and it should be stopped immediately and eliminate the root cause. Reasons may be for example, many bends were introduced/ lower size pipe was introduced in the suction line during the repairs.

Aeration

When air enters the suction line of the pump and passes through it, lot of sound will come, which is similar to cavitation. This will also damage the pump and it should not be allowed to run. If grease is applied on suction line joints, the sound of the running pump will be suppressed immediately, confirming that particular joint is loose. That joint is to be tightened and packing/seal to be changed if required. Excessive aeration will cause the fluid to appear milky and the components will operate erratically.

If the air bubbles generated in the tank or air enters the pump due to low level of oil, the same problem will come.

Compressibility

The change in volume of unit volume of a fluid when it is subjected to a unit change in pressure.

Decompression

The slow release of confined fluid under pressure to gradually reduce the pressure is called decompression.

Hydraulic Hammering

In a hydraulic system, the sudden transition of Kinetic Energy into Potential Energy and vice versa due to sudden opening/closing of valve, results in pressure surges and vibrations. This may result in bursting of pipe lines etc.

Cracking Pressure

The lowest pressure at which pressure relief valve starts opening. The system pressure of a hydraulic system must be set well below the cracking pressure of a relief valve.

Pressure Override

The difference between the cracking pressure of a valve and the pressure reached when the valve is passing the full flow.

Bypass

A secondary passage for fluid flow.

8.5 Maintenance of Hydraulic Systems

Maintenance Practice In Hydraulics

Breakdown Maintenance (Catastrophic Failure)

- Safely Shutting Down the Hydraulic System
- Component Replacements by Identifying Model Code
- Pipe Line Replacements & Clamping.
- Seal Changing

Proactive Maintenance (Eliminating Root Cause)

- Contamination Control

Preventive Maintenance (Schedule Repair)

- General Inspection / External cleaning
- Oil Changing / Pouring
- Pipe Clamping, tightening of joints, Hose checking
- Filter element Replacement
- Heat Exchanger Cleaning
- Accumulator Nitrogen filling
- Leakage arresting

Predictive Maintenance (Checking Physical Attributes)

- Temperature Monitoring
- Vibration checking in Pipelines
- Oil Cleanliness Checking
- Accumulator Gas Pressure Checking

General Maintenance Tips

1. Always follow the standard shut down procedure for starting any kind of repair work in Hydraulic System.

2. Hydraulic System should be kept neat and clean so that no contamination enters the system. The system should never be kept open unattended. (Monitoring of contamination control is most useful)

3. Some contamination is also generated within the system. Hence regular cleaning / changing of filters or inspection of offline filtration systems to be done. Remember oil contamination is the major cause of troubles in hydraulic system, hence recommended ISO / NAS value should be maintained.

4. All flange joints/union joints, clamps foundation bolts etc should be regularly tightened, so that pipes do not vibrate excessively.

5. Hoses should be replaced condition based or time based.

6. The ports of all spare cylinders, valves, pumps and hose connections etc should be kept closed/ capped until just prior to use to avoid contamination entry

7. Do not use Teflon tape or compound on pipe threads as far as possible especially in precision systems with servo/proportional valves.

8. Never allow cooling water to enter the system and monitor the condition of heat exchangers.

9. Timely replace all the seals/ packing so that oil leakages will be minimum. If not done timely, fire accidents may take place or persons may fall down resulting in an accident.

10. Pressure gauges should be in working condition.

11. Regularly check the oil level in the tank and always maintain prescribed minimum oil level in the tanks.

12. Ensure tank low level switch is interlocked with the pump motor and it is in working condition.

13. Good maintenance procedures make it mandatory to keep the hydraulic fluid clean. A daily/ weekly or monthly log should be kept on the hydraulic fluid condition.

14. Seals should be handled delicately while replacing/storing and kept in cool dry places.

15. Maintain temperature of the system within allowable limits to maintain the desired viscosity level and prevent the damage of oil seals and also prevent faster deterioration of oil

16. Always try to do unit replacement of valves, cylinders, pumps etc. Repair of these items are to be done leisurely in workshop/ testing lab under good conditions.

17. Whenever valve/cylinder/pump is opened, try to change all the seals.

18. Always ensure that clogging indicators for filters are in place and in working conditions for knowing the health of filters.

19. Oil topping should always be done by Portafilters to minimize contamination

20. Accumulators gas pressure should be checked periodically and Pre- charge pressure must not be less than one quarter or preferably one third of the maximum working pressure (Follow OEM guidelines as in manual or drawing). Remember gas to be charged is only Nitrogen. By mistake if anybody charges Oxygen, Accumulator can explode. Nitrogen to be charged slowly, do not fully open Nitrogen cylinder valve, Nitrogen may become cold and solidify and may puncture the bladder.

21. Most Important- Oil Cleanliness. We can also use Electro Static Liquid Cleaners (ELC) for critical applications. Off-line filtration systems can also be used.

22. 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)

8.6 Safety in Hydraulics

DO'S

1) Monitor oil contamination level regularly.
2) Oil tank temperature should be kept within 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 at a nearby place of cutting-welding hydraulic pipes.
5) 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)
6) Periodically clean water fillers provided in inlet line of heat exchangers.
7) Keep away from repaired pipe line flanged joints, union joints at the time of testing.

DONT'S

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.

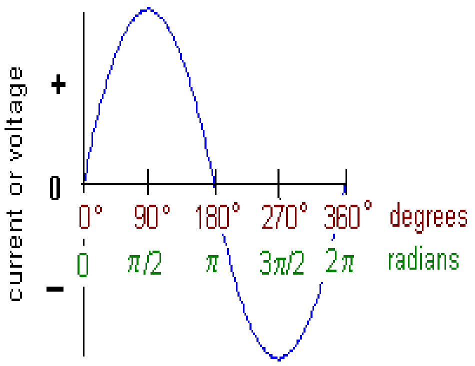
The current **I** can be calculated with the following equation:

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 $T = 2\pi / \omega$.

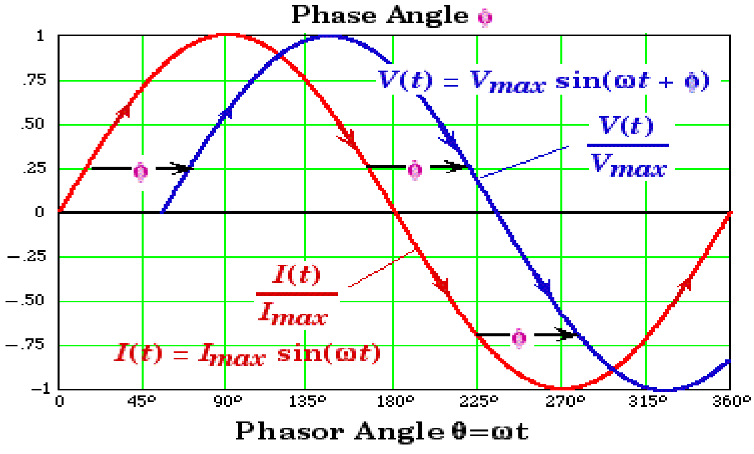
The rate of repetition of the sinusoid function is called its **frequency**, *f*, where

$$f = 1 / T \qquad \text{or, } f = \omega / 2\pi \qquad \text{or, } \omega = 2\pi f$$

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.

<u>Voltage (or Potential Difference)</u>

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, $V = I \times R$. The unit of resistance is ohm (Ω).

The resistance of a conductor is defined by following equation :

$R = \rho(l/A)$ where, 'ρ' is the specific resistance value, 'l' is the length and 'A' is the cross section area of the conductor.

<u>Power and Energy in electric circuits</u>

The power (P) consumed by a circuit element (say a resistor R) through which a current I is flowing is

$P = V \times I$ The unit of electrical power is watt (W).

Electrical Energy consumed over a period of time t is expressed as,
$E=V \times I \times t$ or **$E= P \times t$** 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.

Real, Apparent and Reactive Power, and Power factor

The equations discussed so far for power are valid for DC circuits. In AC circuits, the effective value of a periodic current or voltage is considered. The effective value of a periodic current is the DC current that delivers the same average power to a resistor as the periodic current. The effective value of a periodic signal is its root mean square (rms) value, i.e.,

$I_{rms} = I_{max} / \sqrt{2}$ and $V_{rms} = V_{max} / \sqrt{2}$

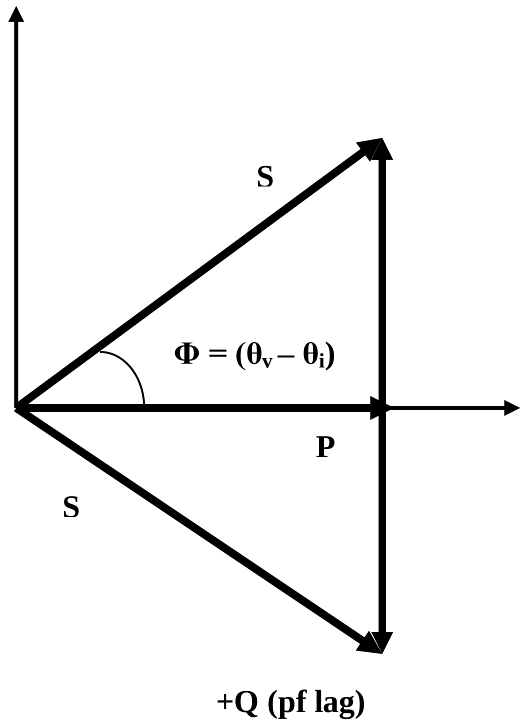
Now let us consider, $V(t) = V_{max} \cos(\omega t + \theta_v)$ and $I(t) = I_{max} \cos(\omega t + \theta_i)$, then the power in terms of rms values can be expressed as

$P = \frac{1}{2} V_{max} I_{max} \cos(\theta_v - \theta_i)$ or, $P= V_{rms} I_{rms} \cos(\theta_v - \theta_i)$ or, $P= V_{rms} I_{rms} \cos \Phi$
where **$\Phi=(\theta_v - \theta_i)$** or the phase displacement between voltage and current.

The power absorbed by a resistor R is

$\mathbf{P = I^2_{rms} R = V^2_{rms} / R}$

The **Power Triangle** in the adjacent figure shows the relationship between Real Power (**P**), Apparent Power (**S**) And Reactive Power (**Q**).



The equation **P**= $V_{rms} I_{rms}$ cos **Φ** can be also written as following

P= S cos Φ , where P is the *active power*

$\mathbf{S = V_{rms} I_{rms}}$ is the *Apparent Power*

$\mathbf{Q = V_{rms} I_{rms}}$ **sin Φ** is the *Reactive power* , represents the inductive / capacitive components in the system.

The unit of active power is watt or W.

The unit of apparent power is VoltAmp or VA.

The unit of Reactive power is VoltAmp Reactive or VAR.

- Q (pf lead)

cos Φ is the **power factor (pf)**.

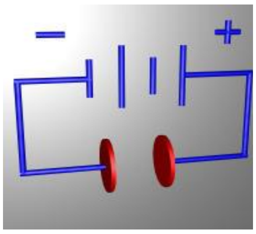
Power Factor (pf) = P / S = cos Φ is the cosine of the phase difference between voltage and current.

For a purely resistive load, the voltage and current are in phase, i.e., $\theta_v - \theta_i = 0$, and hence pf = 1. For a purely reactive load, $\theta_v - \theta_i = \pm 90^\circ$ and pf = 0. In between these two extremes, power factor is leading or lagging. Leading power factor means that current is leading voltage, which means a capacitive load. Lagging power factor means that current lags voltage, indicating an inductive load. Most industrial and domestic loads are inductive and thus have lagging power factors.

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,

$$\mathbf{X_c = 1/ \omega c \quad or, \quad X_c = 1/2\pi} \boldsymbol{fc}$$

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.

<u>Inductor and Inductance</u>

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

$\mathbf{V = L\ di/dt}$ 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

$$\mathbf{L = N^2 \mu A / \mathit{l}}$$

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 ($\mathbf{X_L}$) in ohm,

$$\mathbf{X_L = \omega L \quad or,\ X_L = 2\pi \mathit{fL}}$$

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.

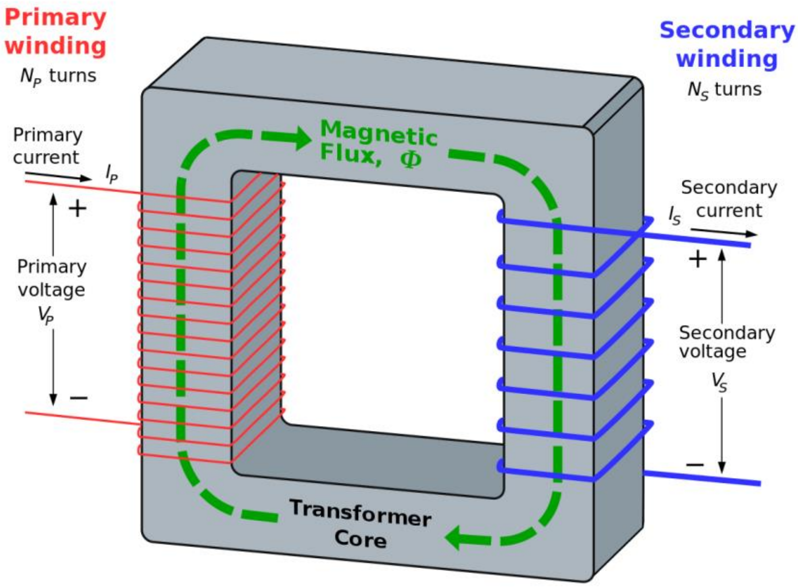


Figure-1 shows ideal single phase transformer

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)

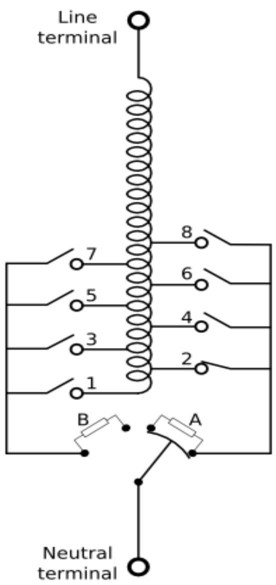
Turns Ratio (k) = Primary Voltage / Secondary Voltage

= 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.



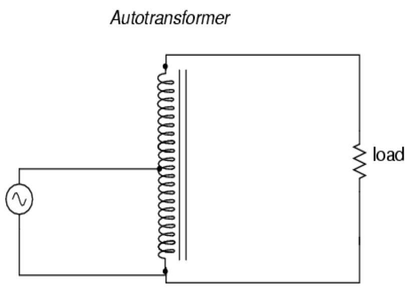
A typical OLTC is shown in Figure-1 where currently tap 2 is selected and current is going from tap-2 via diverter switch in position A to neutral terminal. When tap-3 is selected diverter switch changes position from A to B and the current path completes from tap 3 to diverter switch in position B to 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.

Dry Type Transformer

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.

9.3 Basic Principles of Motor

WHAT IS MOTOR?

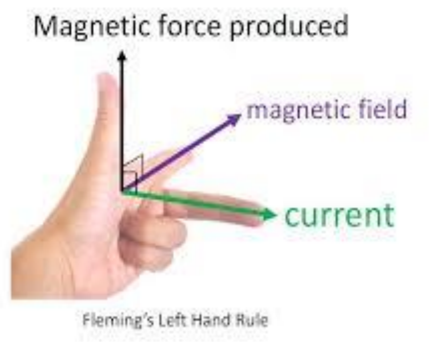
A **motor** is nothing but an electro-mechanical device that converts electrical energy to mechanical energy. In simple words we can say a device that produces rotational force is a motor.

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**



Where,

F is the Force exerted (Newtons)

B is the magnetic field (weber/m^2).

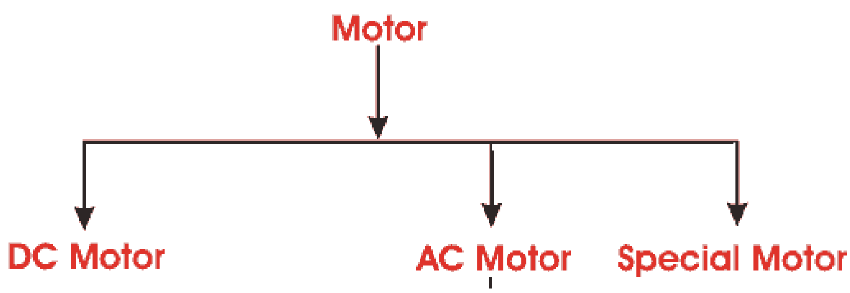
I is the current (Amperes), and

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.

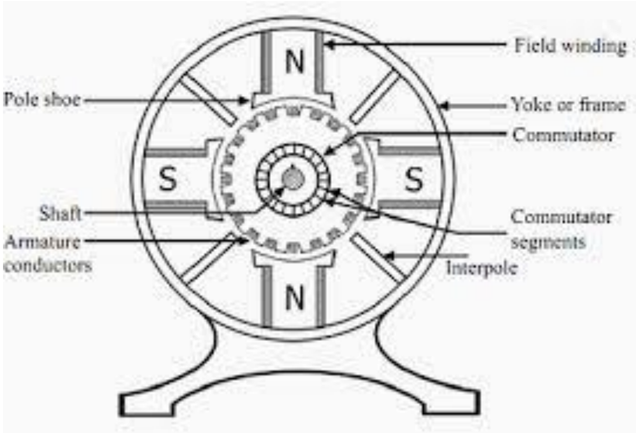


DC MOTOR

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.

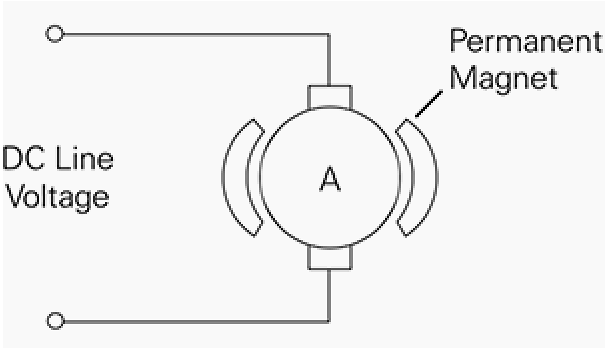
TYPES OF DC MOTOR AND ITS CHARACTERISTICS

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).

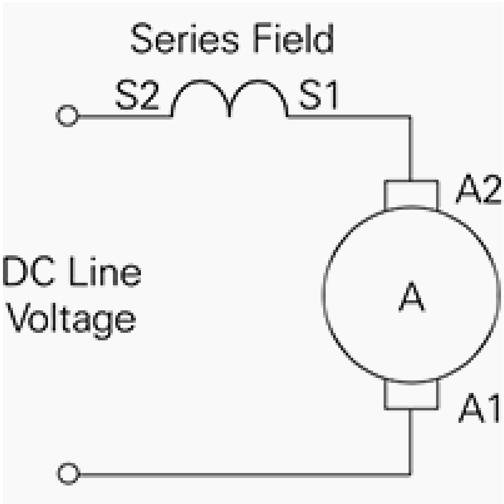
1. PERMANENT MAGNET MOTORS



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



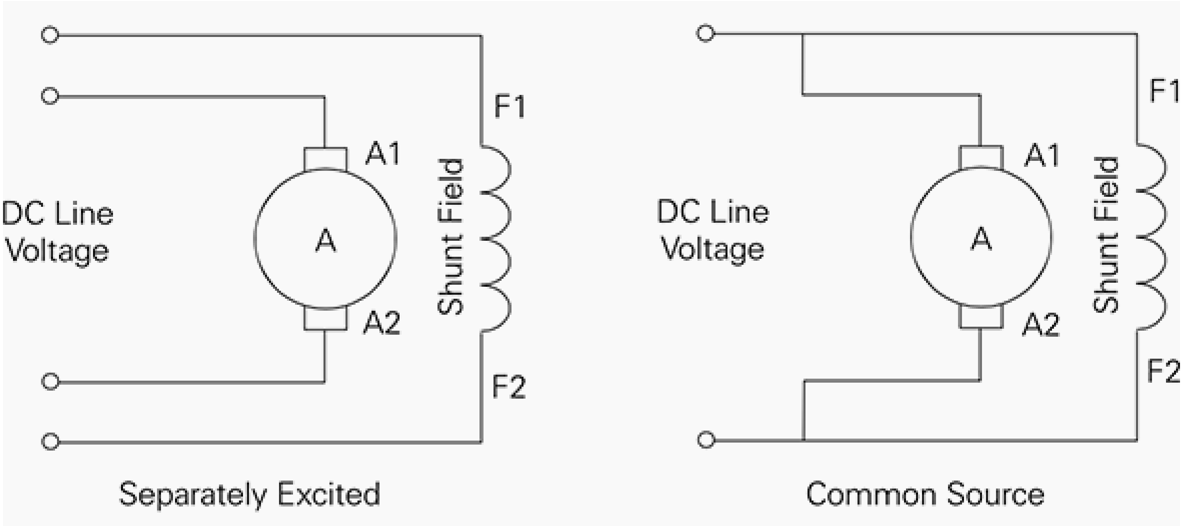
In a series DC motor the field is connected in series with the armature. The field is wound with a few turns of large wire because it must carry the full armature current.

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

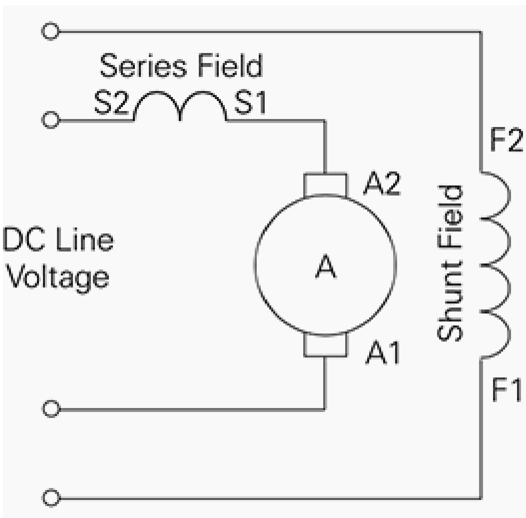


In a shunt motor the field is connected in parallel (shunt) with the armature windings. The shunt-connected motor offers good speed regulation. The field winding can be separately excited or connected to the same source as the armature

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.

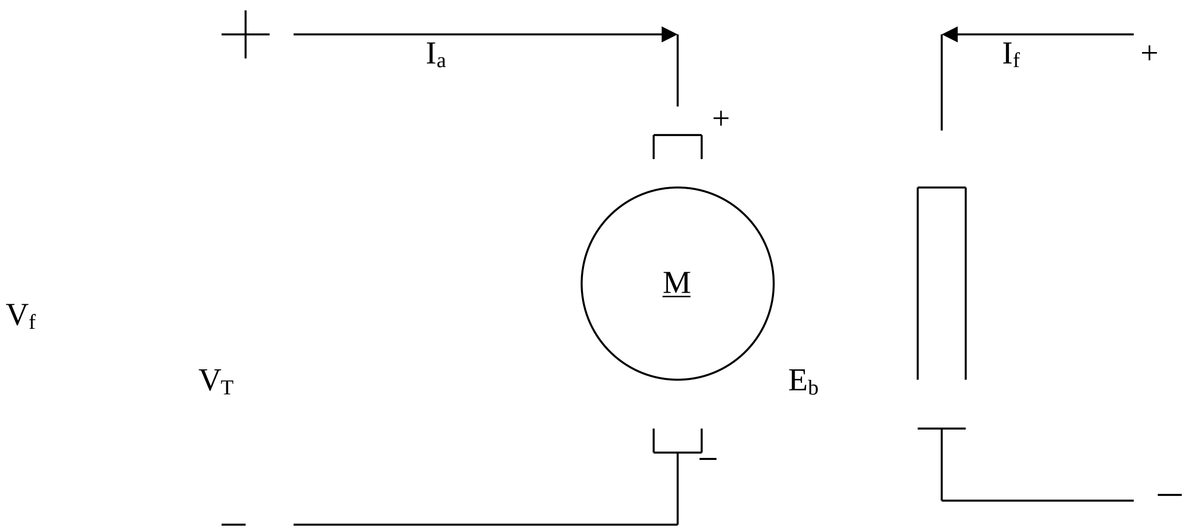
However, the series field can cause control problems in variable speed drive applications and is generally not used in four quadrant drives.

In summary

SERIES WOUND	SHUNT WOUND	COMPOUND WOUND
• Field and armature windings are in series. • Highest starting torque. • Poor speed regulation. Over-speeding if used at no load or light load.	• Field and armature windings are in parallel. • Medium starting torque. • Good speed regulation. • Can be used from low to rated loads.	• 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.

Let's see the basic equations of D.C. motor. (Refer the drawing below)



The figure above indicates typical configuration of a separately excited DC motor.

➢ V_T is terminal voltage applied to the armature.

- I_a the current flowing through the armature winding.
- R_a is the resistance of armature winding.
- V_f is voltage applied to the field winding.
- I_f is current flowing through field winding.
- I_f will produce magnetic flux=ϕ.
- $\phi \; \alpha \; I_f$ hence $\phi \; \alpha \; V_f$.
- When current I_a flows through armature winding, it will also produce its own magnetic field that will interact with field flux. The resultant magnetic field will develop torque on the armature.
- Rotation of armature in the magnetic field will induce "back E.M.F" (E_b) in the armature due to generator action.
- Considering the dynamic condition we can write the following equations.

- $V_T = E_b + I_aR_a$
- $E_b \; \alpha \; N \; x \; \phi$
- (Torque) $T \; \alpha \; \phi \, I_a$ where again $\phi \; \alpha \; I_f \; \alpha \; V_f$
- (Speed of motor) $N \; \alpha \; (E_b / \phi)$
- $I_a \; \alpha$ (Mechanical load on the motor)
- (Power) $P = V_T \; x \; I_a$ ……..input power to armature

  $= E_b \; x \; I_a$……..useful power

  $= 2\pi \; NT$………mechanical power.

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

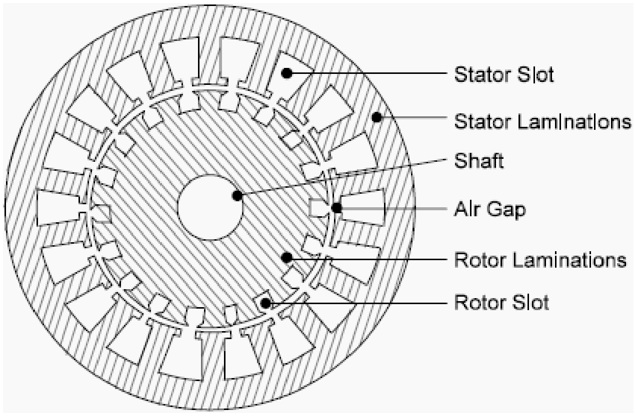
The AC induction motor comprises 2 electromagnetic parts:

- 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

A. THE STATOR



The stator is the outer stationary part of the motor, which consists of:

- **The outer cylindrical frame of the motor**, which is made either of welded sheet steel, cast iron or cast aluminum alloy. This may include feet or a flange for mounting.

- **The magnetic path**, which comprises a set of slotted steel laminations pressed into the cylindrical space inside the outer frame. The magnetic path is laminated to reduce eddy currents, lower losses and lower heating.

- **A set of insulated electrical windings**, which are placed inside the slots of the laminated magnetic path. The cross-sectional area of these windings must be large enough for the power rating of the motor. For a 3-phase motor, 3 sets of windings are required, one for each phase.

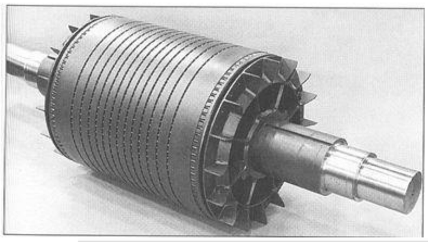
The stator of an induction motor is, in principle same as that of a synchronous motor. It is made up of stampings, which are slotted to receive the windings. The stator carries a 3- phase supply. It is wound for a definite number of poles, the exact number of poles being determined by the requirements of speed. Greater the number of poles, lesser is the speed and vice versa. The stator winding, when supplied with three phase current, produces a magnetic flux which is of constant magnitude but which revolves (or rotates) at synchronous speed ($N_s = 120f / P$). This revolving magnetic flux induces an e.m.f in the rotor by mutual induction.

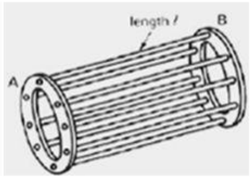
B. THE ROTOR

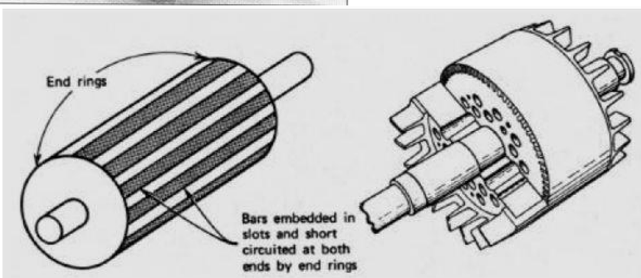
This is the rotating part of the motor. As with the stator above, the rotor consists of a set of slotted steel laminations pressed together in the form of a cylindrical magnetic path and the electrical circuit. The electrical circuit of the rotor can be either:

Construction

1. **Squirrel cage** – the conductors would look like one of the exercise wheels that squirrel or hamsters run on.







Schematic

Part Section

Squirrel cage rotor type, which comprises a set of copper or aluminum bars installed into the slots, which are connected to an end-ring at each end of the rotor. The construction of these rotor windings resembles a 'squirrel cage'. Aluminum rotor bars are usually die-cast into the rotor slots, which results in a very rugged construction. Even though the aluminum rotor bars are in direct contact with the steel laminations, practically all the rotor current flows through the aluminum bars and not in the laminations.

Motors using this type of rotor are known as squirrel-cage induction motors. Almost 90 % of induction motors are squirrel-cage type, because this type of rotor has the simplest and most rugged construction imaginable and is almost indestructible.

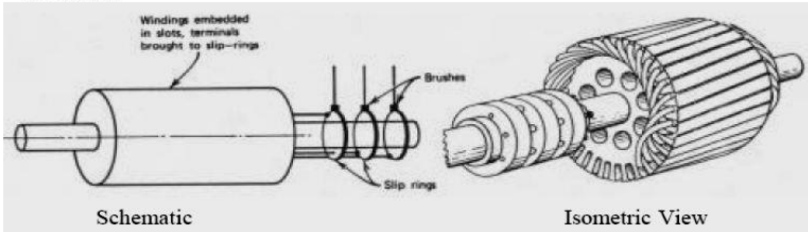
The rotor consists of a cylindrical laminated core with parallel slots for carrying conductors which are not wires but consists of heavy bars of copper, aluminum or alloys. The rotor bars are brazed or electrically welded or bolted to two heavy and stout short-circuiting end rings. Therefore it is not possible to add external resistance in series with the rotor circuit for starting for starting purpose. The rotor slots are not quite parallel to the shafts but are purposely given a slight skew. This helps in two ways:

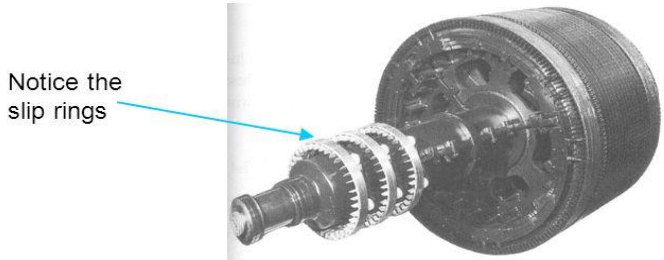
a. It helps to make the motor run quietly by reducing the magnetic hum and

b. It helps in reducing the locking tendency of the rotor i.e. the tendency of rotor teeth to remain under the stator teeth due to direct magnetic attraction between the two.

Construction

2. **Wound rotor** – have a brushes and slip ring at the end of rotor





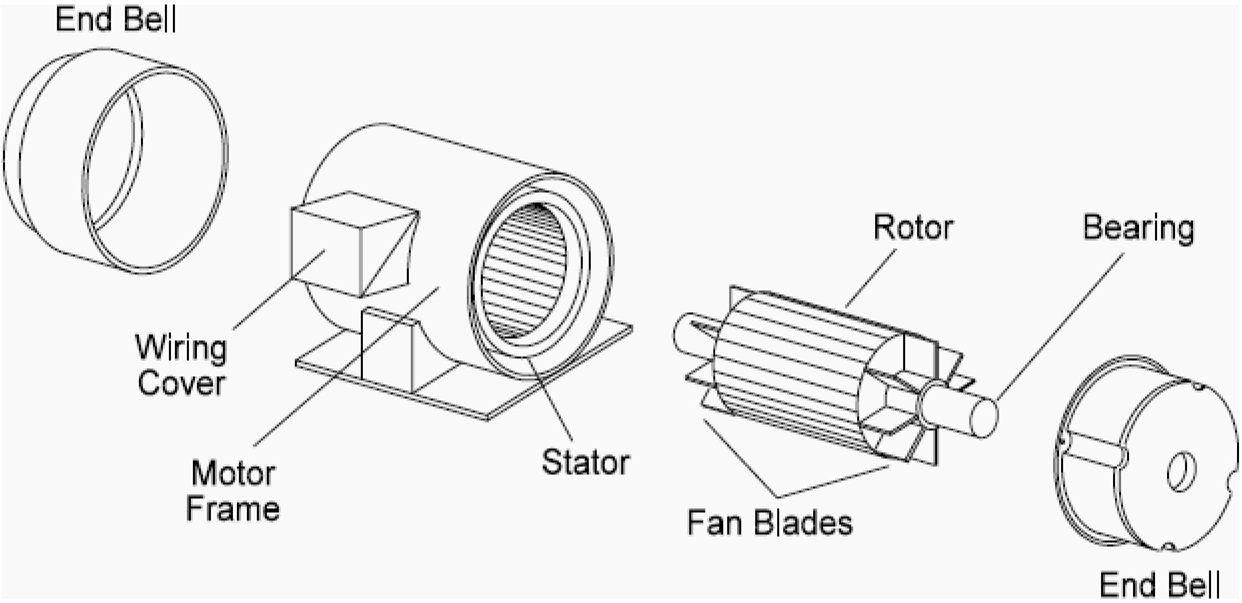
Wound rotor type, which comprises 3 sets of insulated windings with connections brought out to 3 slip rings mounted on the shaft. The external connections to the rotating part are made via brushes onto the slip rings. Consequently, this type of motor is often referred to as a slip ring motor. This type of rotor is provided with 3-phase, double –layer, distributed winding consisting of coils. The rotor is wound for as many poles as the number of stator poles and is always wound 3-phase even when the stator is wound two-phase. The three phases are starred internally. The three winding terminals are brought out and connected to three insulated slip-rings mounted on the shaft with brushes resting on them. These three brushes are further externally connected to a 3-phase star-connected rheostat. This makes possible the introduction of additional resistance in the rotor circuit during the starting period for increasing the starting torque and for changing its torque / current characteristics. When running under normal conditions, the slip-rings are automatically short-circuited by means of a metal collar which is pushed along the shaft and connects all the rings together. The brushes are automatically lifted from the slip-rings to reduce frictional losses and the wear and tear. Hence, it is seen that under normal running conditions, the wound rotor is short-circuited on itself just like the squirrel-cage rotor.

C. THE OTHER PARTS

The other parts, which are required to complete the induction motor, are:

- Two end-flanges to support the two bearings, one at the drive-end (DE) and the other at the non-drive-end (NDE)
- Two bearings to support the rotating shaft, at DE and NDE
- Steel shaft for transmitting the torque to the load

- Cooling fan located at the NDE to provide forced cooling for the stator and rotor
- Terminal box on top or either side to receive the external electrical connections



AC Motor uses electrical energy in AC form to convert it into mechanical energy

SYNCHRONOUS MOTOR

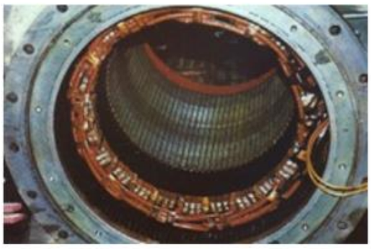
Synchronous Motors are three-phase AC motors which run at synchronous speed, without slip. A **synchronous electric motor** is an AC motor in which, the rotation of the shaft is synchronized with the frequency of the supply current.

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

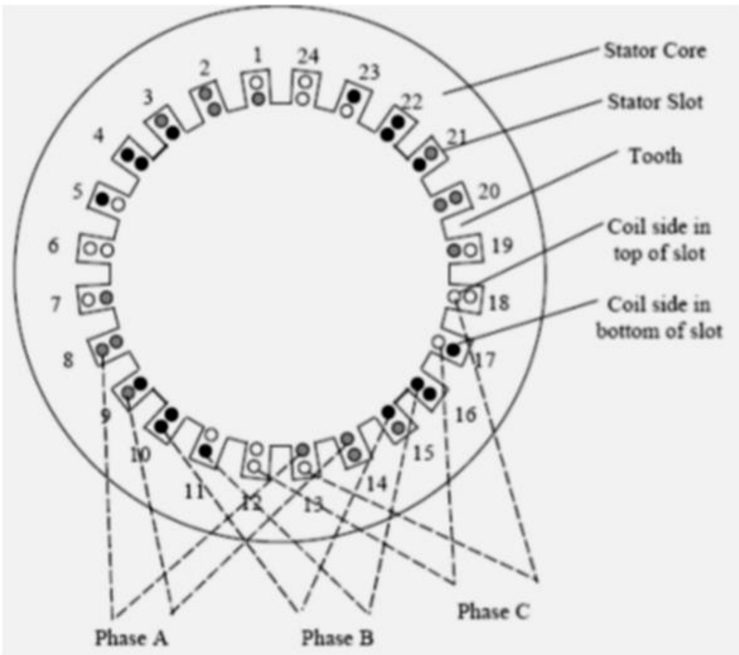
Stator

- 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.



Construction

- Stator



(In an induction motor the rotor must have some "slip". The rotor speed must be less than, or lag behind, that of the rotating stator flux in order for current to be induced into the rotor. If an induction motor rotor were to achieve synchronous speed, no lines of force would cut through the rotor, so no current would be induced in the rotor and no torque would be developed.)

Most synchronous motors are rated between 150kW and 15 MW and run at speeds ranging from 150 to 1800 RPM.

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:

$$\textbf{Synchronous RPM } (N_S) = \frac{\textbf{120 x Frequency (f)}}{\textbf{Number of Poles (P)}} \quad \textbf{or, } N_S = 120\, f / P$$

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

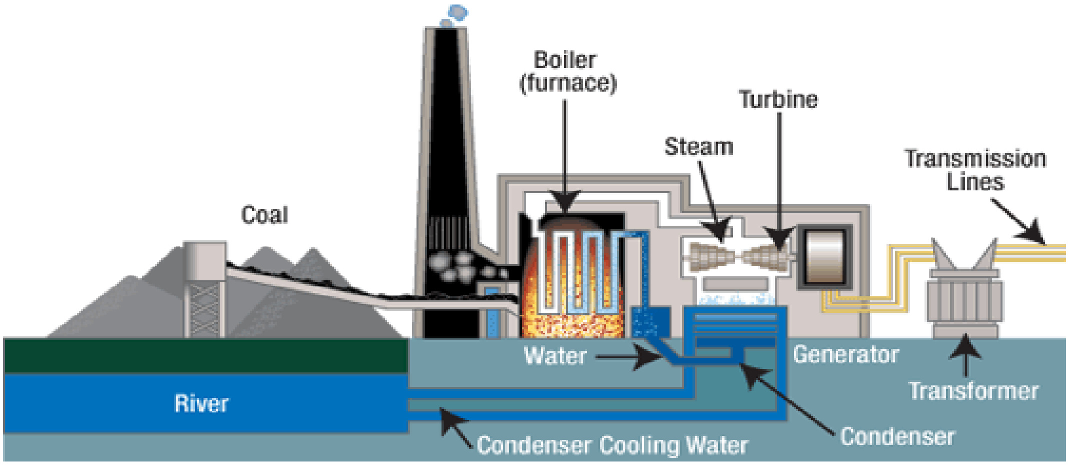
As a system engineer the prerequisite knowledge that person must have is about the vastness of network he is dealing with. As a general philosophy every SAIL Integrated steel plant has two major categories of providing power to the plant

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.

PLANT LOAD FACTOR

Plant Load Factor (PLF) is an important indicator of the efficiency of a power plant.

$$\text{PLF} = \frac{\text{Actual Generation}}{\text{Installed Capacity}}$$

If the average power generated by a 60 MW generator is 57 MW over a one-year period, then its annual PLF is 0.95 or 95%.

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

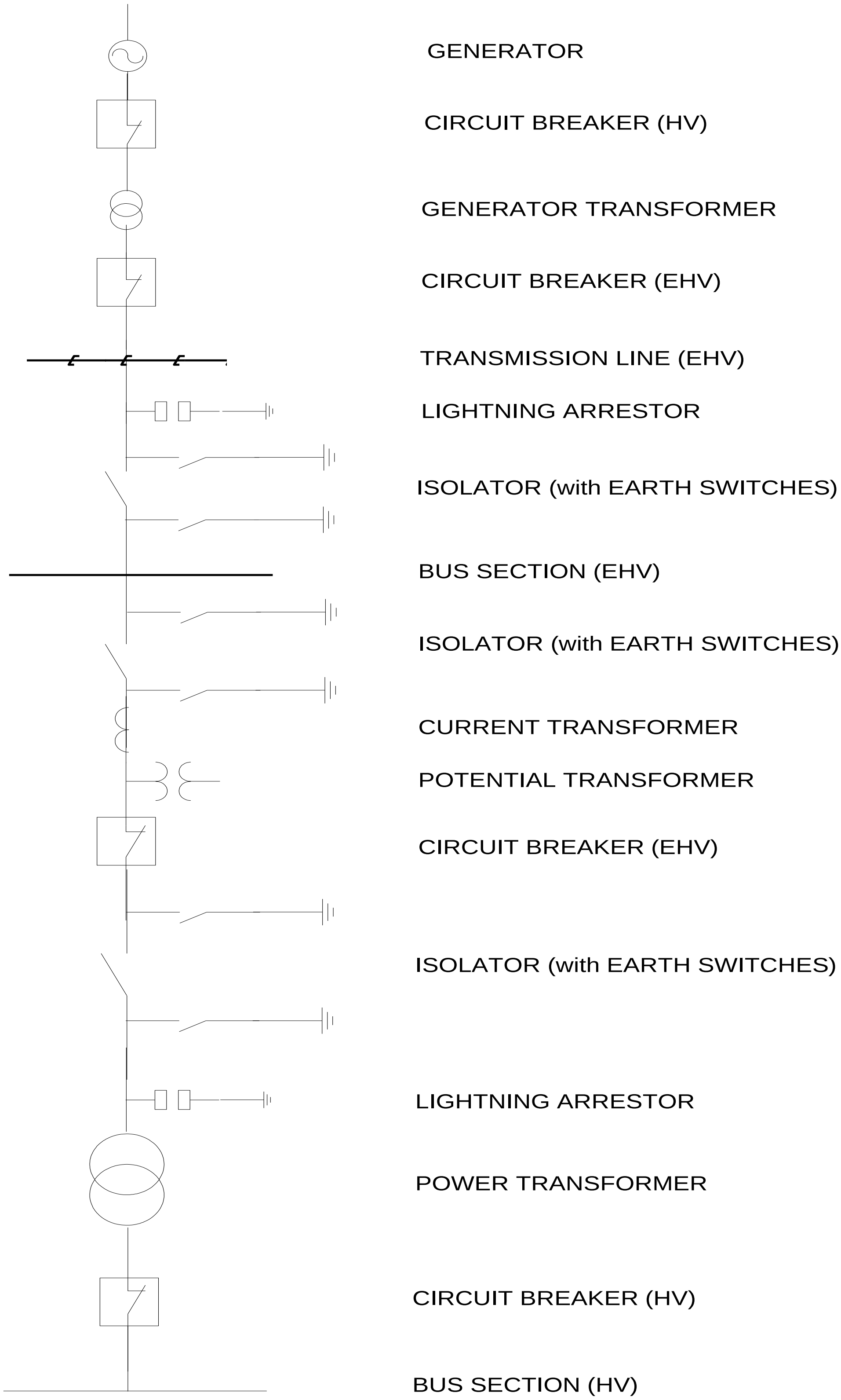
A majority of the equipments in a steel plant have both state grids as well CPP supply. It is important that any paralleling operation at sub-stations is done only after ensuring that the CPP supply is synchronized with the grid supply. If paralleling is done between two supply sources not in synchronism, 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.



Layout of Equipments in a Typical Power Distribution System

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
2) Pneumatic circuit breaker
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

ACB is the circuit breaker which operates in air at atmospheric pressure. The working principle of this breaker is rather different from those in any other types of circuit breakers. The main aim of all kind of circuit breaker is to prevent the reestablishment of arcing after current zero by creating a situation where the contact gap will withstand the system recovery voltage. The air circuit breaker does the same but in different manner. 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.

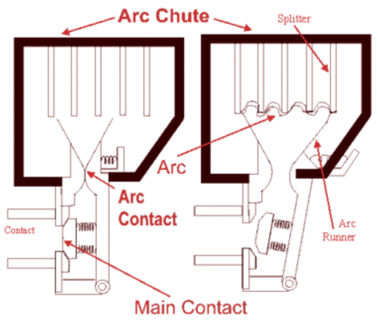
- It may increase the arc voltage by lengthening the arc path. As the length of arc path is increased, the resistance of the path is increased, and hence to maintain the same arc current more voltage is required to be applied across the arc path. That means arc voltage is increased.
- Splitting up the arc into a number of series arcs also increases the arc voltage.

There are mainly two types of ACB available.

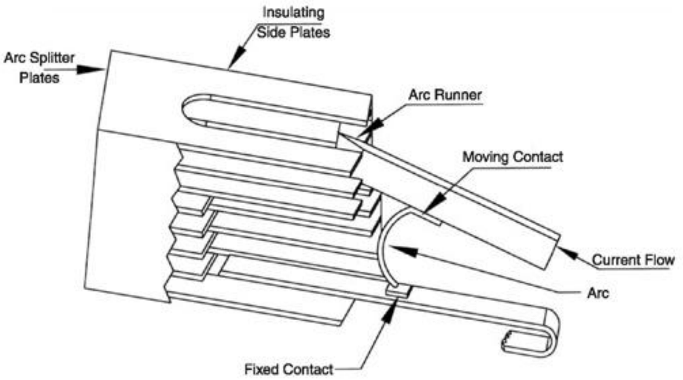
- Plain air circuit breaker
- Air-blast circuit breaker

PLAIN BREAK

Air-break circuit breakers extinguish the arc by simply stretching it until the dielectric strength of the gap is larger than the voltage across the gap. The longer arc has a larger cooling surface and higher resistance, which decreases the current flow and the amount of heat created. To stretch the arc, horn gap shaped contacts are used. Due to a natural convection, the arc moves upwards. To further increase the length, the arc is stretched by forcing it into an arc chute made of metal barriers or insulating material. The metal barriers chop the arc into many smaller arcs. Used from 120 V up to 15 kV.



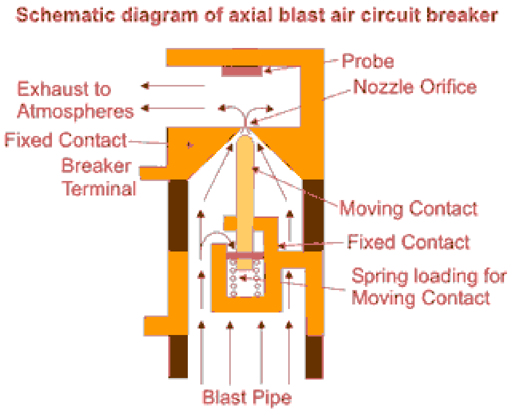
Air breaker - plain break

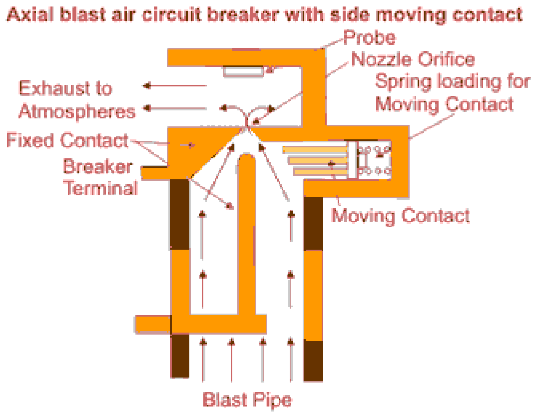


Air breaker - plain break, sketch

AIR-BLAST BREAK

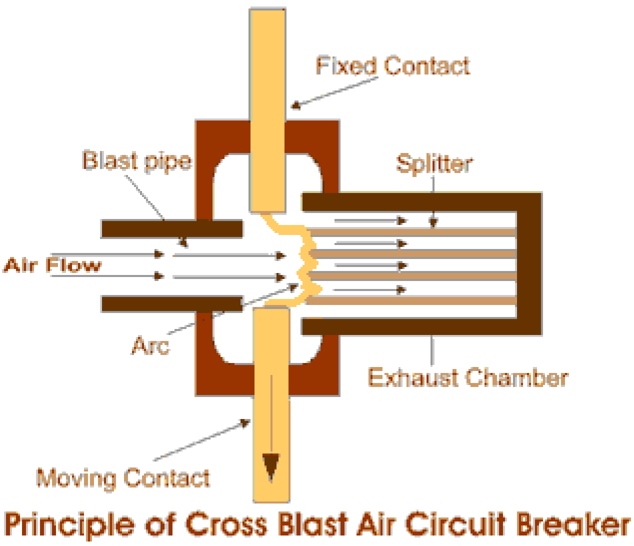
In the air-blast breaker the arc is not stretched. To extinguish the arc, a blast of compressed air is directed into the arc path to cool the ionized gas and remove it from the gap between the contacts. The contacts are held closed by a spring. A blast of air into the interrupting head forces the contacts to open. The contacts will close as soon as the air flow stops. The compressed air can be blown into the arc perpendicular to it (cross blast), or along its axis (axial blast). All modern breakers use the axial blast. The air blast circuit breakers are built up to the highest used voltages (765 kV) by connecting several interrupter heads in series.





a) Axial air-blast breaker

b) Axial air-blast breaker



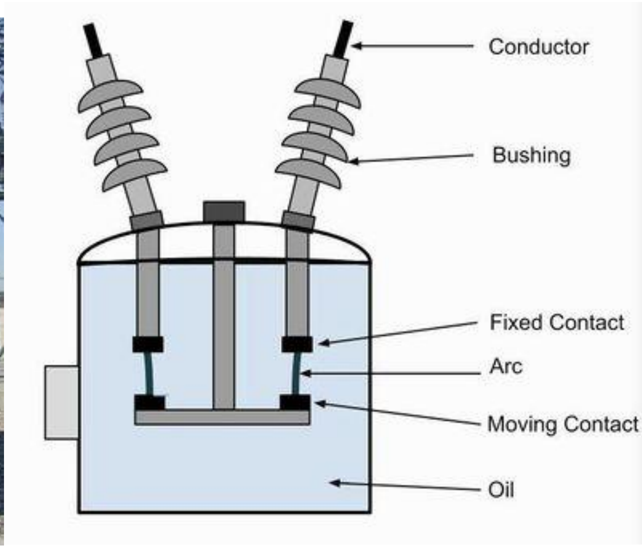
c) Cross air-blast breaker

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.

BULK OIL CIRCUIT BREAKERS (BOCB)

Bulk oil circuit breaker (or BOCB) is a such type of the circuit breakers where oil is used as arc quenching media as well as insulating media between current carrying contacts and earthed parts of the breaker. The oil used here is same as transformer insulating oil. These types of breakers are designed in all voltage ranges from 1 kV up to 330 kV.



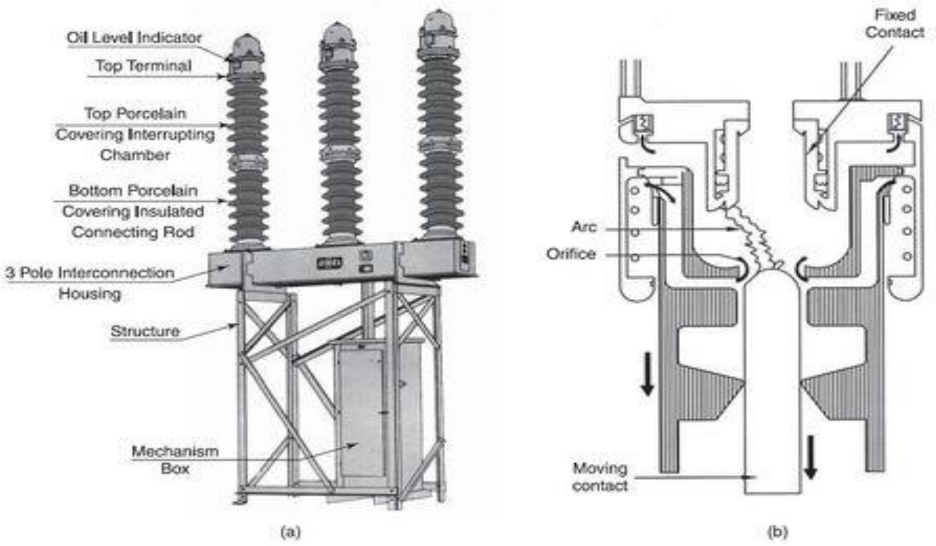
a) 66 kV Oil Circuit Breaker b) Bulk oil circuit breaker

Modern arc-controlled oil breakers have an arc control device surrounding the breaker contacts to improve extinction of arc. In cross blast interrupters, the arc is drawn in front of several lateral vents. The gas formed by the arc causes high pressure inside the arc control device. The arc is forced to bow into the lateral vents in the pot, which increases the length of the arc and shortens the interruption time. The axial blast interrupters use similar principle. Oil breakers are design for both three-phase and single-phase circuit brakers.

At voltages higher than 115 kV, separate tanks for each phase are used. The practical limit for the bulk oil breakers is 275 kV.

MINIMUM OIL CIRCUIT BRAKERS (MOCB)

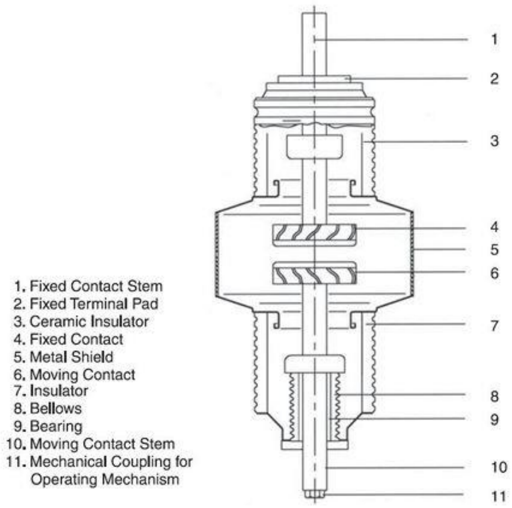
In minimum oil breakers the oil is used only for extinguishing of the arc. The arc control devices are the same as for the bulk-oil breakers. However, unlike bulk oil circuit breakers, these designs place the interrupting units in insulating chambers at live potential. To improve breaker performance, oil is injected into the arc. The interrupter containers of the minimum oil breakers are made of insulating material and are insulated from the ground. This is usually referred to as live tank construction. For high voltages (above 132 kV), the interrupters are arranged in series. It is essential to ensure that each interrupter carries its share of the duty. Care must be taken that all breaks occur simultaneously, and that the restriking voltage is divided equally across the breaks during the interrupting process. The features of designing MOCB is to reduce requirement of oil, and hence these breaker are called minimum oil circuit breaker. These designs are available in voltages ranging from 1 kV to 765 kV using the multi-break technique.



36 kV MOCB a) Typical design, b) Cross-section of the interrupting chamber

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.

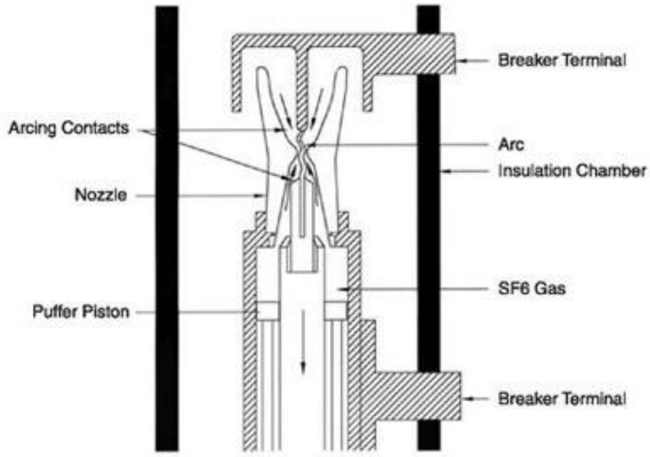
BREAKER PROPERTIES

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:

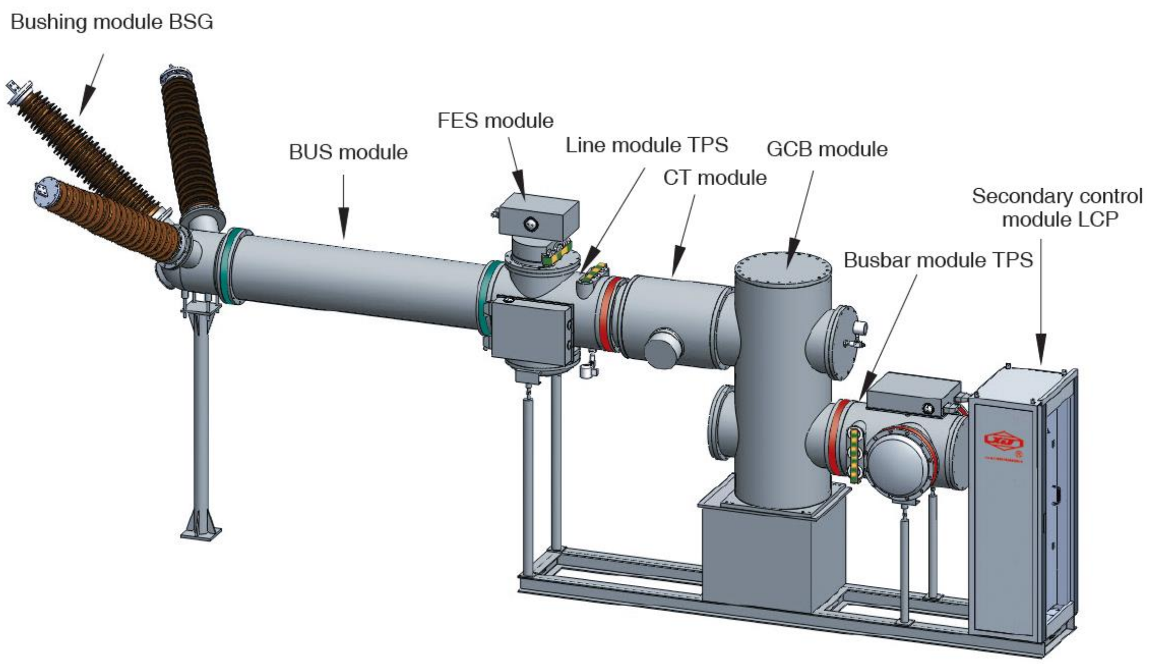
1) Single interrupter SF6 CB applied for up to 245 kV (220 kV) system
2) Two interrupter SF6 CB applied for up to 420 kV (400 kV) system
3) Four interrupter SF6 CB applied for up to 800 kV (715 kV) system

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 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.

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.

However this type of cable not in use nowadays.

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 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

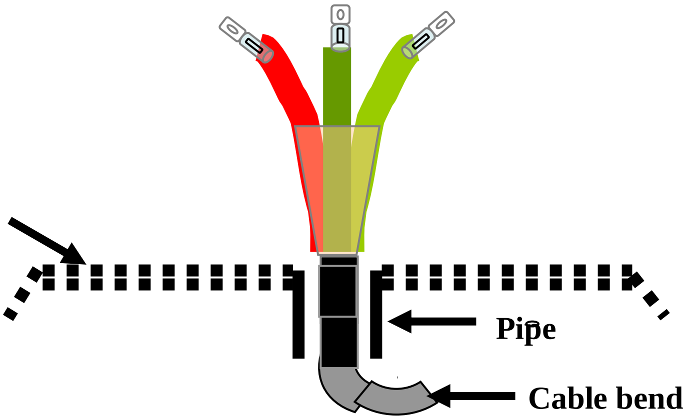
XLPE Cable

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.

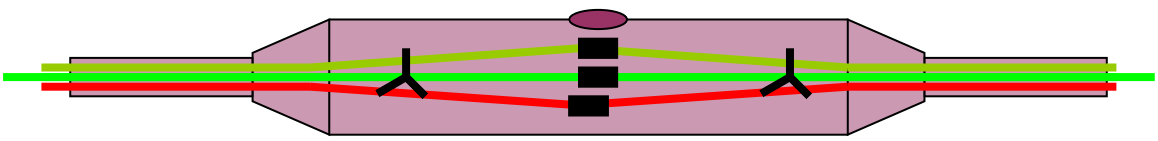
Precautions with cables. PILC cables absorb moisture if left exposed or if their outer sheath is damaged. PVC cables are not stable at temperatures above 80 ºC. XLPE cables suffer from development of water trees over a period of time. Metallic sheaths or polythene coated metal tape (Poly – Al, Poly – 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:**

  i. **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

  ii. **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

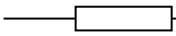
1. **Definition:** Resistor is the electronic device that resists the flow of current.
2. **Unit of Measurement:** Ohms (Ω)
3. **Specifications:** The resistors are specified in terms of:

a. **Value**: Specified in Ohms

b. **Tolerance**: Allowable deviation from the specified value expressed in percentage (1%/5%/10%/20%).

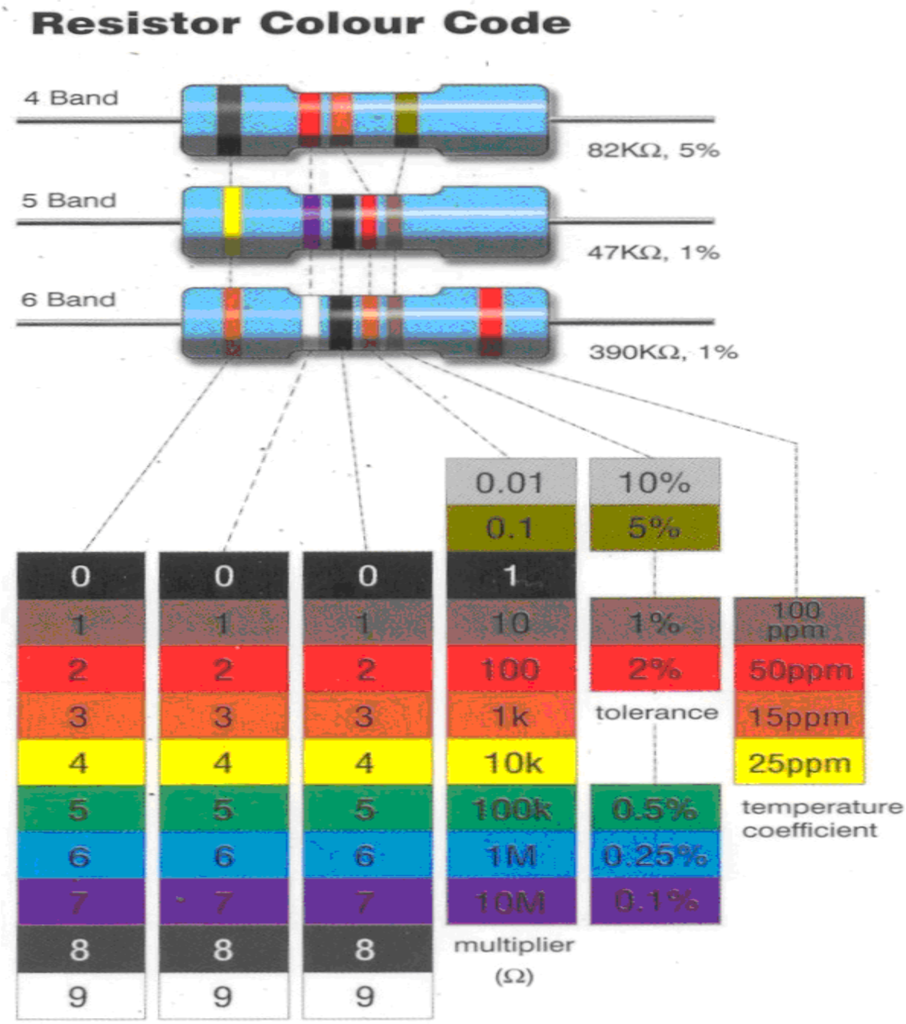
c. **Power**: Resistors are designed to handle a particular amount of power. Same value resistors are available in different power ratings like quarter watt, Half watt, 1 watt etc.

d. **Type**: Depending on the material used for fabrication, the resistors may be Carbon, Metal Film, Wire wound type etc.

4. Symbol:  or 

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)

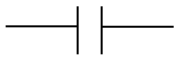
c. **Voltage:** Max voltage which the capacitor can sustain without being damaged.

d. **Tolerance:** Allowable deviation from the specified value expressed in percentage.

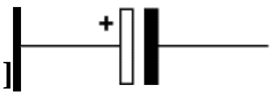
e. **Packaging:** Axial Lead package, radial Lead package, Solder Type Terminals, Screwable terminals etc.

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.

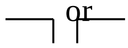
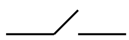
d. As the energy storage device in some switch-mode power supplies.

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.

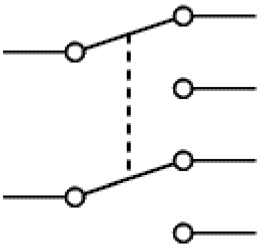
5. **Materials: A**lmost invariably copper as coil material but core can be of different materials.

MISCELLANEOUS COMPONENTS

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:  or 

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.



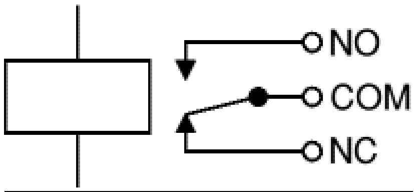
A Double Pole Double Throw Switch

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:

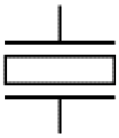


Crystals:

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:



HISTORY OF DEVELOPMENT OF SEMICONDUCTORS:

- Point Contact Transistor developed in 1948.
- BJT came into existence in1950.
- Planer Process introduced in 1959.
- First Integrated Circuit fabricated soon after in early 1960's; housing less than 100 components (SSI).
- MOS Transistor developed in 1962.
- 100 to 10,000 components incorporated on a single chip in 1966 (MSI).
- Large Scale Integration (LSI) technique in 1969.
- More than 10,000 components on single chip by 1975 (VLSI).
- VLSI chips had more than 100000 components even by 1984!

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.

CATHODE RAY OSCILLOSCOPE (CRO):

An **oscilloscope** (sometimes abbreviated **CRO**, for cathode-ray oscilloscope, or commonly just **scope** or **O-scope**) is a type of electronic test equipment that allows signal voltages to be viewed, usually as a two-dimensional graph of one or more electrical signals (on the vertical axis) plotted as a function of time or of some other voltage (on the horizontal axis). A typical CRO has a small screen on its front panel on which the graphs are displayed when the inputs are connected. The front panel of the CRO also has numerous buttons, switches and connectors for setting and connection of inputs. The CRO uses a Cathode Ray Tube for display of graphs which is similar to the picture tube of Television sets.

The CROs can have two or more channels for simultaneous display of more than one signal. A CRO is a very useful tool in troubleshooting electrical and Electronic circuits as it gives a graphical display of the signal which is not possible with a Voltmeter. Also, sometimes it is important to know the precise shape of signals for analysis and design and in such applications; CRO is a very versatile tool.
Originally, CROs were analog equipment but now digital CROs have become commonly available and are much more advanced than their analog predecessors. They can store waveforms and can be connected to computer for download and analysis of waveshapes.

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.

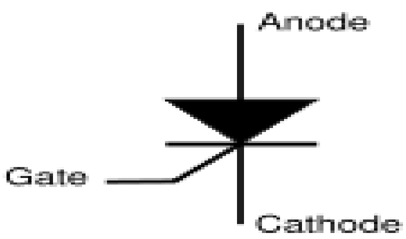
In general, DC drives can control motor speed in two ways.

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.

DC DRIVES (THYRISTORISED CONTROL)- PRINCIPLES OF OPERATION

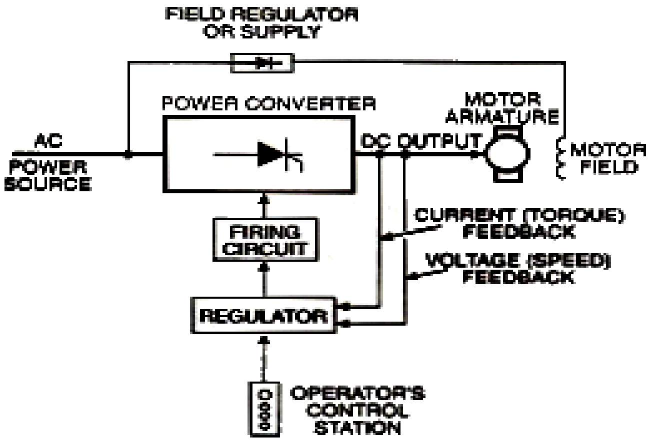


FIGURE 2. Typical DC Drive

A typical adjustable speed drive using a silicon controller rectifier (SCR) power conversion' section, is shown in Figure 2. The SCR, (also termed a thyristor) converts the fixed voltage alternating current (AC) of the power source to an adjustable voltage, controlled direct current (DC) output which is applied to the armature of a DC motor.

SCR's provide a controllable power output by "phase angle control", so called because the firing angle (a point in time where the SCR is triggered into conduction) is synchronized with the phase rotation of the AC power source. If the device is triggered early in half cycle, maximum power is delivered to the motor; late triggering in the half cycle provides minimum power, as illustrated by Figure 3.

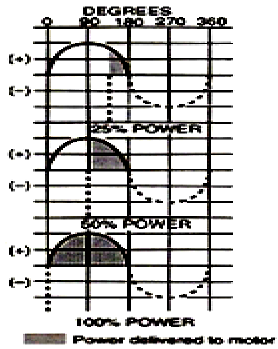


FIGURE 3. Triggering Points for Various Power Outputs

DC DRIVE TYPES

Non-regenerative DC Drives – Non-regenerative DC drives are the most conventional type in common usage. In their most basic form they are able to control motor speed and torque in one direction only as shown by Quadrant I in Figure 4. The addition of an electromechanical (magnetic) armature reversing contactor or manual switch permits reversing the controller output polarity and therefore the direction of rotation of the motor armature as illustrated in Quadrant III. In both cases torque and rotational direction are the same.

Regenerative DC Drives - Regenerative adjustable speed drives, also known as four-quadrant drives, are capable of controlling not only the speed and direction of motor rotation, but also the direction of motor torque. This is illustrated by Figure 4.

The term regenerative describes the ability of the drive under braking conditions to convert the mechanical energy of the motor and connected load into electrical energy which is returned (or regenerated) to the AC power source.

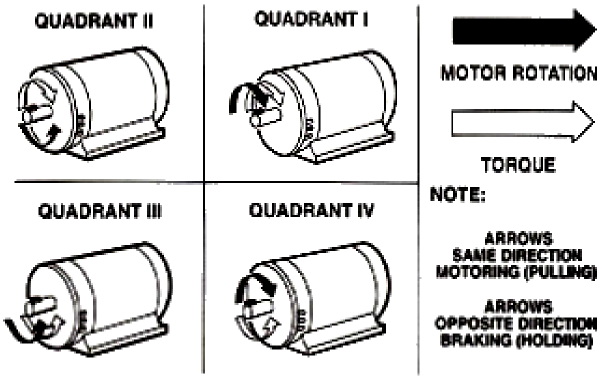


FIGURE 4.

When the drive is operating in Quadrants I and III, both motor rotation and torque are in the same direction and it functions as a conventional non-regenerative unit. The unique characteristics of a regenerative drive are apparent only in Quadrants II and IV. In these quadrants, the motor torque opposes the direction of motor rotation which provides a controlled braking or retarding force. A high performance regenerative drive, is able to switch rapidly from motoring to braking modes while simultaneously controlling the direction of motor rotation.

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

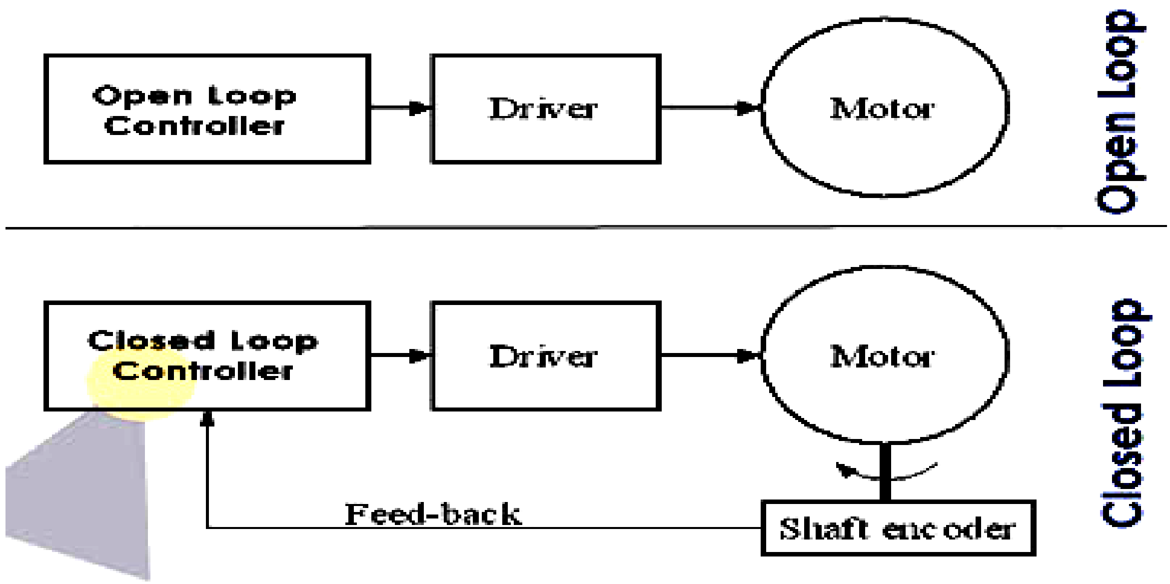
Generally the speed of a dc motor can be controlled up to base speed by Armature Voltage control and above base speed it can be controlled by the field i.e. the field current.

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.

OPEN /CLOSED LOOP CONTROL

In general open loop control means that you send electrical signals to an actuator to perform a certain action, like connecting a motor to a battery for example. In this scheme of control, there is no any mean for your controller to make sure the task was performed correctly and it often need human intervention to obtain accurate results. A very simple example of open loop control, is the remote controller of a toy car; you - the human - have to constantly check the position and the velocity of the car to adapt to the situation and move the car to the desired place.



Closed loop VS Open loop

But what if you could let the electronics handle a part, if not all of the tasks performed by a human in an open loop controller, while obtaining more accurate results with extremely short response time? This is what is called closed loop control. In order to be able to build a closed loop controller, you need some mean of gaining information about the rotation of the shaft like the number of revolutions executed per second, or even the precise angle of the shaft. This source of information about the shaft of the motor is called "feed-back" because it sends back information from the controlled actuator to the controller.

Figure 5 shows clearly the difference between the two control schemes. Both types have a controller that gives orders to a driver, which is a power circuit that drives the motor in the required direction. It is clear that the closed loop system is more complicated because it needs a ‘shaft encoder’ or tacho which is a device that will translate the rotation of the shaft into electrical signals that can be communicated to the controller. In other words, a closed loop controller will regulate the power delivered to the motor to reach the required velocity. If the motor is to turn faster than the required velocity, the controller will deliver less power to the motor.

Thus Open loop control system can be called Manual Control and Closed loop control system can be called Automatic Control. In a closed loop system the actual and desired or reference states are continually compared and if the actual state is different from the reference state, an error signal is generated which the controller uses to force a change in the controllable parameters to drive the system towards the desired operating point.

SINGLE LINE DIAGRAM OF THYRISTOR CONVERTER

As we know motor speed can be controlled by controlling armature voltage and field excitation (current).This diagram shows motor speed control by controlling armature voltage of the motor.

A converter is a circuit that changes the incoming AC power (fixed voltage, fixed frequency) into DC power. The converter can be either single phase or three phase. A thyristor converter is a controlled rectifier which is used to convert AC into DC.

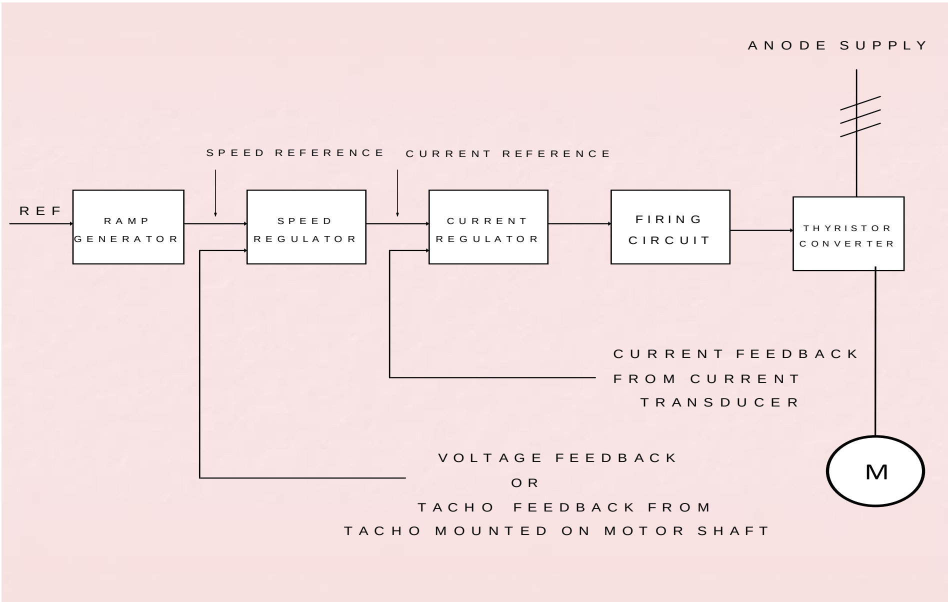


Fig.6 Diagram showing closed loop control of a typical dc motor (armature)

In above Diagram, M stands for Armature of DC Motor, REF stands for Reference (say speed reference) from Operator.

In the single line diagram above (Fig.6), REF (Reference) from operator or from other system enters RAMP Generator and the signal is processed through Speed Regulator, Current Regulator etc. The output of current regulator controls the pulses position in firing circuit so that armature voltage can be controlled.

ANALOG / DIGITAL DRIVES

Analog Drive: An analog drive is a drive where the components used in regulation circuit like the velocity/speed and current loops are analog components (such as op-amps). The gains of the amplifiers are set using passive components (such as resistors, potentiometers, and capacitors).

Digital Drive: In a digital drive, all the functions of the drive is performed by microprocessor/microcomputer. In digital drive, unlike analog drive, all analog external signals like current feedback, speed feedback are converted into digital form by Analog-to-Digital converter. All the controlling blocks of analog Drive like Ramp function generator, Speed controller, Current controller and firing sequence generation are realized in the microprocessor of the digital drive through programs/ parameters .Preferably a digital tacho (pulse tacho/encoder) is used instead of analog tacho for better accuracy. Digital drives can also provide powerful diagnostic aids for maintenance and fault finding. It can store event history, fault history. Digital drive provides auto tuning of speed and current control functions.

Comparison of Analog and Digital Drives:

The analog drive offers the benefit of lower cost and, in the case of a drive using tacho feedback, very high performance.

The digital drive, while more costly, is comparatively easy to set up and adjustments can be quickly repeated across several units. Automatic self-tuning can be a distinct advantage where the load parameters are unknown or difficult to measure.

The various adjustments needed to tune an analog drive are usually made with potentiometers. With a little experience, this can usually be performed quite quickly, but in some difficult applications it may take longer.

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 MOTOR CONTROL CHARACTERISTICS

The synchronous speed of an AC induction motor is directly proportional to the applied frequency.

$$\text{Speed} = \frac{120 \times \text{Frequency}}{\text{No. of Motor Poles}}$$

The synchronous speed is the speed of the rotating electrical field, not the actual motor rotor speed. The difference between the synchronous speed and the full-load motor speed is called slip, which is normally expressed in percent. The percentage of slip is determined by the design of the motor, primarily the rotor resistance. NEMA has assigned code letters (A, B, C, D, etc.) to standardize motor characteristics including slip. The type most commonly used is NEMA Design B with 3% slip at rated operating conditions. Figure 9 shows typical speed/torque curves for NEMA Design Band D motors.

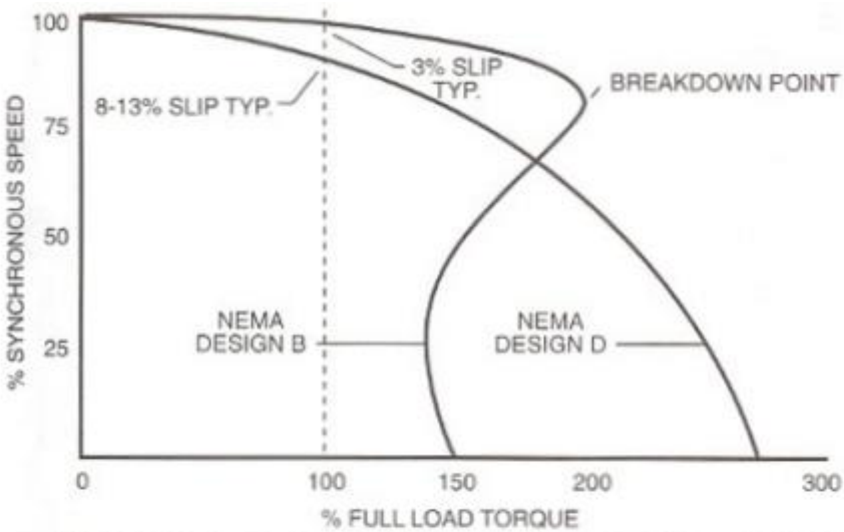


FIGURE 9. Typical Speed-Torque Characteristics at Rated Voltage & Frequency

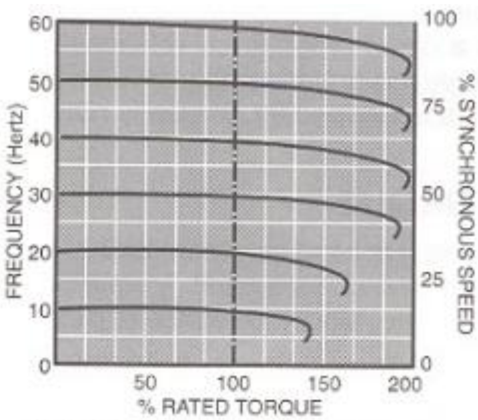


FIGURE 10. Typical Speed Torque Curves for 60 Hz NEMA Design B Motor (Without Voltage Boost)

As the applied frequency is changed, the motor will run faster or slower as shown by Figure 10. The actual full-load motor slip (as a percent of the motor synchronous speed) varies in inverse proportion to the frequency, where a 3% slip motor 60 Hz would have a 6% slip at 30 Hz or 1 1/2 % slip at 120 Hz. Motor speed is limited only by the maximum inverter output frequency, load torque requirements, and the mechanical integrity of the motor.

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:

- **<u>VFD : VARIABLE FREQUENCY DRIVE</u>**

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.

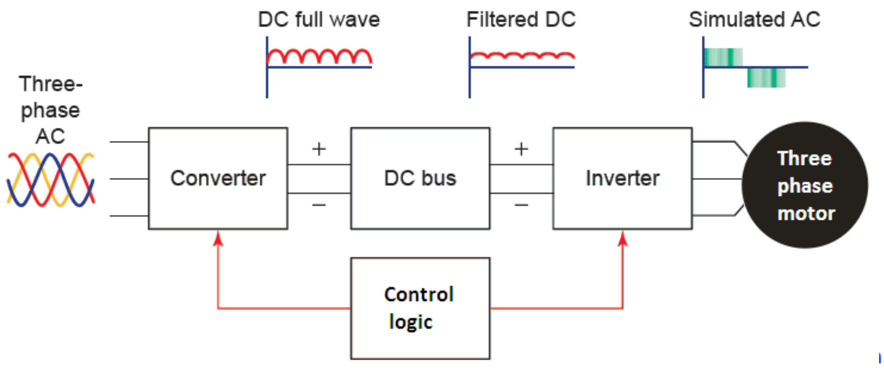
Utilizing these "switches" is what allows the VFD to adjust the frequency that the VFD supplies to the motor. This, in turn, controls the speed of the motor.

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

BLOCK DIAGRAM OF VFD DRIVE



▪ **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 = 2πfl) 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.

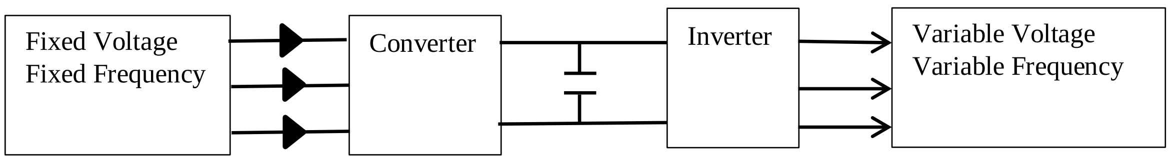
Advantages

- 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 Uninterrupted Power Supply (UPS)

Introduction

Most of the industrial and even domestic processes being electricity dependent for the operations, electricity has assumed immense important in our life.

Among the industrial activities there are many which require not only the continuous power but also very good quality electrical power. These are listed as following:

1. Telecommunication systems.
2. Data processing equipment and systems
3. Process controls
4. Drives in continuous production processes
5. Life support systems in hospitals
6. Air Traffic control systems
7. Safety systems in power stations and many others

SOURCES OF POWER

We normally get electrical power from the public grid set up by the government agencies like State Electricity Boards. These grids are generally powered by HYDEL power plants, Thermal power plants, Nuclear power plants etc. The quality of power has following considerations:

The shape of the voltage waveform should be pure sinusoidal.

It should not contain any harmonics.

It should be continuously available without any interruptions or undesired fluctuations in the magnitude and frequency.

Unfortunately there are many problems associated with power and they include:

Spikes – Spikes are high magnitude split second events. They are mostly caused by lightening, which strike on or near power line or even miles away causing spikes in power system. Other cause of spikes include switching large electrical current on or off., mains switching and static discharge

Effects: the most disastrous effect spikes can be actual hardware damage. High voltage impulses can actually blow holes in delicate microchips. Less catastrophic effects include corrupted data, printer or terminal error and data processing error.

Surges - surges are over voltages that last longer than one cycle. Surges can be caused when device on the line that was drawing large amount of power suddenly stops or is shut off. Surges can also be caused when utilities switch large load off the line.

Effects: Surges are most dangerous because of their duration rather than their magnitude. Long and frequent surges can damage sensitive electronic equipments.

Sags- Sags are under voltages that last longer than cycle. Sags are, in fact opposite of surges. Earth faults, undersized power systems and starts-ups of large electrical loads are causes of voltage sags. Lightning is also a major cause of sags.

Effects: Sags can cause the computers to lock up. Sags can also slow the speed of disk drives, causing read errors or disk crashes.

Noise- Noise is collective term for various kinds of frequency impulses that ride on the normal sine-wave. Noise is caused when high frequency signals that travel on electrical wires. High frequency noise is referred as Radio frequency (RF) noise, which can be generated by lightning, radio transmission and power supply.

Effects: Noise can create erratic behavior in any electronic circuit. Noise can cause computer processing errors, incorrect data transfer and printer or terminal errors.

Brownouts- Brownouts are long term under voltages , lasting

minutes or even hours. They are often instituted by utilities when peak demand exceeds generating capacity.

Effects: Brownouts can cause computer malfunctions and hardware damage the same way that sags do.

Blackouts: Blackouts are extended zero volt conditions, lasting for minutes, hours or even days. Blackout can be caused by faults generation, transmission and distribution network, earth faults, accidents, lightning strikes or other acts of nature.

Effects: Blackouts can cause damage of system components and disk drives. They can also cause the data loss.

Harmonic distortion: Harmonic are distortion of normal sine-wave. They appear in the form of changed shape of sine-wave. Harmonics are transmitted-back in to the mains by nonlinear loads.

Effects: Harmonics can cause communication error and hardware damage. Harmonics can also cause overheating of transformers and conductors generating excessive heat leading to fire hazards.

9.13 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.

9.14 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

<u>For Electrical Agency</u>:

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.

<u>For Non-Electrical Agency</u>:

Shutdown on electrically driven stationary equipment for carrying out work by other than electrical agencies is issued on a separate form.

<u>For Mobile Equipment</u>:

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

<u>Check Points before granting permission</u>:
(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?

<u>Return / Withdrawal of *Permit To Work*</u>

- 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:

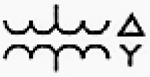
i. Always hold the two probes of the multi-meter in different hands. Either ask another person to hold the meter or use the stand of the meter to firmly place it on a safe place.

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.

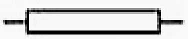
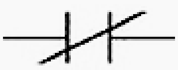
9.15 Single line diagram (SLD)

We usually depict the electrical distribution system by a graphic representation called a **single line diagram (SLD)**. A single line can show all or part of a system. It is very versatile and comprehensive because it can depict very simple DC circuits, or a very complicated three-phase system. We use **universally accepted electrical symbols** to represent the different electrical components and their relationship within a circuit or system. To interpret SLDs you first need to be familiar with the electrical symbols. This chart shows the most frequently used symbols.

Individual electrical symbols		
Symbol	Identification	Explanation
	Transformer	Represents a variety of transformers from liquid filled to dry types. Additional information is normally printed next to symbol indicating winding connections, primary /secondary voltages and KVA or MVA ratings.
	Removable or drawout circuit breaker	Normally represents a MV drawout circuit breaker 5kV and above.
	Future removable or drawout circuit breaker position	Represents a structure equipped to accept circuit breaker in the future, commonly known as provisions.

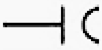
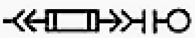
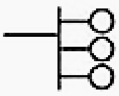
Cont…

Cont…

Individual electrical symbols		
Symbol	Identification	Explanation
	Non-drawout circuit breaker	Represents a fixed mounted low voltage circuit breaker.
	Removable or drawout circuit breaker	Represents a drawout low voltage circuit breaker.
	Disconnect switch	Represents a switch in low or medium/high voltage applications (open position shown)
	Fuse	Represents low voltage and power fuses.
	Bus duct	Represents low and medium/high voltage bus duct.
	Current transformer	Represents current transformers mounted in assembled equipment. A ratio of 4000A to 5A shown.
	Potential or voltage transformer	Represents potential transformers usually mounted in assembled equipment. A ratio of 480V to 120V shown.
	Ground (earth)	Represents a grounding (earthing) point
	Battery	Represents a battery in an equipment package
	Motor	Represents a motor and is also shown with an "M" inside the circle. Additional motor information is commonly printed next to symbol, such as horsepower, RPM and voltage.
	Normally open (NO) contact	Can represent a single contact or single pole switch in the open position for motor control
	Normally closed (NC) contact	Can represent a single contact or single pole switch in the closed position for motor control

Cont…

Cont…

Individual electrical symbols		
Symbol	Identification	Explanation
	Indicating light	The letter inside circle indicates the color. The color red is indicated.
	Overload relay	Protects a motor should an overload condition develop.
	Capacitor	Represents a variety of capacitors.
	Ammeter	A letter is usually shown to designate the meter type (A = ammeter, V = voltmeter, etc.)
	Instantaneous overcurrent protective relay	The device number designates the relay type (50 = instantaneous overcurrent, 59 = overvoltage, 86 = lockout, etc.)
	Emergency generator	The symbol is frequently shown in conjuction with a transfer switch.
	Fused disconnect switch	The symbol is a combination of a fuse and disconnect switch with the switch in the open position.
	Low voltage motor control	The symbol is a combination of a normally open contact (switch), overload relay, motor and disconnect device.
	Medium voltage motor starter	The symbol is a combination of a drawout fuse, normally open contact (switch) and motor.
	Meter center	A series of circle symbols representing meters usually mounted in a common enclosure.
	Load center or panelboard	One circuit breaker representing a main device and other circuit breakers representing feeder circuits usually in a common enclosure.

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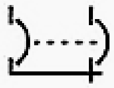
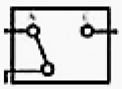
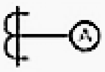
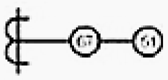
Individual electrical symbols		
Symbol	Identification	Explanation
 or 	Transfer switch	• Circuit breaker type transfer switch • Non-circuit breaker type transfer switch
	Current transformer with connected ammeter	The instrument connected could be a different instrument or several different instruments identified by the letter.
	Protective relays connected to current transformer	Device numbers indicate types of relays connected, such as: • 67 – Directional overcurrent • 51 – Time overcurrent

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Chapter – 10

INSTRUMENTATION & PROCESS CONTROL

10.1 Instrumentation & Process Control functions in an Integrated Steel Plant

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.

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/LDCP, 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
- Calorific Value (CV) Analyzer measurement.

Sintering Machine

- Sinter Charge Bunker level measurement
- Moisture measurement & control of sinter charge at secondary mixing drum
- Water flow at SMD (secondary mixing drum)
- 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
- Angle of Repose measurement & Control

ESP

- Vibration and temperature measurement at IDF and bearings
- Suction and discharge pressure control

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 Calorific Value Analyzer.

CO Gas Analyser

a. For better process control, it is necessary to monitor exhaust gases composition.
b. The Stack 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 systems are used for on line moisture measurement and control of raw sinter mix.
f. Nucleonic Moisture Sensor is 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. Weigh Feeders and Belt Weigher are installed to control the accurate proportioning of Iron Ore, flux, mill scale, flue dust, lime dust, coke, in plant sinter return.

Belt Weigher

i. To measure and control material flow rate 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 systems 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 HT Motors/ Equipments.

Temperature Monitoring System:

Consists of Temperature scanners with 10/12 RTD/Thermocouple input
Additionally critical RTDs are connected to DCS directly.
TC-.K type is used for wind legs temperature.
S-Type for Ignition Furnace temperature
Pyrometer is used for monitoring 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 meters
For combustion air to furnace– DP based flow meters
For water flow meters – DP based flow meters/Electromagnetic flow measurement

Besides these the following are also installed for efficient running of the plant

Flow Switches for different parameters
Pressure Switches for different 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
- Channel & waste gas temperature in each shaft
- LSHS oil temperature; pressure &flow measurement with oil flow counter
- Shaft level measurement & control
- Burning time count control system

2. TBDB Shop

- Temperature measurement for tempering Kilns
- CO gas pressure measurement

3. Rotary Kiln

- Furnace temperature
- CO gas pressure & flow measurement & control
- Air pressure measurement

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 Dust 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. Encoder / CMR for Burden position in Furnace
9. Gas Analysers – CO, CO_2, H_2, O_2
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
- O_2 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 been provided.

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 Continuous 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 Furnaces & R.H. degassing Unit
- Continuous Casting shop (CCS)
- Desulphurization Unit (DSU)
- Gas Holder for LD gas
- Propane Plant for Torch Cutting Machine
- 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 O2 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, Temperature Oxy 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” 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 loops and 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 (S/B-type) are used for temp. 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/slabs are preheated in the reheating furnaces of these mills before being rolled into different products like angles, channels, TMT rods, plain rods, wires, rails, structural and HR/CR Coils & Plates. The Merchant Mill, Wire Rod Mill, Rail Mill, Medium Structural Mill, R&SM, Hot Strip Mill, Cold Rolling Mill, Hot Dip Galvanizing Mill, Plate Mill, Wheel and Axle Plant are the finished product Mills.

The important control parameters involve d in the process of making finished products are:

Furnace Parameters:

- Furnace Pressure measurement and control
- Furnace Soaking zone Temperature Control
- Furnace Heating Zone Temperature 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

<u>Gas Mixing and Gas booster Station :</u>

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 mmWC and delivered to the distant Mills. The critical control parameters at this place are:

- BF gas flow
- Calorific Value (CV) Analyzer
- CO gas flow
- CO enrichment flow
- Mixed gas pressure before and after booster
- 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 pressure 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 through Insertion type Flowmeters and Electromagnetic Flowmeters, Ultrasonic flow meters
- 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.

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 explosion through 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 for welding 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 Trace N_2 in the argon produced from the distillation column. CO_2 analysers based on infrared absorption is 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.

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.
- Weighbridges, 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 the process.
- 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

10.2 Instrumentation & Control for different process parameters:

Temperature :

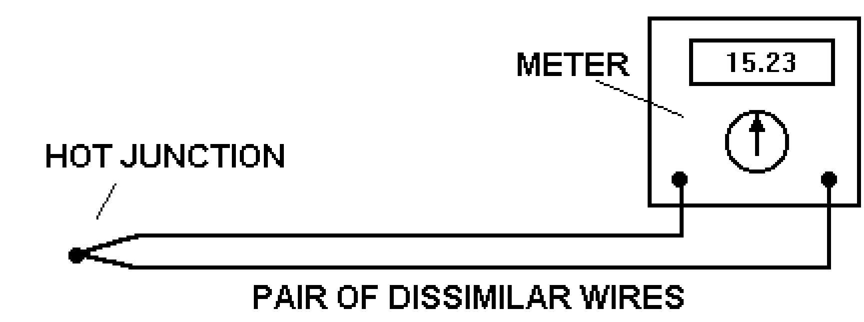
Temperature measurement in Steel Plants is having wide variety of needs and applications. Temperature measurement is done for mediums viz. water, Lubrication oil, Hot metals, various types of gases and chemicals. Based on these applications sensors and devices are used. Temperature measurement can be 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.

$$e = \square(\square_1 - \square_2) + \square(\square_1^2 - \square_2^2)$$

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.

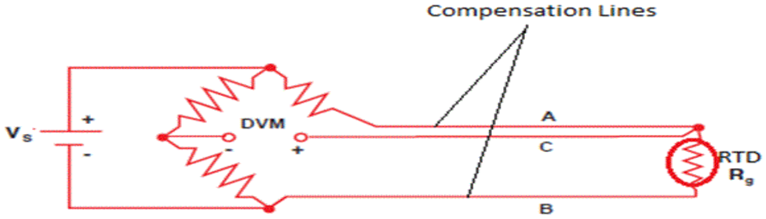


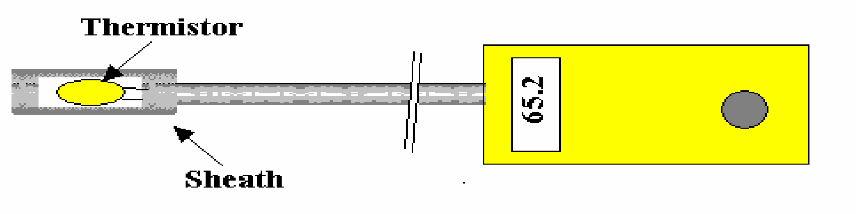
Fig.4. Three wires RTD Bridge

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.

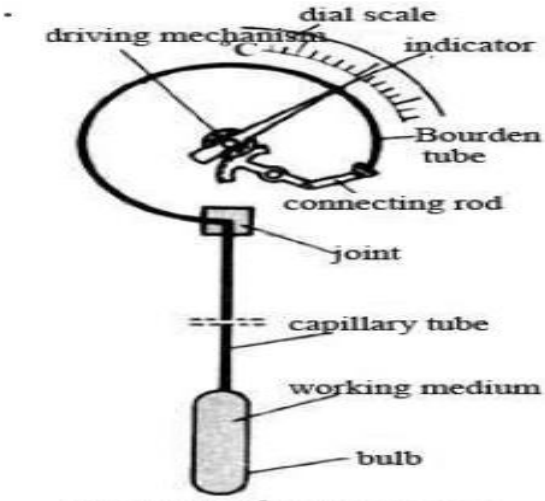
They are only used for a typical range of -20 to 120◦C and are commonly used in small hand held thermometers. The relationship between resistance and temperature is of the form

$$R = Ae^{B/\theta}$$



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.

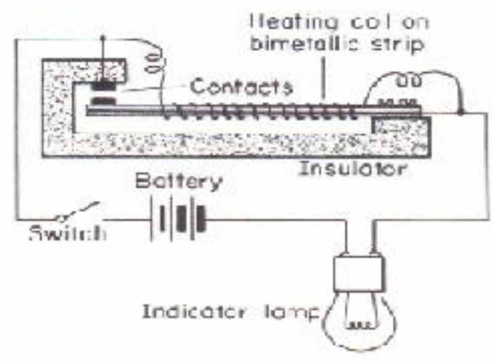


Fig. 15.7. Flasher unit

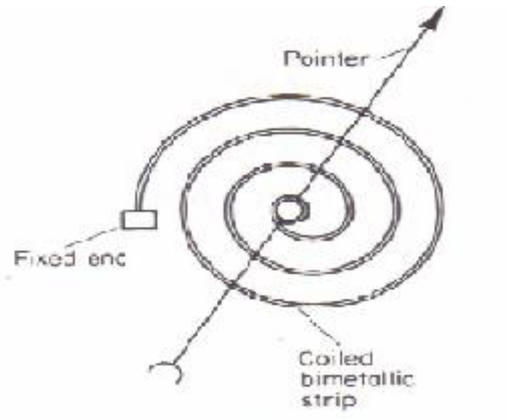
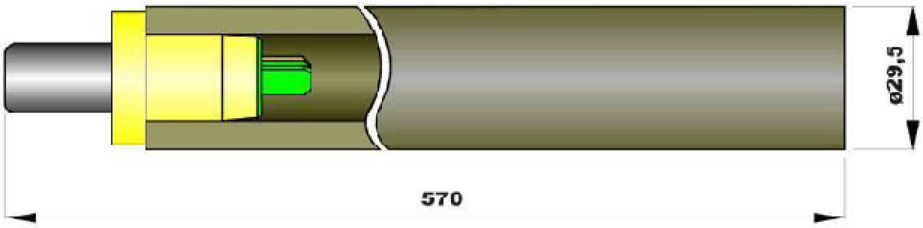


Fig. 15.8. Bimetallic thermometer

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



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.

TARGET ⇨ ATMOSPHERE ⇨ DETECTOR ⇨ DISPLAY

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:

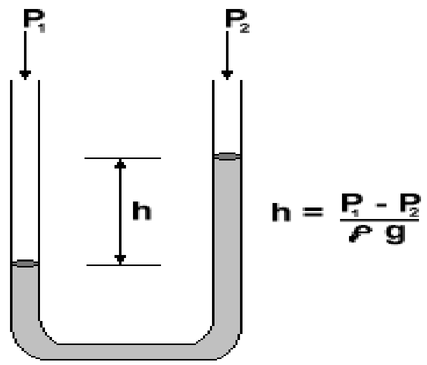
a) Pressure gauge

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.

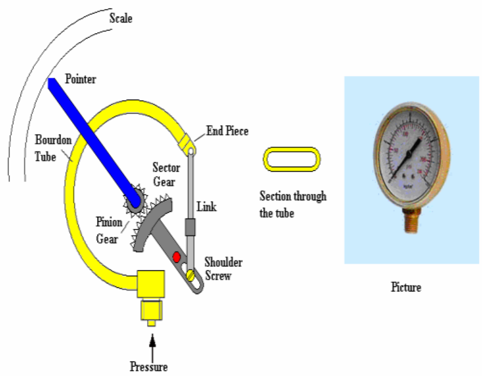
b) Manometers

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.



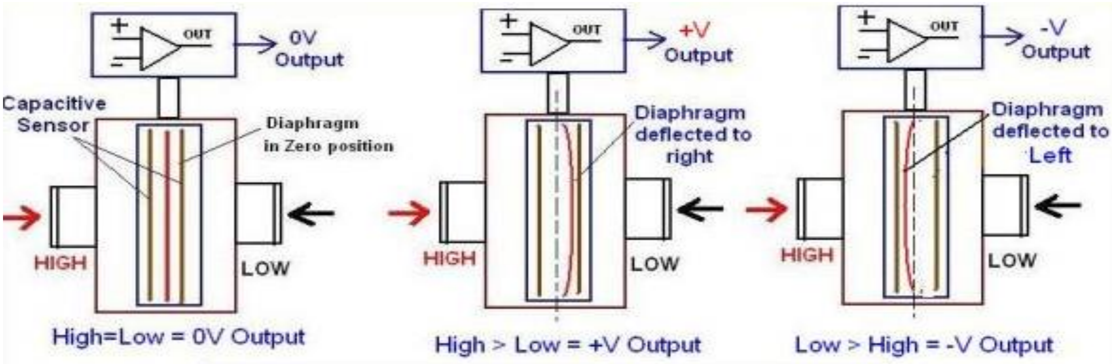
c) Pressure Transmitter

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.



Internal arrangement of Bottom & Top Half of DP Transmitter

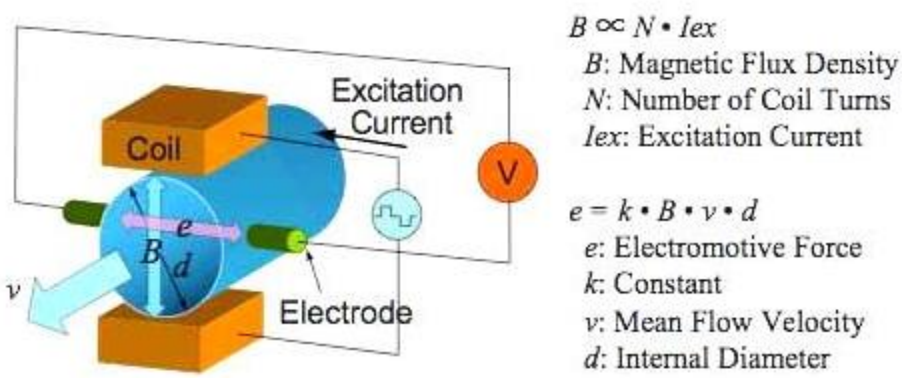
- **<u>Flow:</u>**

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:

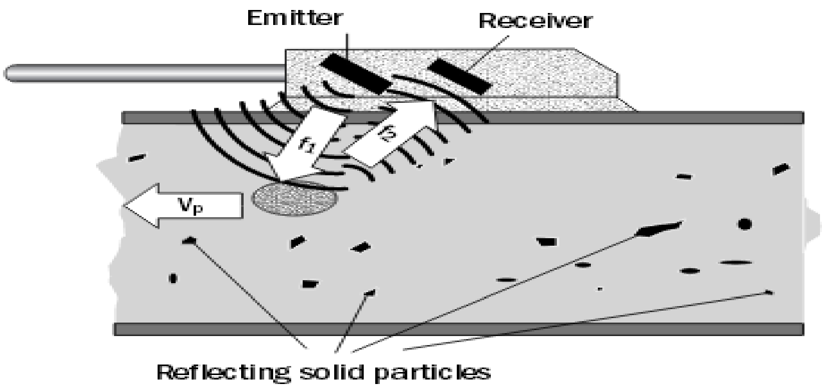
<u>a)Magnetic Flow Meter</u>

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.



<u>b) Ultrasonic Flow meter</u>

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.

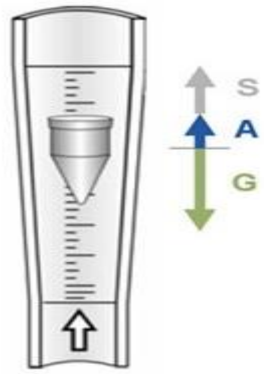


c) Variable Area type Flow meter

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.

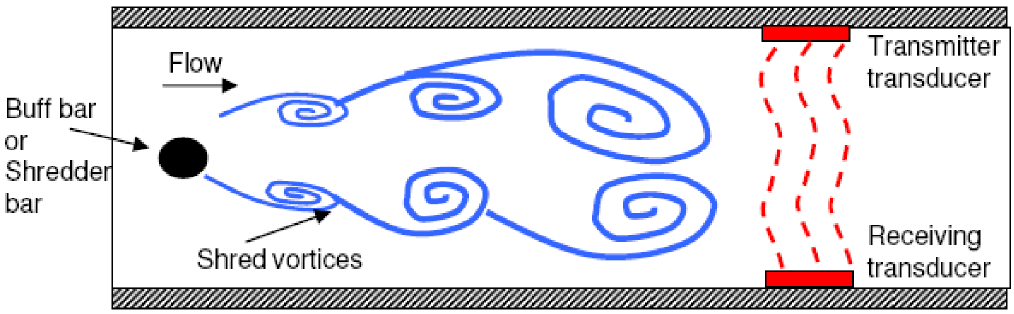
Three main Forces acting on the Float are:

- 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.

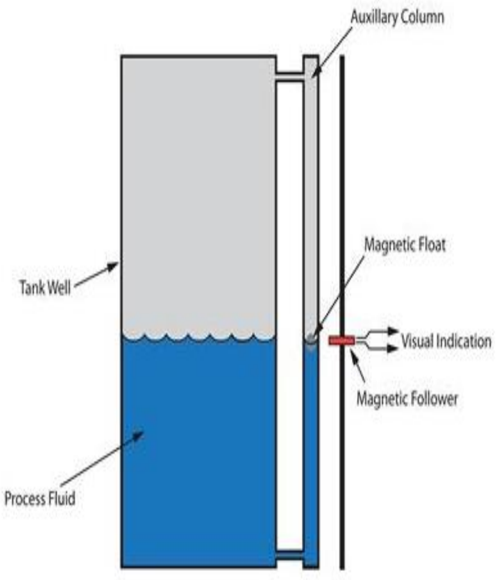
b) Displacers, Bubblers and Differential Pressure Transmitters

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.

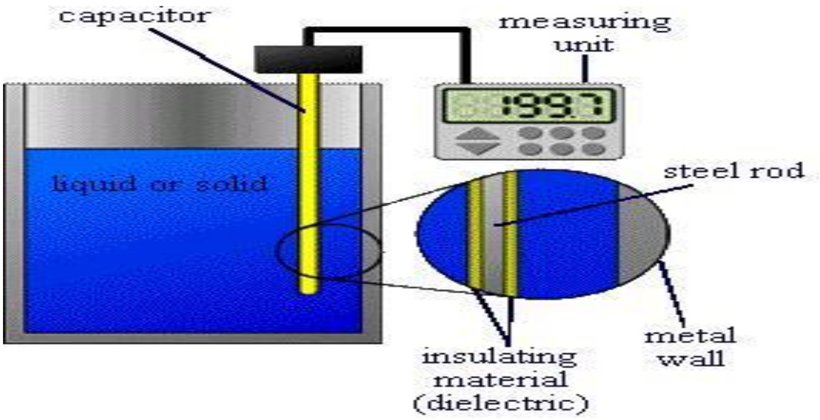
The float is laterally confined by the column so it remains close to the side wall of the chamber. The position of the float moves up and down according to the fluid level, which is indicated by a magnetized shuttle or a bar graph that moves along with it, showing the float's position and thereby indicating the level.

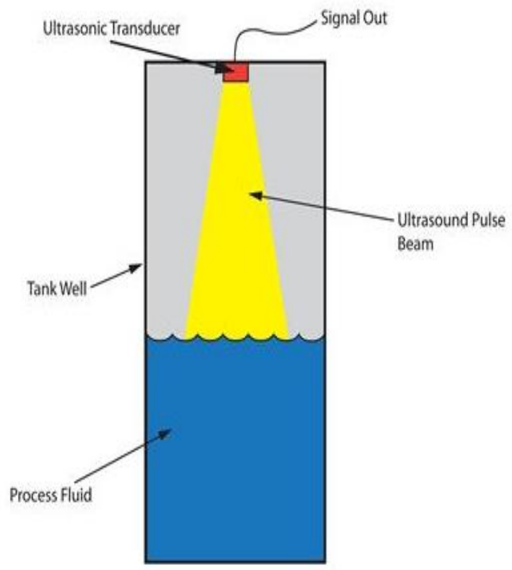


d) Capacitance Transmitters

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).

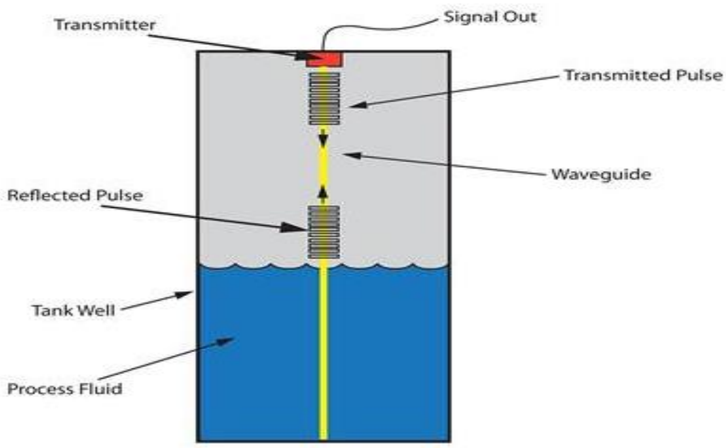
The operational frequency of these transmitters is tens of kilohertz and the transit times are approximately 6 ms/m. The composition of the gas mixture in the headspace and its temperature affect the speed of sound (340 m/s in air at 15°C). Even though the sensor compensates for temperature, it is limited 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) Nucleonic type Mould Level Measurement System

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.

Calorific Value /Wobbe Index/CARI Meter:

In Steel Plants to ensure proper combustion and optimized utilization of fuel gases measurement of Calorific Value/Wobbe Index/ CARI Meter is Calculated.

Calorific Value:

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.

$$\text{Wobbe Index} = \frac{\text{Heating Value}}{\sqrt{\text{Specific Gravity}}}$$

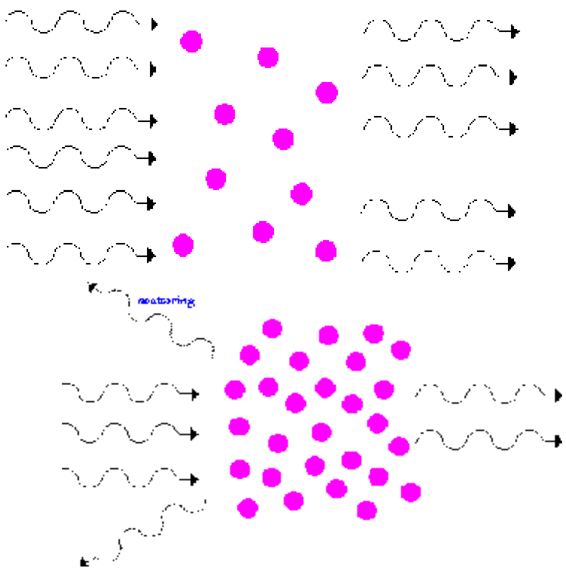
$$\text{Where, Specific Gravity} = \frac{\text{Density of Fuel}}{\text{Density of Air}}$$

- **<u>Environmental Analyzer systems</u>:**

To follow the environment related guidelines given by Central Pollution Control Board (CPCB) number of various type of Analyzer are installed to monitor the Stack emission, SOx, NOx, CO and Monitoring of Dust etc.

a) <u>Opacity Monitor:</u>

Opacity is formally defined as the measure of the impenetrability of electromagnetic radiation through a sample. The opacity Monitors are primarily used to analyze air and smoke. These media types can be informally described as "clear" or "dirty" depending on their opacity. Opacity measurement largely depends on the concentration of particles within a sample. When electromagnetic radiation, visible light or infrared radiation is emitted toward a sample, suspended solids will scatter, reflect, and absorb the radiation, preventing it from passing through. Opacity sensors measure the quantity of transmitted light and convert it to a relevant value.



Radiation through clean medium Radiation through Dirty Medium

b) <u>Sox, Nox Analyzer</u>

In Steel Plants units for calcinations, melting or sintering ores as well as the production of non-ferrous metals have rough environmental conditions, such as high dust loads and strong vibrations. The gases produced due to fuels used, such as coal, oil or gas. The pollutants like CO, NOX ,SO2 in particular must be continuously measured during the procedures are processed further and must be measured and monitored accordingly.

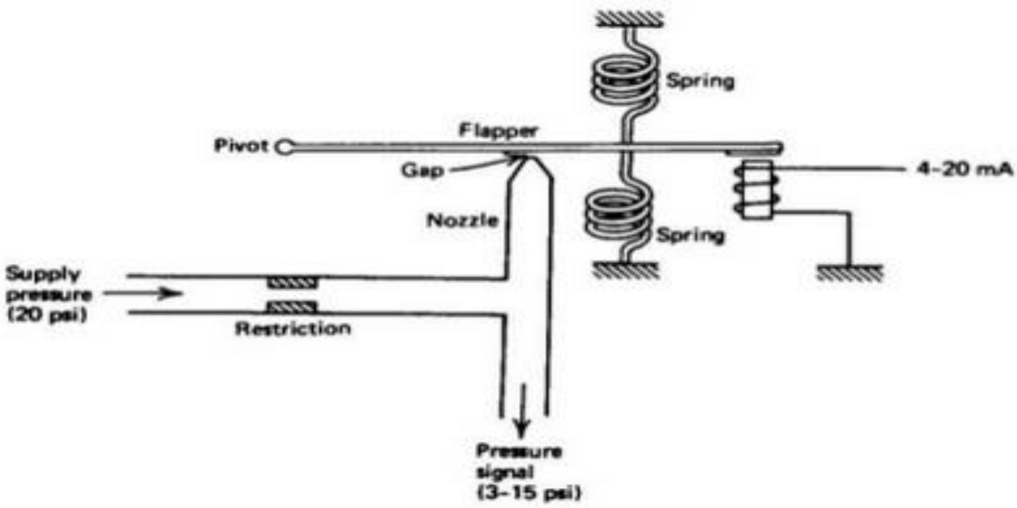
c) <u>CO Monitor</u>

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.

- **<u>Electropneumatic Convertors:</u>**

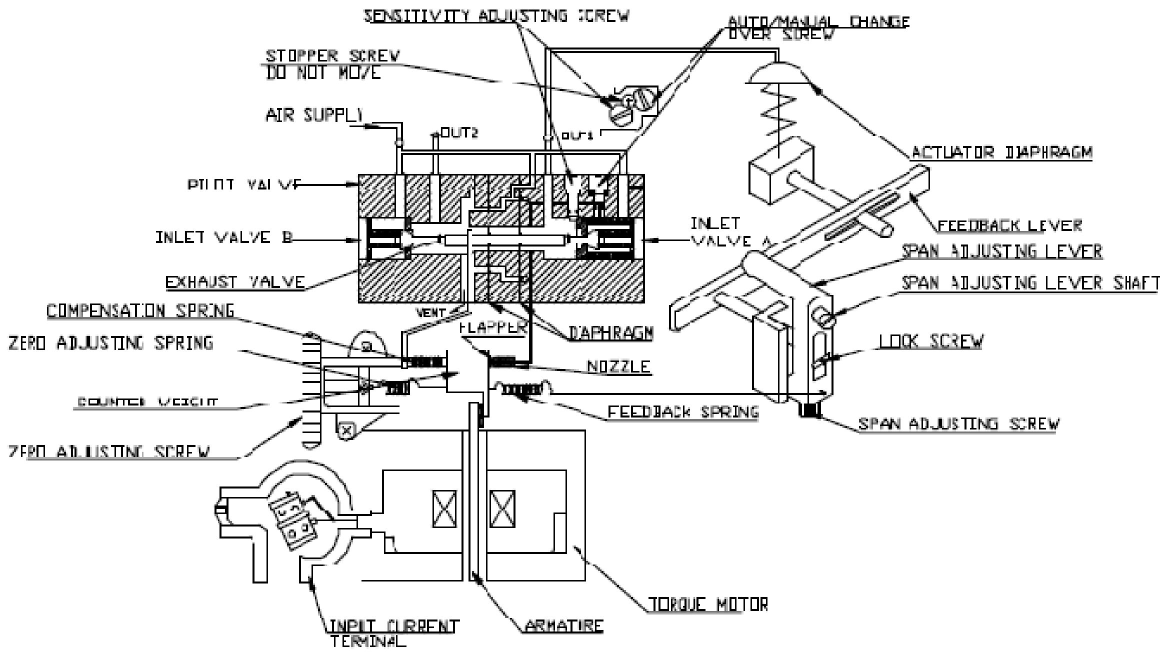
Electro-pneumatic Converts transforms current or voltage input into proportional output pressure. They are often paired with valves, pneumatic relays, and flow regulators in process control applications.
Electro-pneumatic (also known as E/P or I/P) convertors typically accept a standard current loop, 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.



- **<u>Electro pneumatic Positioners:</u>**

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

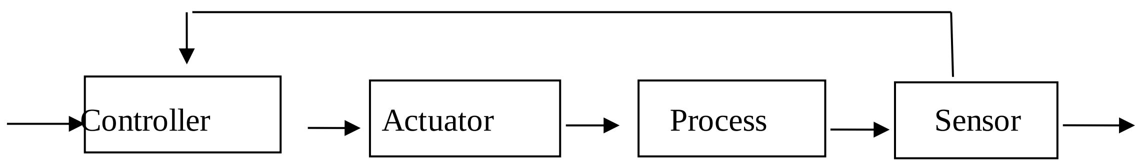
torque the counter weight/ flapper moves towards left side and the clearance between the Nozzle & the Flapper increases, due to which, the back pressure in the Nozzle decreases.



- **<u>Final Control Element/Actuators</u>**:

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.



<u>Types of Actuator:</u>

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.

- **<u>Pneumatic actuator with valve</u>**

The pneumatic valve is an air-operated device which controls the flow through an orifice by positioning appropriately a plug (Fig. 1 and 2).

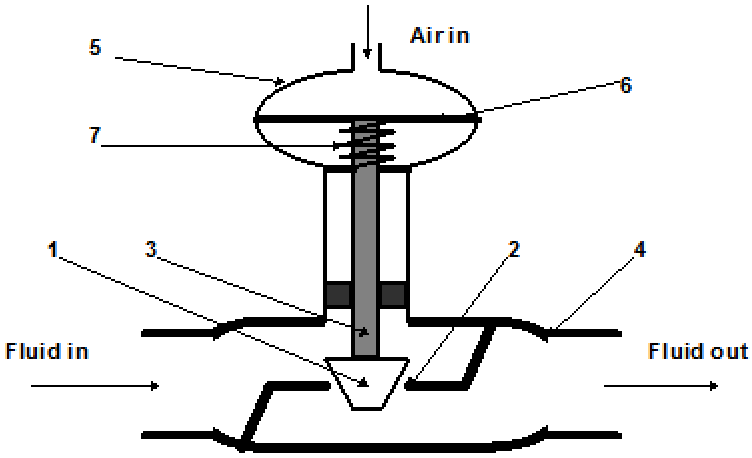


Fig.1 Air-to-close pneumatic actuator with valve

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.

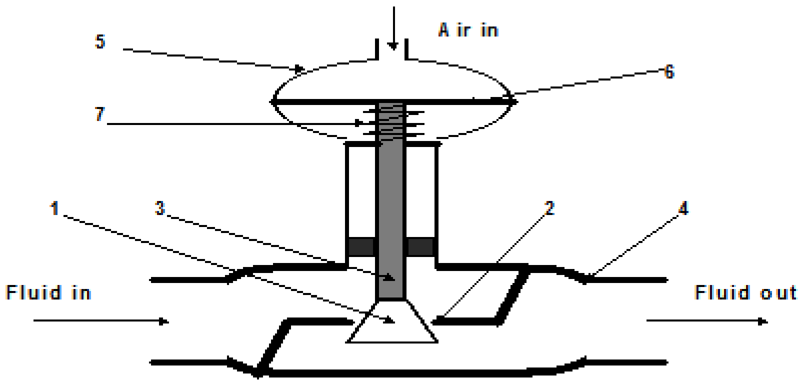


Fig.2 Air-to-open pneumatic actuator with valve

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

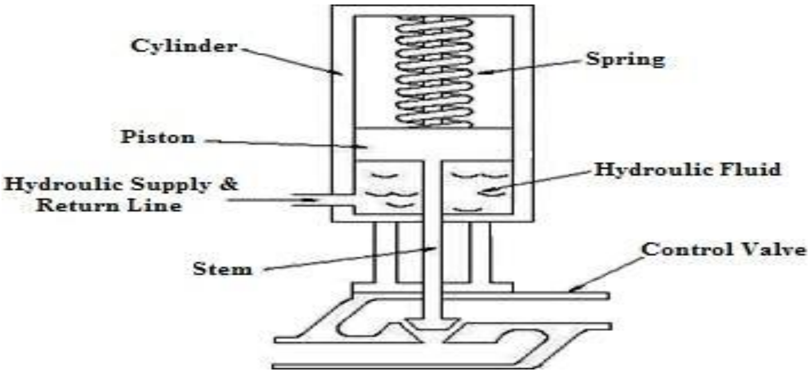


Fig. 3

- **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.

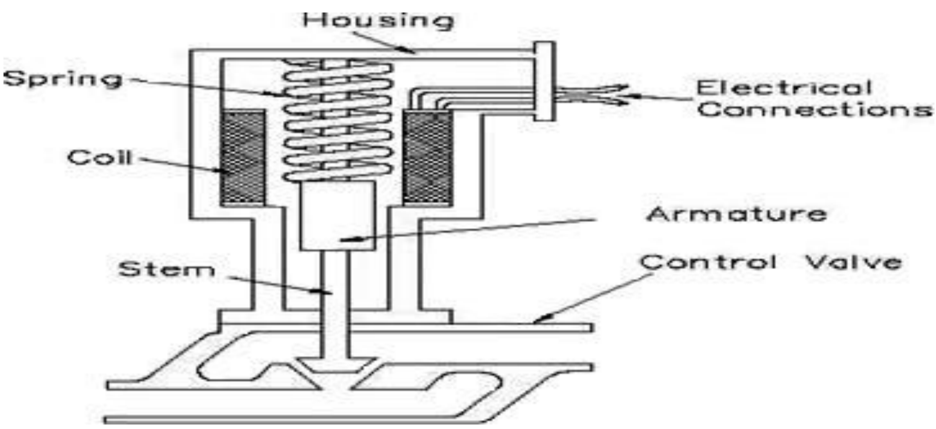
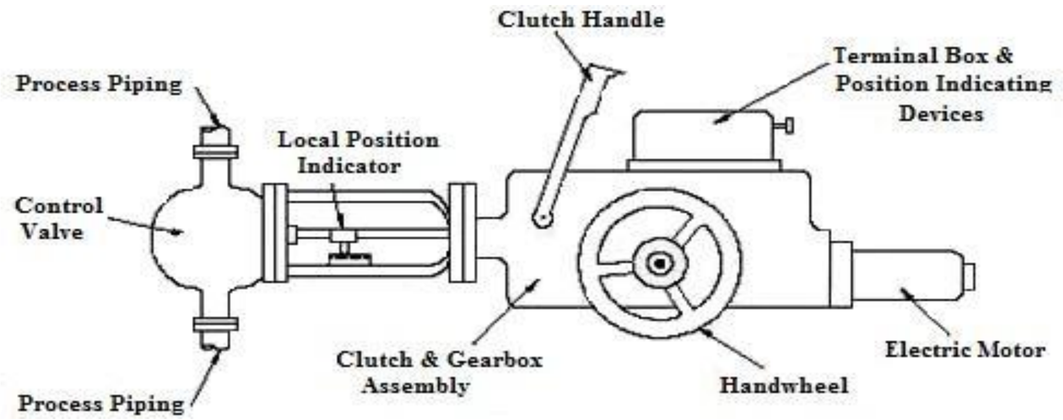


Fig.4

- **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.



- **<u>pH & Conductivity measurements:</u>**

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.

<u>New technologies in process instrumentation & automation:</u>

- **<u>Foundation Field bus based field Instruments:</u>**

FOUNDATION field bus was introduced to meet different needs within the process automation as well as a replacement for the 4-20 mA standard. Now days it is coexisting alongside other technologies such as Modbus, Profibus, and Industrial Ethernet etc. Foundation field bus is an all-digital, serial two-way, multi-drop communication System. The two related FF Communication system uses different physical media and communication speeds.

a) FOUNDATION Fieldbus H1 - Operates at 31.25 kbit/s and is generally used to connect to field devices and host systems. It provides communication and power over standard stranded twisted-pair wiring in both conventional and intrinsic safety applications. H1 is currently the most common implementation.
b) HSE (High-speed Ethernet) - Operates at 100/1000 Mbit/s and generally connects input/output subsystems, host systems, linking devices and gateways. Currently It doesn't provide power over the cable.

A typical fieldbus segment consists of the following components.

- H1 card - fieldbus interface card (It is common practice to have redundant H1 cards, but ultimately this is application specific)
- PS - Bulk power (Vdc) to Fieldbus Power Supply
- FPS - Fieldbus Power Supply and Signal Conditioner (Integrated power supplies and conditioners have become the standard nowadays)
- T - Terminators (Exactly 2 terminators are used per fieldbus segment. One at the FPS and one at the furthest point of a segment at the device coupler)
- LD - Linking Device, alternatively used with HSE networks to terminate 4-8 H1 segments acting as a gateway to an HSE backbone network.
- And fieldbus devices, (e.g. transmitters, transducers, etc.)

- **<u>Profibus PA & DP based instruments:</u>**

PROFIBUS is an international fieldbus communications standard for linking process control and plant automation modules. Instead of running individual cables from a main controller to each sensor and actuator, a single multi-drop cable (or other communication link – e.g. fiber or wireless) is used to connect all devices, with high speed, bi-directional, serial messaging used for transfers of information.

There are two different versions of PROFIBUS.

PROFIBUS DP

Simplistically, PROFIBUS DP is usually run over violet sheathed, two core screened cable, at speeds from 9.6 kbps up to 12 Mbps, using RS 485 balanced transmission. Note that the RS 485 standard allows connection of only 32 devices – larger networks may be built by adding more, electrically isolated, segments using repeaters and/or hubs.

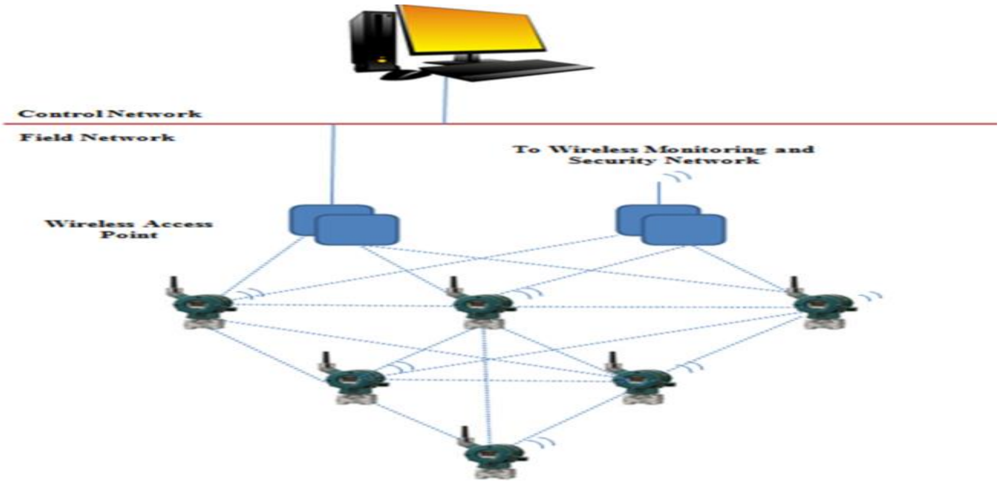
PROFIBUS PA.

PROFIBUS PA is normally run over heavier gauge, two core screened cables, often with blue outer sheath, at fixed 31.25 kbps communications speed, with near identical message formats to those of PROFIBUS DP, but here with both slave power and communications signals often carried over the same wires. PROFIBUS PA communication may be employed for systems needing intrinsically safe equipment where risks of explosion must be minimised.

- **<u>Wireless Instruments:</u>**

Wireless technologies are integrated into almost every part of our daily lives. Wireless technologies for Instrumentation offers significant cost savings such as faster commissioning, efficient maintenance when compared to traditional wired networks. Wireless instrumentation represents major cost savings through elimination of local field cable, associated field-run cable trays and ease of maintenance. The production facilities are more often subject to changes which are expensive and wireless instrumentation provides flexibility to a larger degree compared to the traditional wired instruments during such upgrades. For offshore facilities, weight savings is also a preferred advantage introduced by wireless instrumentation. In Brownfield projects, the Significance of cost savings and weight reduction by using wireless instrumentation is even higher.

Modern wireless networks offer a reliable upgrade path that even provides some unexpected benefits when compared to traditional copper networks.



10.3 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 and Logic Change, 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.

<u>**Hardware (CPU, Power Supply, Digital and Analog I/O)**</u>

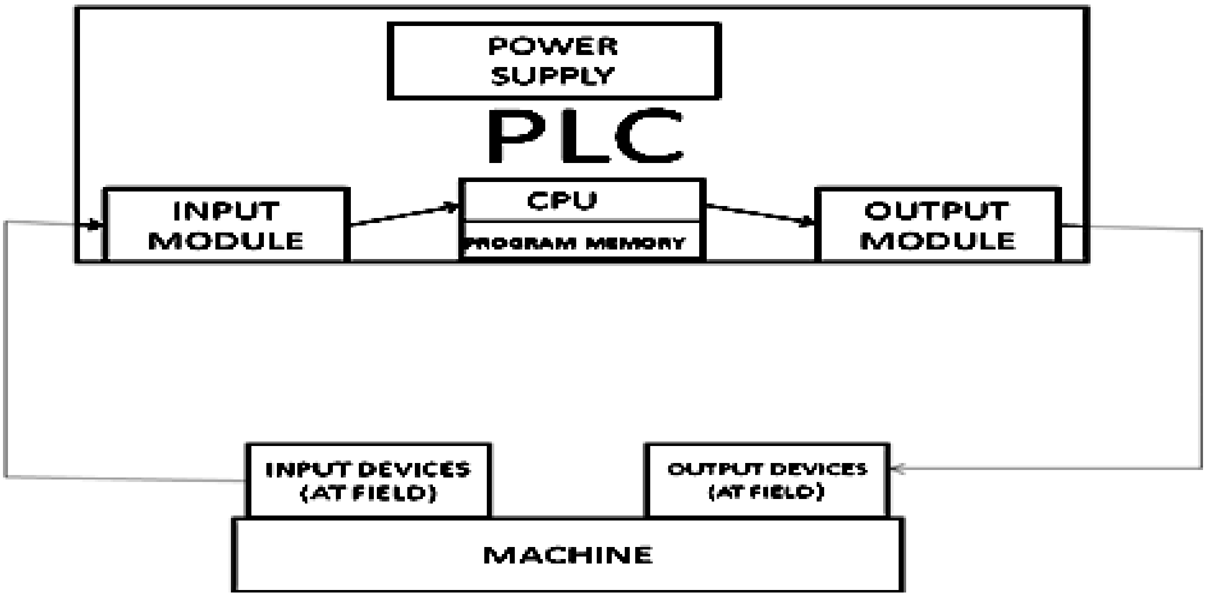
What Constitutes a PLC/DCS?

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



Functions of Various Blocks That Make PLC/DCS

Input Module

The input module acts as an interface between the field control inputs and the CPU.

The voltage or current signals generated by the input devices such as sensors, transducers, limit switches, push buttons etc. are applied to the terminals of the input module.

The input module helps in the following way:

It converts the field signal into a standard control signal for processing by PLC. The standard control signal delivered by input module could be 5V or 9V whereas the field signal received by it could be 24V DC or 230V AC.

If required, it isolates the field signal from the CPU.

Depending upon the nature of input signal coming from the field, the input module could be

Analog Input Module

Digital Input Module

The typical **analog current input modules** are 4-20 mA, 0-20 mA and **analog voltage input modules** are 0 -50mV, 0-500mV and 0-10 V.

The typical digital input modules are 24V DC, 115V AC and 230V AC.

(A **digital input** typically is like a switch and depending on the switch's open/closed status, the sensing device detects a voltage or no voltage condition, which in turn generates a logical 0 or 1, on or off, or similarly defined state. An **analog input** is a measurable electrical signal with a defined range that is generated by a sensor. The analog input changes continuously in a definable manner in relation to the measured property.)

Central Processing Unit

The Central Processing Unit or CPU consists of the following blocks:

- Arithmetic Logic Unit (ALU)
- Program memory

- Process image memory (i.e. internal memory of CPU)
- Internal timers and counters
- Flags
- The heart of CPU is its microprocessor / micro-controller chip.
- The working of CPU is fully controlled by the instructions/program stored in 'user program memory'.
- The user program directs and controls the CPU's working.
- This program is prepared by the user based on the control logic required for the control and automation task.

Output Module:
- The output module acts as a link between the CPU and the output devices located in the field.
- The field output devices could be relays, contactors, lamps, actuators, solenoid valves, etc. These devices actually control the process.
- The output module converts the output signal delivered by CPU into an appropriate voltage level suitable for the output field device. The voltage signal provided by CPU could be 5V or 9V, but the output module converts this voltage level into say 24V DC, or 115V AC or 230V AC etc.
- Thus the output module on receiving signal from the processor switches voltage to the respective output terminals. This makes the actuators (i.e. contactors, relays etc.) or indicating lights etc. connected to the terminal to come ON or OFF.
- Like input module, an output module could be an analog or digital. Typical **analog output modules** have the ratings of 4 - 20mA or 0 -10V and the **digital output modules** have 24V DC, 115V AC, 230V AC or relay output.

(A **digital output** typically consists of a switch (either mechanical as in a relay, or electronic as in a transistor or triac) that either opens or closes the circuit between two terminals depending on the binary state of the output. An **analog output** is a measurable electrical signal with a defined range that is generated by a controller and sent to a controlled device, such as a variable speed drive or actuator.)

Power Supply:
The power supply module generates the voltage required by CPU and the system.

Additional Modules:
In addition to the above listed modules, the other frequently used modules for special functions are Interface Module, Communication Processor and Intelligent Periphery or function Modules.

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.

2. Processing of Signals using Program:

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.

4. 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.

Programming of PLC/DCS

The PLC/DCS, like computer, is a software-driven equipment. How the PLC/DCS should work or control the machine or process is decided by the user through 'User Program' or 'Application Program'.

Depending upon the process control requirement the user prepares the program, i.e. 'writes the instructions'. These instructions are then stored in the'User Memory' or 'Program Memory' of CPU in the form of machine code.

The CPU sequentially reads these instructions and operates the control elements taking into consideration the input status and the program instructions. In this manner the PLC controls the process.

We can write the user program in any one of the following forms:

1. Statement List (STL)
2. Function Block Diagram (FBD)
3. Ladder Diagram (LAD).

Basic concepts of PLC/DCS Networking

Like computers in network, PLCs/DCSs can be put in a network. When many PLCs/DCSs are put in a network so that they can exchange data among themselves to control processes in a mill or shop, they are said to be in PLC/DCS network. Each PLC/DCS in the network is termed as a node and is given a unique node number.

The vast majority of PLC/DCS communications is networked through Ethernet or a propriety network and protocol with twisted pair cables or fibre optic cables. Most PLCs /DCSs are capable of handling communications with host computers, printers, terminals, and other devices.

Fiber-optic communications are gaining greater acceptance and are being used in more and more installations. Fiber-optic cable is virtually impervious to harsh environmental conditions and electrical noise. Also, these links can span extremely long distances and transmit data at very high speeds. For example, in some LAN systems, these links can transmit at relatively high speeds and span long distances before requiring a repeater. When repeaters are used, virtually unlimited distances can be achieved.

To understand the PLC's/DCSs communications versatility, let's define the terms used in describing the various systems.

CPU. This stands for "central processing unit," which actually is that part of a computer, PLC, or other intelligent device where arithmetic and logical operations are performed and instructions are decoded and executed.

I/O. This stands for "inputs and outputs," which are modules that handle data to the PLC (inputs) or signals from the PLC (outputs) to an external device.

Kbps. This stands for "thousand bits per second," which is a rate of measure for electronic data transfer. (Kilo bits per second)

Mbps. This stands for "million bits per second." (Mega bits per second)

Node. This term is applied to any one of the positions or stations in a network. Each node incorporates a device that can communicate with all other devices on the network.

Protocol. Network protocols define the way messages are arranged and coded for transmission on the LAN(Local Area Network). The following are two common types.

Proprietary protocols are unique message arrangements and coding developed by a specific vendor for use with that vendor's product only.

Open protocols are based on industry standards such as TCP/IP or ISO/OSI models and are openly published.

Many PLC/DCS vendors offer proprietary networking systems that are unique and will not communicate with another make of PLC/DCS. This is because of the different communications protocols, command sequences, error-checking schemes, and communications media used by each manufacturer.

RS232. This is an IEEE standard for serial communications that describes specific wiring connections, voltage levels, and other operating parameters for electronic data communication

Serial. This is an electronic data transfer scheme in which information is transmitted one bit at a time.

Serial port. This the communications access point on a device that is set up for serial communications.

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.

DCS typically uses custom designed processors as controllers and uses both proprietary interconnections and communications protocol for communication. Input and output modules form component parts of the DCS. The processor receives information from input modules and sends information to output modules. The input modules receive information from input instruments in the process (a.k.a. field) and transmit instructions to the output instruments in the field. The field equipments include Pressure Transmitters, Resistance Temperature Detectors (RTD), Valves, Flow meters etc.

Computer buses or electrical buses connect the processor and modules through multiplexer or de-multiplexers. Buses also connect the distributed controllers with the central controller and finally to the Human-Machine Interface (HMI) or control consoles.

A typical DCS consists of functionally and/or geographically distributed digital controllers capable of executing from 1 to 256 or more regulatory control loops in one control box. The input/output devices (I/O) can be integral with the controller or located remotely via a field network. Today’s controllers have extensive computational capabilities and, in addition to proportional, integral, and derivative (PID) control, can generally perform logic and sequential control.

DCSs may employ one or several workstations and can be configured at the workstation or by an off-line personal computer. Local communication is handled by a control network with transmission over twisted pair, coaxial, or fiber optic cable. A server and/or applications processor may be included in the system for extra computational, data collection, and reporting capability.

DCS allow centralized configuration from the operator or engineering console in the control room. You can change programming offline, and download without restarting the system for the change to be effective.

The typical DCS has integrated diagnostics and standard display templates that automatically extend/update when your database changes. This database is central to the system. DCS have user-friendly configuration tools, including structured English, control block libraries, SFC (sequential function chart). A DCS allows for more flexibility in growing a system and additional functionality can be added and the for the most part, the existing working system can be left alone.

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

Chapter - 11

COMPUTERS

11.1 Introduction to 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

a) 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

b) Types and Classification

- Desktop or Laptop (notebook) Personal Computer
- Palmtop or Personal Digital Assistant (PDA)
- **Workstation** - A powerful desktop computer with enhanced capabilities for performing 3D Graphics, game development etc
- **Server** - A computer that has been optimized to provide special services to other computers over a network. E.g., Database-Server, Application-Server, Proxy-Server, http-Server, Mail-Server, File-Server etc
- **Mainframe** – belonging to early days of computing processing millions of transactions every day.
- **Supercomputer** – comprise of multiple high performance computers working in parallel as a single system. The best known supercomputers are built by Cray Supercomputers.

c) Computer Characteristics and Advantages

- 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 up to 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 Organization.

d) 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.

e) Hierarchical System of Computers in Steel Industry Level-I to IV

A typical manufacturing digital control system has the following levels and achieves the defined functions-

- Level I consisting of Programmable Logic Controller (PLC), Distributed Control System (DCS) and Instrumentation Data Acquisition / control system achieves Direct Control

- Level II consisting of supervisory monitoring and control, achieves process control and optimization. Example: Supervisory control and data acquisition (SCADA)
- Level III consisting of Plant level computer achieves production planning and control, maintenance and materials planning. Example: Manufacturing execution systems (MES)
- Level IV consists of corporate computer and is used for business and finance planning. Example: Enterprise resource planning (ERP)
- Communication exists between same level computers and higher level / lower level computers

11.2 Hardware and Software Concepts

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 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.

  Types of ROM

  i) Mask-Programmed ROM (MPROM) – Programmed at the factory.
  ii) Programmable ROM (PROM) – Can be custom-programmed by the user (once) using special circuitry.
  iii) Erasable Programmable ROM (EPROM) – Can also be programmed and erased by the user using ultraviolet light and special circuitry external to the computer.
  iv) Electrically Erasable PROM (EEPROM) – Can be erased and reprogrammed by special circuitry with in the computer.

- **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

  Types of RAM

i) Static RAM (SRAM) – stores binary bits in such a manner that the bits remain in RAM as long as power to the chip is not interrupted
ii) Dynamic RAM (DRAM) – requires the stored data to be refreshed, or rewritten, periodically to keep it from fading away. As a matter of fact, each bit in the DRAM must be refreshed at least once every 2 milliseconds or the data dissipates
iii) Synchronous DRAM (SDRAM) – runs in synchronization with the memory bus. Most Pentium or Celeron systems purchased in 1999 have SDRAM.
iv) Double Data Rate RAM (DDR RAM) – is a type of SDRAM, difference between SDRAM and DDR RAM is that instead of doubling the clock rate it transfers data twice per clock cycle which effectively doubles the data rate.

- 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 thin layer aluminium applied to the surface. Information is created in the CD by creating pits on the surface by laser. Any data file (for example 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, write 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 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.

Digital Computer Data Representation

- Integer data like whole numbers are stored in blocks of 4 bytes or 8 bytes. The larger storage is required for large numbers
- Real or floating point is generally stored in 4 byte or 8 byte blocks which is split up into mantissa and exponent portions
- Character data is generally stored in ASCII (American Standard Code for Information Interchange) based on a universal conversion table. Unicode standard is required for using characters in other languages like Hindi, Tamil etc

11.3 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 Mill

Application Integration using ERP package

- Enterprise Resource Planning (ERP) is a software system which is based on open industry standards. This system is centrally deployed and globally accessed. The database is so designed that there is no duplication of data and there will be application to application integration. Generally ERP implementation requires change in infrastructure like hardware, network, disaster recovery as well as training and adoption to the new architecture. One example of ERP software package is SAP
- ERP addresses all the information needs of an enterprise with the process view of the organization to meet the organizational goals and integrates all the functions of the enterprise.
- Along with ERP, Business Process Re-engineering is implemented through elimination of non-value adding processes, simplification and automation of business processes
- Some of the benefits of ERP are best practice solutions with customization, enterprise-wide information sharing, better supplier - customer interactions, optimum utilization of resources and improved profitability

11.4 Operating Systems and Computer Architecture

- 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.

- 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.
- Examples of Common Operating System are MS-DOS, Windows, Unix, Linux, and Solaris.

Host-Centric, 2-Tier and 3-Tier Program Implementation

- In-house developed programs used to be developed and stored in a server and dumb terminals on serial connection were used for operator interface. Such systems are known as host-centric. One example is SUN-Server machine running on Solaris Operating system with Oracle RDBMS and text based Forms for Finance applications
- With the advent of Windows operating system, 2-Tier architecture (client / server) was introduced where Server and clients work in LAN. Example: Supervisory Control And Data Acquisition System (SCADA).
- With advancement of internal networking of steel plants, web based programs are developed using the three tiers i.e., application server, database server and client PC. The program residing in the Application Server is executed by the client by using a web browser like Internet Explorer with appropriate web-address (URL- Uniform Resource Locator) (e.g., http://10.135.0.5/myweb/homeconew.asp). Internal mail system, , departmental home pages are examples of this system

Online, Offline and Real-Time Processing

- Batch jobs (or offline jobs) are set up so they can be run to completion without human interaction, with all input data pre-selected through command line or program parameters. Example of a batch job is pay slip preparation for all employees
- "Online" or interactive jobs are those which prompt the user for input. Example of online jobs are 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

Boot Procedure and Working of Computer

Bootstrapping is the process of starting up a computer from a halted or powered-down condition. When the computer is switched on, it activates the memory-resident code which resides on the CPU board. This procedure is referred to as bootstrapping, booting or cold boot.

Bootstrapping typically consists of the following steps:

1. Self-test
2. Identify boot-device (normally hard disk), System start, device configuration

3. Do first time jobs like setting computer-name, file consistency check and connecting network interface
4. Bring up the system for user operation

Shutdown of Computer

- A computer should be switched off only after doing a proper shutdown. Commands for shutdown are available in every operating system. The shutdown procedure stops the running jobs and closes the open files in a systematic manner such that there is no bad data in computer. A sudden power off of any computer will lead to inconsistent disk data and corruption of Operating System files.

11.5 Computer Language and Application Software

Programming Concepts

- To solve a problem, we need to evolve an algorithm, which is a sequence of finite instructions.
- Algorithm can also be expressed graphically as a flow-chart.
- High level Programming language is a precise notation used to express algorithms

Program Development Lifecycle:

The various steps for implementing application software are as follows:

- Analyze user requirements
- Design a solution approach and software framework
- Develop database structure and program code
- Test for quality and deploy the solution / implementation
- Post Implementation corrections
- Continuous improvement and supportive maintenance

Examples of High Level Computer Languages

- Higher level programming Languages used by the steel industry are FORTRAN, C-Language, Visual-BASIC, COBOL, C++, JAVA, C#, Visual C++ etc.
- For database related activities (like create table, select, update, delete, insert record), SQL (Structured Query Language) is mainly used.

11.6 Data Centre Management

Data Storage in Central Server

- Data Centre is a secured room that houses server computers and network equipments. Generally these air-conditioned rooms have Uninterruptible Power Supply (UPS) with redundancy. The data center is normally manned 24x7. All the user programs and the data are residing in the hard disks of central servers in data center. The hard disk is a direct-access device, which means that the location of storage can be directly accessed in a short time. The role of the Data Centre staff is to troubleshoot technical problem and coordinate with concerned agency for resolving problems.

Backup Devices like Magnetic Tape & DAT

- In addition to coordination, the Data Centre personnel are also responsible for certain data-processing batch jobs, printing jobs and central data backup jobs. Most of the data that we deal with falls into transaction data and master data. It is necessary to keep latest copies of these in a different media for minimizing data loss in case of main server hard disk failure or any eventuality in the data centre.
- The backup of data are normally done in magnetic-tape and Digital Audio Tape (DAT). In these devices the data gets written in a sequential manner in combination of full data in the beginning and incremental data backups done at regular intervals. Magnetic tape and DAT media are portable and can be stored in a different safe location.

Data Restore Procedures for Recovery

- In case of server hard disk failure, the data which are stored in full data and incremental backups (in magnetic tape or DAT) are imported into the new database so that we can revert back to a stable system on the hard disk corresponding to the latest incremental backup.

11.7 Network and Connectivity

Local Area Network (LAN), Wide Area Network (WAN)

- A local area network (LAN) is a computer network covering a small geographic area, like an office building. The major characteristics of LANs are the higher data transfer rates, smaller geographic range, and lack of a need for leased telecommunication lines.
- Wide Area Network (WAN) is a computer network that covers a broad area. WAN normally is a network that uses routers and public leased telecommunication lines.

Cables and Network Equipments like Router, Modem, Switch etc

- Different medium is used for connection, such as telephone cable, co-axial cable, twisted pair cable (e.g. UTP – Unshielded Twisted Pair, STP – Shielded Twisted Pair), optical fiber cable (OFC- having glass as the communication medium) and radio waves are used for wireless communication.
- An IP address (Internet Protocol address) is a unique address that is given to each network node like PC and network equipment in order to identify and communicate with each other on a computer network. Some IP addresses are intended to be unique within the scope of the global Internet, while others need to be unique only within the scope of local network. Ipconfig command helps in finding out the IP address of a PC in the network
- A router is a computer device whose function is routing and forwarding of messages. Router connects two or more logical networks which have different addresses.
- A network switch is a computer networking device that connects network segments, generally within a sub-network. For example upto 16 number of PCs in an office or a shop-floor can be connected by means of a 16 port network switch. Each PC will have to be wired upto the network switch using network cable

- Modem (modulator-demodulator) is a device that is used to transmit computer data over a long distance generally using communication cables. The data rate is generally specified in bps (bits per second). One example Internet connection at home using telephone line and modem.

Ports for Network Connectivity like Serial, Parallel, Ethernet, USB ports

On a Personal Computer we can find the following communication ports

- Serial Port: this is normally a 9-pin or 25-pin port which helps in communicating with serial devices like weigh-bridge controllers, modems etc. The data in serial communication flows in a serial fashion, one bit following the other.
- Parallel Port: this is normally a 25-pin port on the PC for parallel devices like Dot Matrix Printer using special cable. The other end of the cable is having special connector and clip for printer. Here the communication flows parallel.
- Ethernet Port: Most of the current PCs have a network interface card that has an Ethernet-port having RJ-45 standard cable connection. Generally this cable is connected to network switch
- USB Port: A number of USB (Universal Serial Bus) ports are provided on the Personal Computer for connection of devices like Printer, keyboard, mouse, camera, pen-drive etc

11.8 Introduction to Windows

Start Windows, Moving through Windows

- When PC is powered on, Windows operating system comes up after proper username, password as a GUI (Graphical user Interface). We need mouse as well as keyboard to operate. Windows desktop has icons displayed for disk access, program running etc
- Several jobs like opening Word document, EXCEL document, web-access can be run simultaneously. However we use only one screen at a time. Each of these programs is visible at the bottom of the screen in the Task Bar. Switching over from one program to another can be done by clicking on required task bar item

Maximize, Minimize, Exit Windows

- Each program will have minimize, maximize and close buttons on right side top of screen. Normally menu items like File, Edit, Insert Format, Help etc will be available

File Management

- Folders are places in the file system that contains more folders and files. Files are the storage place for data. Files can be created as new, deleted, copied, moved or re-named. Data in two or more files can be cut / copied and pasted. File has specific format with specific extension like .doc/.docx, .xls/.xlsx, .ppt/.pptx depending on the type of data that is stored
- It is the responsibility of each user to backup their data in CD or pen-drive

Using Floppy, CD, Pen-Drive, Printer

- Floppy disk can be used to store data up to 1.44 Mega Byte by using copy command. However this is very low capacity and is no longer useful
- We can write data once in CD-R and several times in CD-RW media. For this we need to have CD write drive in our PC. Generally for writing into CD (known as burning) we use the product software provided like Nero Express for CD burning
- Generally pen-drives are automatically recognized by the operating system when they are inserted into the USB drive and the file system is displayed. At this point, copy, delete operations can be done. It is necessary to safely close the device by software before physically taking out from USB port
- Printers have their driver-software supplied in driver-CD and this software needs to be installed in our PC. When we want to print from WORD, EXCEL etc the Operating System uses the driver software to communicate with the printer

11.9 Office Automation software (MS Office used in SAIL)

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 POWER POINT

- 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

11.10 Database Concepts

Data and Information

- Number, character, images that can be accessed by humans and computer, capable of getting stored and processed by computer is known as data. Data is in raw form without having meaning in itself. For example 12345, 10000.0, 1000.0 are various forms of raw data
- Data when undergoes processing becomes meaningful information. Information is data that has been given meaning by way of relational connection. For example Personal-No= 12345, basic-pay = Rs. 10,000.0, DA = Rs. 1,000.0 is information

Structured Storage of Data in Rows and Columns

- A computer database is a structured collection of records of data that is stored in a computer system. Database describes the objects and the relationships among them. A database relies upon software to organize the storage of the data and to enable us to extract desired information. The data is stored in such a way that they are independent of the programs that use them. Each group of data items is generally stored in a database table which has fields

11.11 Intranet and Internet

Host-Centric, 2-Tier and 3-Tier Program Implementation

- In-house developed programs used to be developed and stored in a server and dumb terminals on serial connection were used for operator interface. Such systems are known as host-centric. One example is SUN-Server machine running on Solaris Operating system with Oracle RDBMS and text based Forms for Finance applications
- With the advent of Windows operating system, 2-Tier architecture (client / server) was introduced where Windows Server and clients were used in LAN. Supervisory Data Acquisition system is an example of this system
- With advancement of internal networking of steel plants, web based programs are developed using the three tiers i.e., application server, database server and client PC. The program residing in the Application Server is executed by the

client by using a web browser like Internet Explorer with appropriate web-address (e.g., http://www.sail.co.in). Internal mail system, Oracle 9i / 10G systems are examples of this system.

Definitions of 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

Web Based Search Engines and Web Surfing

- 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. One example of web browser is Internet Explorer
- 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, which 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

o SAIL :	www.sail.co.in
o Indian Railway information:	www.indianrail.gov.in
o Internet railway booking:	www.irctc.co.in
o The Hindu newspaper	www.thehindu.com
o 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

11.12 Introduction to ERP

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.

Some of the benefits that are achieved through ERP are

Tangible benefits

- Integration
- Helps reduce operating costs as a result of improved coordination between functions
- Facilitate day-to-day management
- Improves productivity of process/personnel
- Lead time reduction

Intangible benefits

- Organisational transparency increases
- Faster/Accurate Access to Information
- Supports Strategic Planning
- Uniform reporting according to global standards
- Accessibility

Important modules available under SAP

1. FICO (Financial Accounting and Controlling)
    a. FI module containing General Ledger, Accounts Receivable, Accounts Payable, Tax and Financial Reporting, Asset Accounting
    b. CO module consisting of Cost Center Accounting, Project Accounting, Cost and Revenue Planning, Product Costing, Profitability Analysis
2. PP (Production Planning) consisting of Production Planning and execution, annual business planning / long term planning, monthly production planning, weekly production planning, daily production planning, production scheduling in different departments taking into consideration capacity availability, tracking of production orders / process orders, booking consumption of materials at each stage, reporting production at shift ends / day end, other processes supporting operations etc.

3. PM (Plant Maintenance) module includes functions of decentralized maintenance departments and also centralized services departments. Provides support to maintenance sections of different departments. Activities like planning of preventive maintenance, recording breakdown maintenance, condition based maintenance, outsourcing of some maintenance activities etc.
4. SD (Sales and Distribution) module containing Order Management, Despatches, Pricing and Rebates, Discounts, Billing, Sales Information system, Real Estate Management
5. MM (Material Management) module consisting of Procurement, Receiving, Inventory Movement, Vendor Evaluation, Invoice Verification. SRM (Supplier Relationship Management) is an internet dependent module that caters to the tendering process and online interaction with vendors.
6. QM (Quality Management) module supports tasks associated with quality planning, quality inspection, quality certification (example: Test certificate) and quality control throughout an enterprise. It sets the specifications for quality and standard testing procedures. It also stores the quality data for raw materials, goods-in-process and finished goods.
7. PS (Project System) module having Project Registration, Project Budget Management, Project Schedule Control, Project Cost / Resource Management, Project Accounting, Project Reporting.

11.13 Do's and Don'ts

Computer Standard Operating Procedures

Do's

- Input power supply with proper earthing is very essential. It is recommended 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 giving 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**
- **Don’t switch off UPS while PC is working**

Meaning of Computer Virus and its Effect

- Computer viruses are unwanted 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 load/install in our computer, the latest version of antivirus software. 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

Computer Hardware Maintenance

It is essential that we know about the parts of our computer system and also follow the Standard Operating Practices (SOPs). However, the computer maintenance is normally carried out by a computer department. Hence as a user we have to register compliant with the maintenance agency and get their assistance to rectify the problem

11.14 Introduction to Industry 4.0

Industry 4.0 refers to a new phase in the Industrial Revolution that focuses heavily on interconnectivity, automation, machine learning, and real-time data. Sometimes it is referred to as smart manufacturing. It is basically a combination of physical production and operations with smart digital technology, machine learning, and big data to create a more holistic and better-connected ecosystem for companies that focus on manufacturing and supply chain management. This can also be called as Cyber Physical System (CPS).

While every company and organization operating today is different, they all face a common challenge—the need for connectedness and access to real-time insights across processes, partners, products, and people.

Understanding difference between Digitization, Digitalization and Digital Transformation: -

- Digitization refers to representation of data in digital format.
- Digitalization is linked with improvement of product, automation of process, simplification of communication, etc. This will result in saving money for the Company.
- Digital Transformation is improving business outcomes.
    - This will earn money for the company in terms of improved sales, customer experience, etc.
    - The various outcomes will range from engaged customers & suppliers, empowered employee, optimized operations, transformed products and safer environment.
    - The impact will be in terms of increased sales, optimized costs, asset availability, reduced defects, and secure workplace.

Digital Transformation is basically the transition to Industry 4.0.

Interoperability, Virtualization, Decentralization, Real-time capability, Service orientation, and Modularity are six **Design Principles** of Industry 4.0.

Some of the **well-known tools/technologies** of Industry 4.0 are –

- The internet of things (IoT)
- The industrial internet of things (IIoT)
- Cyber-physical systems (CPS)
- Smart manufacture.
- Smart factories.
- Cloud computing.
- Cognitive computing.
- Artificial intelligence.

Some of the **proof of concept of Industry 4.0** in Steel Sector-

- Use of data analytics to predict failure of equipment using artificial intelligence and taking preventive measures using machine learning.
- Usage of technology to get additional information about viewing parts by leveraging Augmented Reality.
- Modelling, control, and big data processing in production processes to improve product quality and reduce energy consumption
- Creating a digital twin of processes

Chapter – 12

MINING

12.1 Introduction

Mining is the process of extracting valuable minerals or other geological materials from the earth.

Mining involves a number of stages which occur in a sequence. This sequence of stages is known as the mining sequence. The mining sequence covers all aspects of mining, including: prospecting for ore bodies, analysis of the profit potential of a proposed mine, extraction of the desired materials and, once a mine is closed, the restoration of all lands used for mining to their original state

To develop mines we have to understand the geology of the area.

The formation of ore body is important in this respect. An ore is considered to be an aggregation of minerals from which a metal or metallic compound can be recovered economically on a commercial scale. When the percentage of metal or valuable in the ore is too low for profitable recovery, the rock ceases to be an ore.

A mineral may be regarded as a naturally occurring chemical compound having a definite chemical composition and crystal structure. The physical properties of minerals play the most important role in the economic processing of various ores.

Physical properties of minerals:

The physical properties of minerals can be determined without the use of chemical tests. They depend upon the kind and arrangement of atoms in their crystal structures. The various physical properties of minerals include transparency, luster, colour, specific gravity, hardness, cleavage, fracture, magnetic properties, electrical properties, radioactive and optical properties.

<u>Transparency</u>

This term used to describe the case with which we can see through a mineral. Three terms for transparency are in common use i.e. opaque, transparent & translucent. The opaque minerals are those through which no light can be seen. Transparent minerals are those which can be seen through clearly. Translucent minerals are those through which a little light can be seen.

<u>Luster</u>

This may be defined as the amount and quality of the reflection of light from mineral surface. The luster of mineral refers to its surface appearance.

Colour

In most cases the colour of mineral is due to absorption of certain wavelength of light energy by the atoms making up the crystal. The remaining wavelengths of the light that are not absorbed give the sensation of colour to the eye.

Luminescence

This refers to the emission of light by a mineral which is not the direct result of incandescence. Luminescence in most minerals is faint and can be seen only in the dark. Minerals which luminance during exposure to ultraviolet light and x-rays, are called fluorescent.

Specific Gravity

Specific gravity of a particular mineral is practically constant, it may vary a little with the presence of some impurities. The difference in specific gravity affords one of the surest means of separating minerals from each other and has been put to practical use. Simple washing in water affects an efficient separation of gold grains from quartz sand, whereas use of heavy liquids affects the separation of lighter coal from heavier shale. Difference in specific gravities forms the basis of a class of ore-dressing process known as 'gravity concentration method'.

Hardness

This may be defined as the ability of a mineral to resist scratching. This is different from the ease with which it can be broken. Diamond is one of the hardest material known, but it can be shattered easily. Like other physical properties, the hardness is dependent on the kinds and arrangements of atoms in mineral structures. The basis of the test is a set of minerals selected by the Austrian mineralogist, F. Mohs to which all other minerals could be compared to determine relative hardness. The scale numbered 1 to 10 in order of increasing order of hardness became known as Mohs Scale of Hardness, and is very useful as a means for identifying minerals or quickly determining hardness. The scale is not a linear scale, but somewhat arbitrary

Mohs scale of Hardness

Hardness	Mineral	Associations and Uses
1.	Talc	Talcum powder
2.	Gypsum	Plaster of paris. Gypsum is formed when seawater evaporates from the Earth's surface.
3.	Calcite	Limestone and most shells contain calcite.
4	Flourite	Fluorine in fluorite prevents tooth decay.
5	Apatite	Apatite is an inspirational stone. It develops psychic abilities and spiritual attunement. Use it to aid communication and self-expression. Apatite is most often seen in blue, but also can be found in brown, pink, yellow, green (from Spain called asparagus stone) and a rare variety of violet. Apatite heals bones, aids absorption of calcium, helps cartilage, bones, teeth and motor skills. Relieves arthritis, joint problems. Overcomes hypertension
6	Orthoclase Feldspar	Orthoclase is a feldspar, and in German, "feld" means "field".
7	Quartz	Quartz is the most common mineral found on the surface of the Earth. A significant component of many igneous, metamorphic and sedimentary rocks, this natural form of silicon dioxide is found in an impressive range of varieties and colours.
8	Topaz	The November birthstone. Emerald and aquamarine are varieties of beryl with a hardness of 8.
9.	Corundum	Sapphire and ruby are varieties of corundum. Twice as hard as topaz.
10	Diamond.	Used in jewelry and cutting tools. Four times as hard as corundum

Logging

The purpose of logging is to determine the thickness of ore body/coal seam and also to ascertain the quality of the ore/coal. For this purpose a bore hole is driven down the hole through core drilling and core is recovered which is placed in a core box with utmost care. The geologist/mining engineer measure the core length of the earth crust carefully and a picture is drawn on paper of the length and location of the ore body/coal seam. Simultaneously ore/coal seam sent to laboratory for quality analysis. This provides the basic information for the Geological and Assay database for any mining software like surpac, datamine to be used for the Reserve estimation, establishing average quality, Ore modeling, preparation of the mine plan and finally the mine scheduling to produce targeted quantity of Ore with stipulated quality.

Bench wise excavation plan

To meet the targeted production with desired quality a systematic and scientific bench wise excavation plan is prepared synchronizing the overburden removal to expose sufficient ore benches for the desired production and excavation from different ore benches of different ore quality which can be blended at the crusher level for the desired final product for dispatches to the steel plant

Reading of excavation plan

The size and shape of topography where mining is to be carried out is depicted in a mine surface plan which is drawn on a suitable scale together with every surface features in a schedule manner called mine surface plan. The various surface features are shown according to a specified schedule under the statute. Excavation plan can be prepared on the mine surface plan or separately on mine working plan showing all the mine working benches/faces clearly demarcating the area with the length and breadth of the planned excavation in particular stipulated period. Normally excavation plan is prepared every month with respect to the annual excavation plan under five year Mining Scheme approved by Indian Bureau of Mines. Excavation plan can vary with deviations in the requirements, but annual planned quantity shall not be increased more than the quantity stipulated in the mining scheme without the permissions of IBM.

Short & Long term excavation plan

Long term plans

All the long term excavation plans have to be made in line with the mines plans, mining scheme and the mine closure/progressive mine closure plans approved by IBM.
Progressive Mine Closure Plan is the essence of mine planning in which the planning starts from the final pit limit at the end of mine life with systematic reclamation and rehabilitation so that at the end it is restored to the original landform as far as possible.
Mine Plan is the plan of systematic excavation plan for the applied lease period normally for 20 years with due considerations of the Environmental protection and the mineral Conservation. There are always possibilities of the deviations from the mine plan if there are shortages from the target or any changes in demands.
Mining Schemes;- To accommodate the deviations from the original mine plan a Mining Scheme is prepared after every 5 years of the Mine Plan period.. Five year mining scheme shows the modified mine excavation plan with clear details of each year excavation. All the plans are prepared for mining of ore body/coal keeping in view the objective and mission of our Company. In long term plan Govt. of India five years plan in the development of society & our Country are also taken care of. For example vision 2025 have been drawn where steel production is augmented to 100 million tones in India.

Short term plans

In order to reach the goal and to fulfill the objective of the Organization based on the long term excavation plan like the mine plan and the mining schemes, short term plan is prepared for annual/monthly excavations where every detail is worked out.

Waste dump/making of waste dump plan/slope stability/illumination

Waste dump is defined as stacking of broken waste material which do not conform to economic value but the volume is so high that a careful assessment and planning of waste dump is required which plays a vital role in running an open cast mine. It should be stacked on non mineralized area on a firm ground or old mine working within the lease. It should be so planned that re-handling of waste dump is minimum or not at all required i.e. away from ore body/coal. With the present environment concerns dumping in the hill slopes is not being permitted by the forest as well as the pollution control departments. It is therefore desired that mine excavation should be planned in such a way that excavated mine working is available for back filling of the old mined out area from where entire mineral has been exploited.

. The waste dump can be made in different segment in 30m height so that slope failure is minimum or not at all possible. For this purpose a horizontal length all along the periphery is left. The draw angle i.e. the angle of repose of waste material is normally kept at 33.5 degree from vertical to avoid slope failure. Waste dump are being manned by mining sirder /mining mate & dump man and frequented by shift I/c. With the help of dozer/pay loader a berm should be prepared all along the dump yard in the direction of extension of dump. Regular water sprinkling to suppress the dust should be done. While designing a dump utmost care should be taken that the waste is not carried away by the rain water into the natural water course or the river stream during monsoon.

While breaking a new area if any top soil is available it should not be dumped with the waste materials at the waste dump but it should be stacked separately for the future use for plantation in the process of mine rehabilitation.

If the mine operation continue in the dark hours the dump shall be adequately lighted to facilitate the free flowing movement of dumpers. Minimum illumination level as per Mines Regulation, illumination to the level of 3.5 lux is required to be maintained.

Equipment planning/Selection of equipment

The selection of equipment for opencast mine is dependent on the size and shape of ore body, ore reserves, volume of production desired and the time frame to close the mine. For example if a deposit is highly erratic and selective mining is required, it has to be worked manually. In a small deposits higher capacity of equipments are not desired whereas in big deposits where large excavation is required, higher capacity equipments are effective and economical in operation. So selection of equipment is an important phenomenon for open cast mine. The following combinations are suitable and normally used as per the rocks/minerals to be excavated.

a) Excavator dumper combination
b) In pit crusher belt conveyor combination
c) Bucket wheel excavator
d) Drag line

Bucket wheel excavator is a large capacity continuous excavator which is used in soft formations for directly excavating material from the mine faces and transporting to the desired locations through the conveyors. It is also being used in some mines and the ore handling plants at the steel plants for reclamation of the lumps/fines of the Iron ore.

Dragline is a giant excavator which can be used for directly side casting the overburden to large distances .It can be effectively used also for temporary shifting of the overburden for mining and backfilling the mined out area after extraction of the entire deposit where the thickness of the deposit are not very thick..

Equipment

Equipments required for opencast mining :

a) Excavators : Shovel/ Excavator (9.5cum,7.5 cum, 4.5 cum), Front end loader, Back hoe
b) Dumper: 35t capacity, 50t capacity, 85t capacity, 100t, 120t capacity etc.
c) Drill : Electric driven, Diesel driven
d) Dozer: D-155,D-355,D-510
e) Grader
f) Water sprinkler

Major Manufactures of Earth Moving Equipment

BEML, Caterpillar, TELCON, L&T – Komatsu, AtlasCopco etc

Combination of equipment

Combination of equipment is dependent on the volume of production required with a targeted quality. In all the SAIL mines except the manual mines, excavator-dumper combination is used for excavation and the transport of ore to the crushing and the screening plant large dia drills from 100mm to 200mm are used for drilling. Dozers and the road graders are used for leveling at the mines and the mines roads respectively. Big water sprinklers are used to suppress the dust in the mines which are very essential because no other operation in the mine is possible unless the dust is suppressed.

12.2 Mines Operation

Drilling/Placement of drill/Sub grade drilling

Ahead of the mine production faces in different benches, a drilling block should be maintained of sufficient length and width in all the faces to manage quantity of material at least for one week. This enables easy weekly blasting and prevents from frequent shifting of the machines. For good blasting efficiency effective drilling parameters should be followed. Drilling parameters are dependent on the rock characteristics. Distance from the free face to the first line of the holes is known as Burden, hole to hole distance in a row is called spacing and the extra drilling more than the height of the bench is called the sub-grade drilling. Drilling block is properly leveled with the use of a dozer and prior to start of the drilling operations, positions of the drill holes are physically marked on the ground as per the desired drilling parameters. Drilling parameters can be fixed on the trial and error basis following the general prescribed thumb rules. Harder rock requires smaller burden and spacing while the larger spacing and burden can be given in the soft rocks where less energy is required for breaking of the rocks.

. The following thumb rule is in practice for determining the drilling parameters in the mine

a) The burden of drill holes can be 200 to400 times the dia of the holes.
b) Spacing can be 1.5 times of burden.
c) Stemming is normally 1/3 of hole depth but not less than the burden
d) Sub-grade drilling should be approx 10%to11% of the bench height.

Marking of holes on the surface can be on a square pattern or the staggered pattern. When the spacing of the holes in the second row are in line with the first row making a square, it is called the square pattern and when the holes of the second row are placed between the two holes of the first row forming a triangle are called staggered pattern. Sub grade drilling are required to compensate the drilling loss after the drill is removed. For good blasting, length of the hole should be at least equal to the height of the bench or otherwise toes will be formed at the foot of the bench which restricts the digging efficiency of the excavator

Blasting

Blasting is done to provide fragmented rock mass for shoveling. It's the lifeline of a mines operation because the efficiency of all other operations like excavation, loading of dumpers, transportation and crushing and the screening are dependent on the blasting efficiency i.e. the fragmentation of the basted mass. Different types of explosives are used for rock fragmentation.

a) High prime charge
b) Prime charge
c) Base charge
d) Column charge

The blasting circuits used in an open cast mines :

By use of the Safety fuse—Plain detonator-Detonating fuse-High prime charge-Prime charge –Column charge-base charge. Detonating Relays are used between the rows of the blast holes to manage row to row delay of 17 seconds in each row in blasting for better fragmentation than the solid blasting without delays.

By use of electric detonators

Electric plain detonator/electric delay detonators-detonating fuse-high prime charge-prime charge-column charge-base charge. Delay sequencing is managed between the rows by use of the electric delay detonators which are connected in series and fired by an exploder.

By use of the non-electric detonators

Above systems are old conventional system of blasting. But nowadays nonel system of blasting is being practiced in practically all the large open cast mines. Instead of detonating fuse, nonel tubes are used in this system (shock tube technology). **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. Providing a free face is the essence of the blasting technology. In the above systems delay is provided between the rows to provide free face between the rows. In nonel system, hole to hole delay is created and hence the hole to hole free face is provided for efficient blasting.

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. More energy is utilized in breaking the rock instead it is wasted in the atmosphere causing air blast and the blast vibrations.
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
e) Safer in handling and blasting.
f) Large no. of holes can be blasted effectively in single shot providing large volume of the blasted mass.
g) There are less chances of misfire as all the surface connections are charged before down the hole non electric delays are initiated.

Operation schedule/deployment/monitoring

Operation schedule is a daily/weekly operation plan taking into consideration of quality parameters &targeted production. It is synchronization between available bench wise blasted material quality, quantity and available shovel combination. To get a desired result the bench wise shovel operation must be monitored throughout the shift.

Trans port /arrangement of transport

For transporting men and material, arrangement of transport is vital in a mines operation.

Quality/monitoring

It's a desirable practice that wining of ore shall commence after blasting of ore body. Before blasting all extraneous materials 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.

Crushing plant

Transported ore from the quarry is fed to primary crusher. Primary crusher is normally a gyratory crusher and sometimes Jaw crushers, which crush the ore upto a size of 300mm.The crushed ore is then feed to a secondary cone crusher through conveyor belt to get a desired size of 40mm and below. The mixture of sized lump &fines is stocked into a stock pile for feeding to screening plant through conveyors.

Screening plant

The job of screening plant is to separate lump (-40mm to +10mm) & fines (-10mm) through double deck screen and transport the material to Ore Handling Plant stockpiles through conveyors. In wet screening the lump &fines are washed with waters in the double deck screen for removing impurities during monsoon.

Ore Handling Plant

The job of ore handling plant is to feed the wagon loader from stock pile by a bucket wheel excavator. From the bucket wheel excavator the lumps &fines are transported to wagon loader for loading into wagons by conveyors.

Loading and dispatch

Managing loading and dispatch within the free time without incurring demurrages and loading correct weight to avoid heavy penal freight is the prime requirement and the big challenge. There are different systems of loading in different mines. Loading are done by wagon loader, shovels or the pay loaders. No. of the loading equipments depend on it's capacity and the free time provided by the railways.

12.3 Safety in Mines

Safety / Personal Protective Equipment (PPE)/Safety of men/machine

The safety of persons employed in mines and also the equipment are the responsibility of the 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 equipments, follow general principles laid down in permission letters by the Directorate General of Mines Safety Official as per MMR 1961/CMR1957.General condition of mines atmosphere shall be congenial, airborne dust shall be suppressed at the place of formation by water sprinkling.

Heavy electrical & other drills and also shovels 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.
