COKE OVENS & COAL CHEMICALS PLANTS

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ABSTRACT

Steel plantsgenerally refer toindustrial plants maintained for the purpose of manufacturing steel. This paper briefs the in-plant industrial training completed at the Vishakhapatnam Steel Plant titled, "Observation of different processes in Steel Making". The main objective ofsaid training was gainingknowledge ofcoke preparation,sintering process, and raw material handling. Maintenance, spares and the working principles of different material handling systems in Steel Making were focused on to gain a thorough knowledge.

1. Introduction

Steel is a carbon and ironalloy witha carbon percentage less than 2%, 1% manganese and trace amounts of other substances, i.e.,oxygen, phosphorus, silicon andsulphur. Steel is the leading material for constructionand engineering. It is applied in mostparts of our lives, namely: refrigerators, washing machines,cargo ships, surgical scalpels, cars and other construction products. Steel isn't a singular product; with varying physical and chemical properties, steel features more than 3500 different grades.

Steel is highly environment-friendly,fully recyclable, withhigh durability, and a low energy requirementfor production, in comparisonto other materials. Innovation in light-weight steelconstructions,such as, rail-related vehicles and automobiles, help in savingboth resources and energy.The steel industry has made tremendous progress in limiting pollution in theenvironmental for the past few decades.Consumption of energyand CO_2 emissions are now around half in comparison to the last few decades.

Our area of focus in this paper is the Steel Manufacturing at theVishakhapatnam SteelPlant.

2. About the Company

Visakhapatnam Steel Plant iscommonly known as Vizag Steel, referred hereafter as VSP.It is the mostdeveloped Indian government-owned steel company. Theyproduce oneof the best products in the world market in an Integrated Steel Plant. ExportstoDubai, Germany, Singapore,Australia, United States,Japan, and some South American countries, etc draw in the majority of the income of steelproducts. VSP was awarded Navratna status on November 17th, 2010.Since its foundation in 1971, and the company has continued focusing on continually producing steel which is value-added**.**Modern Technologies are a part of VSP, giving ita capacity of 2.656 million tonnes of saleable steel and 3 million tonnes per annum of liquid steel.At VSP, seamless integration, total automation and efficient upgradation are given the most emphasis. This resultsin many structuraland long products to satisfy the strict demands of judicious customers both within the country and overseas. The products at VSPfulfil even theacclaimed International Quality Standards such as DIN,BS, JIS, BIS, etc.VSP has many production facilities including,

1) 3 batteries for the coke oven of 67 ovenswith 41.6cubic meters volume each,
2) 2 312 square meters area Sinter machines,
3) 33200 cubic meters of usable volume Blast furnace,
4) Steel Melt Shop containing 3 L.D. converters of 150 Tonnes capacity each and six 4strand continuous bloom casters,
5) Light and Medium Merchant Mill of 710,000 Tonnes per yearcapacity,
6) Wire rod mill with a capacity of 850,000 Tonnes per year,
7) Medium Merchant & Structural Mill with a capacity of850,000 Tonnes per year.

Repair and maintenance at the same timethe spare partsmanufacturing of are done by extensive facilities. A Thermal Power Plant and an Air Separation Plant is also a part of the current plant facilities.

Modern technologies have been more used now in different production areas; with some being introduced in India for the first time. These include: Pneumatic Separation of Coal, Selective crushing of coal, conveyor charging and bellless top for blast furnaceon-ground blending of Sinter base-mix, dry quenching of coke, cast house slag granulation for blast furnace,7 meter tall coke ovens, gas expansionturbine for power generation utilizing blast furnace top gas pressure,computerization for process control, hot metal de-sulphurization, sophistication in high speed and high production rolling, andextensive treatment facilities of effluents for proper environmental protection.

3. Plants Visited During Training

3.1 Raw Material Handling Plant

Raw Material Handling Plant hereafter referred to as RMHP deals with the incoming and basicprocessing of rawmaterials at VSP. It is broadly divided into two departments:

1. Ore Handling Plant (OHP)
2. Coal Handling Plant (CHP)

The Ore Handling Plant,or OHP, deals with the iron ore and flux materials likelimestone and dolomite. While the Coal Handling Plant, or the CHP, deals with coking andnon-coking coal. Some of the major sources of raw material are given below.

Raw Material	Source
Iron Ore Lumps and Fines	Bailadilla, Madhya Pradesh
Blast Furnace Limestone	Jaggayyapeta, Andhra Pradesh
Steel Melting Shop Limestone	United Arab Emirates
Blast Furnace Dolomite	Madharam, Andhra Pradesh
Steel Melting Shop Dolomite	Madharam, Andhra Pradesh
Manganese Ore	Chipurupalli, Andhra Pradesh
Boiler Coal	Talcher, Odisha
Coking Coal	Australia
Medium Coking Coal	Gidi, Swang, Rajarappa, Kargali

Table 3.1 Sources of Raw Materials

Iron ore, flux material and coal are classified into Lump, Sized or fines according to their sizes. If thesize is more than 40mm then it is a *lump*, if it is less than 10mm then it is*fine*, or if it is between 10mm to 40mmthen it is *sized*. Basically,sized ore and coke are required for blast furnaces. The materials are measured interms of sieve sizes only. The major features of RMHP are:

3.1.1 Wagon Tipplers

Raw materials like iron ore, limestone and coal are supplied to VSP from the mines by the IndianRailways through rakes consisting of 51 to 58 wagons. The rotary tipplers are designed for unloadingof broad-gauge open railway wagons by inverting the wagons, to a maximum of 175 degree andtherebydischarging its contents into the hoppers below the rail. The operating angle is kept at 165 degrees. Thetipplers are constructed to handle wagons and have a gross load going up to 110 Tonnes. The ideal tipplerworking cycle is 60 seconds which means that the ideal rake retention time should be around 3hours but practically it takes around 8 to 9 hours.The ore, flux and the coal all fall into bunkers which feed the materials to apron feeders, which are metalbelt conveyors designed to take the load of the bulk material. Next, they are conveyed to ashuttle conveyor which in turn distributes the material uniformly into different conveyors. Finallythey are carried to the stockyard.

Working Principle: The tippler consists of 3 circular rings, a platform with travel rails, support rollers as well as aclamping device which retains wagons from top and side during tippling. It is driven by a drive unitlocated on one side of thetippler. The drive unit consists of a motor, flexible couplings, thrusters operated brakes, helical gear-box, pinion andtoothed rings.The wagons are placed on the pre-tippler with the help of Pusher cars. The wagons are manually de-coupledfromthe rakeand pushed forward by the Pusher car into the tippler platform.The tipplerturns by a small angle till the point sides ofthe wagonsare clamped to the side wall. On further rotation, the platform moves in such a way that the wagons get clamped at thetop, ensuring rotation up to 175 degree just by the virtue of their own weights. After dischargingthe bulk material, the wagons are brought back to initial position by the tippler and pushed by Pushercars to the rake storage area.The principle of working is called *Rotary Gravity Clamping Mechanism*.

3.1.2 Ground and Track Hoppers

These are railroad freight cars used to transport loose flux material such as limestone,quartz, dolomite and sand into VSP. These are dumped out manually into bunkers and the materials aresent to the stockyard with the help of conveyors. The application of hoppers is done when wagon tipplers aren't as economical and when there is a chance of the wagon being damaged.

3.1.3 Stock Yard Systems

For bulk materials handling, the main function of stockyards is buffering,storage and blending between the materials that come in and go out.The stockyard systems include stackers and reclaimers and some stacker cum reclaimers. At VSP,there are 3 reclaimers, 3 stackers, and 4 stacker-cum-reclaimers**.**A stackerrefers to abig machine generallyused for bulk material handling, i.e., making a stockpile by piling bulk materialslikex limestone, iron ore and coal**.** A reclaimer is used to remove the material from thestockyard. The reclaiming rate is 550 Tonners per hour and the stacking rate in VSP is 750 Tonners per hour.The other features of a stockyard system are travelling unloader and feed table which are used instacking and reclaiming respectively. In case of stacker cum reclaimers both are used.A travelling car is also used to move the machines to any track from any track over the entire area ofthe stockyard**.** Each reclaiming chute uses a strapper to secure sticky material from the yardconveyors.The machines have three basic motions viz. longitudinal travel, slewing i.e. lateral movement of armand luffing i.e. vertical movement of arm. The major drive mechanism are longitudinal drive, slewingdrive, bluffing drive, boom conveyors, bucket wheel drive, power cable reeling drive etc. In boomconveyors garlanding idlers are used for shock absorption.

3.2 Lump Ore Screening Plants

In this plant the lump iron ore and flux materials are screened. This screening is done onthe basis of screen mat sizes.There are,

1) Two primary vibrating screens, and
2) Three secondary vibrating screens

In the case of a primary vibratingscreen, the drive mechanism is lubricated by oil and there is a capacity to screen 350-450 Tonnes per Hour. While in the secondary vibrating screens, the drive mechanism is lubricated by grease and they screen about 200-250 Tonnes perhour.

The Screens have an exciter system and vibration amplifier springs to ensure better flow of the bulkmaterial. Flywheels are provided for maintaining inertia. The vibration frequency is maintained with the help of Stroke Measurement Diagrams. In VSP the standard reading is 10.

Working Principle: Lump ore and flux material are first screened in the primary vibrating screens. The sized material andfines pass through the screening mats and are sent back to the stockyard. The lumps which arescreened are sent to crushers which are again screened in the secondary vibrating screens. Theprocess is repeated until the materials are converted to the optimum size i.e. less than 40mm.

3.3 Crushing Plant

At VSP, there are two different Crushing plants i.e.the Lump Ore Crushing Plant and the Non-Coking Coal Crushing Plant.

3.3.1 Non-Coking Coal Crushing Plant

Coal crushing plants crush the boiler coal into any sizes less than 25mm and supply it to the Thermal Power Plants. Coal is a soft material so Ring Granulators are applied to crush the coal.Initially, the Ring Granulators Scoop Controlled Fluid Coupling Unit were put to use but due to the high rate of issues with maintenancein current days, Delayed Chamber Fluid Coupling Units are more commonly seen.

The machine itself has a screen plate or cage bar steel box containing an opening for introducing thematerial we need crushed**.** A sloping breaker plateis arranged on a hingedcage frame and is set to one side of the feed entry. A horizontal main shaft which is power driven passes fromframe side to this breaker plate parallely.The main shaft is carried in the roller bearings from the box sides,and it supportsthe many circular disksfixed at constant intervals across the length in the frame. Running parallelto the main shaft, a series of barsgo in these disks near the outer edges.The bars are equidistantfrom themain shaft centre. They also carry a series of rings free to rotate on the bars irrespective of the main shaft rotation**.** Below the rotor assembly,ring running periphery radius is marginally smaller thantheradius at which the movable cage frame is carried.

Working Principle of Ring Granulators: The material is dropped in the feed opening and isstruck in the air by multiple rings driven towards the breaker plateby the rotor discs. These rings are fixed on suspension bars. When the rotor is put inmotion,the centrifugal force moves the ring out against the materials to be crushed. The rings are forced back towards the rotor centre, as the material is fed to the machine. This happens until the ring’s internal surface encountersa bar and a driving force is exerted in the forward direction. The material iscrushed and discharged using the screen plates or cage bars. This eases the load and allows thering to go out to be held again by suspension bar before it encounters the feedcoming in once again.So the rings are in deep contact with the material on the cage bars andthey continue to revolve like a planet relative to the direction of rotor rotation. Aconstant effective crushing action is provided by rolling, which guarantees a grain-like material size.

3.3.2 Lump Ore Crushing Plant

Lump Ore Crushing plants crush hard bulk materials such as flux and iron ore in Gyratory ConeCrushers. Here, lubricating oil is supplied using 2 pumps connected to the driving mechanism. Oil rate of flow is kept at 70 litres per minute in input as well as output pipes. Additionally, to maintain oil temperature, heat exchangers are installed.The main parts of a crushers are: motor, cone assembly, socket assembly,feed arrangement and chute, andpinion or counter shaft bevel gear bowl assembly. A square box, wedges, half rings, Lower Mantle, and a feed plate are all parts of the Cone Assembly.The crushing surfaces, i.e., the bowl lining and lower mantle are lined with Manganeseto increase material hardness. For shock absorption, a backing material ore is used in the middle of the bowl lining, the reverse surfaces of lower mantle, andthe mainframe.

Working Principle of Gyratory Cone Crusher: A cone crusher breaks the ore and flux lumps by pressing the material with an irregularlyGyrating spindle. A wear-resistant mantle covers the spindle, whereasa bowl liner or a manganese concave, covers the enclosing concave hopper. As the material enters the cone crusher, itiscrammed and pressed between the mantle and the bowl liner. The large pieces oforefall to a lower position after being brokenas the size is now smaller. Here, they arecrushed again. The said process goes ontill the pieces becomesmaller, enough to pass through the smallopening in the lower part of the device.

A number of mid-hard and above mid-hard ores and fluxmaterial can be crushed by a cone crusher. It has adependable construction, good productivity, uncomplicated adjustment and operational costs that are cheaper. In a cone crusher,the spring release system is providedas an overload protection thatallows the tramp to go through the crushing chamber with little or no damage to the crusher.After this process, the material is sent to the Sinter Plant and Blast Furnace.

4. Coal Carburization

Also known as Coke Making. Some coals when heated in the absence of air, melt and go in a plastic state, then swell and re-solidify to give a solid coherent mass named*coke*. With the heating of the coal, a series of chemical and physical changes occur with the rise of gases and vapours, and a solid residue. Conventional coke making occurs in coke ovens, with the battery of the ovens kept in the middle of the heating walls. Carbonization occurs at around 1000-1100 degree Celsius till a point of de-volatization to make metallurgical coke with requiredthermo-chemical and mechanical properties. During the carbonization process, coking coals go undera change into plastic state at around 350-400 degree C; they swell and solidify near 500-550 degree C to first produce semi-coke and finally coke. In these ovens, when the coal is charged, layers of plastic startforming near the heating walls. With time, these layers move to the centre of oven from both sidesbefore finally meeting at the centre.

When making coke, two reactions that are opposite in nature take place, i.e.,pyrolysis and condensation. The overall quantity and quality of the plastic layer formed is of the utmostsignificance as it controls the innate strength of our coke matrix.

4.1 Coke Ovens and Coal Chemical Plant

The most commonly seen steel making technology is the Blast Furnace – Basic Oxygen Furnace Route. Cokeis used a thermal energy source and a reductant in the Blast Furnace (hereafter referred to as BF). The process entails firstly thereduction of ore to get liquid metal in a blast furnace. Then comes the process ofrefining the metal in a convertor toproduce steel. The different parts of the steel plant are detailed further.

4.1.1 Coal Preparation Plant

The Coal Preparation Plant, or CPP, deals with the processing & storage ofdifferent grades of coal and their dispatch to the Coke oven batteries according to need. In VSP, coalof different grades from the storage yard is collected in one place using reclaimers and feed table. It is thenstored in 16 large storage bins according to their grades. This coal is combinedin different proportions to produce coking coal of optimum composition. This mixture is sent through roller crusher to produce coal of size less than 3mm,and is finally sent to the cokeoven battery.

4.1.2Crushing Section

In the crushing section, roll crushers are used. These are also called compression-typecrushers. The Roller Crusher consists of one Stationary Roll and one Moveable Roll. When any rigid material is encountered, immediate relief is provided by the MovableRoll by quickly moving away from the Stationary Roll andcoming back to its original position. Range of the roll diameters is from 457.2-1930.4mm andthe widths go up till 3048mm.Roll crusher producesa fine size distributionend-product; little dust or fines are producedwhen operating. Minerals with lowabrasive levels are widely be crushed with these crushers.

The most common application of roll crushers is in coal mining. Both single roll and double roll crushers may be used. The rollssurface have teeth or raised forms, when coalmining. Whereas,smoothsurface rolls are used for mineral and metal ores.

4.1.3Battery of Coke Ovens

There are 4 Coke Oven Batteries that are 7 meters tall, each having 67 ovens. Each of these oven has41.6 cubic metersvolume and theya capacity to hold 31.6 Tonnes of dry coal charge. Between 1000-1050 degree C for 16 hours to 18 hours in the absence of air, the carbonization takes place.

4.1.4Coke Oven Machines

The following oven machines are under operation at *top charged battery*.

- **Charging cars-** discharge crushed coal to the oven and generally operate on the top of the ovens.
- **Pusher cars-** designed for pushing coke out of the ovens. This machinecarries out some main operations, i.e., coke oven door extraction, levelling of coal charge, pushing coke out of coke oven. The machine is equipped with a mechanism that fulfilsoperations such as,cleaning and service of doors or frames, burning graphite on coke oven roof, discharge of coal spilled when levelling,raising, lowering, and cleaning of leveller hatch, receipt, storage and spillage cleaning.
- **Guide Cars-** operate on the coke side of the battery. They open the coke side door, guidethe hot coke into the quenching car, followed quickly by closing the coke-side door.
- **Quenching Cars-** Receive the hot coke and take it to the quenching station for waterquenching.

4.1.5Coke Dry Quenching Plant

Coke dry quenching is a system known for a remarkable energy recovery and at the same time, reduction in air pollution, especially whenrelated with coal preheating. Adding on,coke which has been dry quenched isstronger and harder, and with amuch lower moisture content compared to wet quenched coke.The coke dry quenching equipment broadly consists of awaste heat recovery boiler and a coke cooling tower, which consists of a pre-chamber andcooling chamber. Red-hot coke at a temperatureof approximately 1200°C is put into the coke cooling tower where liquid Nitrogen enters in from thebottom and anexchange of heatoccurs with the Nitrogen being circulated. The gas is heated to temperature approximately up to 800°C, then it is circulatedinto the heating tubes of the waste heatboiler. The water in the boilers is converted into steam. There is a reduction in the temperature of coke at the coolingtower outlet, it comes down to around 200°C.

A gas - steam mixture with a temperature up to 700°C, is introduced asa counter current to the coke flow. The hydrocarbonsconversion in the presence of water vapourgives a gas that contains hydrogen (H) and carbon monoxide (CO). 700°C blast furnace coke is passed from middle chamber to the lower part of the chamber. Here it gets cooled to a temperature between 200°C and 250°C, with a flow of Nitrogen. At VSP, there are 4 Coke Dry Quenching Plants with four cooling chambers each. Eachof these cooling chambers had a capacity of is 50-52 Tonnes per Hour. The recovery of heat from the Nitrogen is carried out byproducing steam, expanding it in two back pressure turbines, producing 7.5 Megawatt power each.

4.1.6Coke Coal and Chemical Plant

Another essential part of the coke making process is coke oven by-product plant. The inflammable matter in coal isvaporized and moved from the oven chambers asraw, hot coke ovengas. Once the raw gas leaves the chambers, it is cooled resulting in a separate liquidcondensate flow and a gas flow. The function of this by-product plant is to carry the twoflows from the coke oven to process them. This is donetoretrieveby-product coal chemicals. This gas is condition to be further used as fuel gas.

Stream	Destination
Coke Oven Gas	Fuel gas for steel and works coke oven batteries
Flushing Liquor	Re-coursed to the Coke oven battery
Waste Water	Moved to the treatment plant
Tar	Sold as Product
Ammonia or Ammonium Sulphate	Sold as Product
Light Oil	Sold as Product

Table 4.1 By-Products of Coke Ovens

5. Composition of the Coke Oven Gas

Along with tending to the coke oven gas, our by-product plant also conditions the flushing liquor to begiven back to the coke oven battery. It also treats the waste water producedin the coke making process. Raw coke oven gas typically has the followingcomposition:

	Dry Basis	Actual Composition (Water saturated)
Water Vapor	-	47%
Hydrogen	55%	29%
Methane	25%	13%
Nitrogen	10%	5%
Carbon Monoxide	6%	3%
Carbon Dioxide	3%	2%
Hydrocarbons(Ethane, Propane etc)	2%	1%

Table 5.1 Composition of Raw Coke Oven Gas

6. Spontaneous Combustion of Coal

Self-Ignition of coal is an exothermic chemical reaction where anensuing rise in temperature occurs in the combustible material without anyinfluencefrom an additional source. Self-ignition takes placeif thermal equilibrium,of two counteracting effects of the heat released by oxidation reaction and the heat loss due to heat transfer to atmosphere, is disrupted. When the heat production ratesurpasses the heat lost, a rise in temperature in the material takes place as a result. At VSP, more than 40% of the total non-coking coal in the stockyard gets exhausted due to the self-combustion.

Explanation and Reactions

Coal fire requires the basic element to exist, i.e., air. The spontaneous combustion of coal is started off by oxidation, which takes place when the Oxygen reacts to fuel i.e. in this case,the coal. This produces heat. At a high temperature, there is a higheroxidation rate. In due course,the material reaches a temperature where itis ignited.

$$Coal + O_2 \rightarrow CO + CO_2 + H_2O + \Delta$$

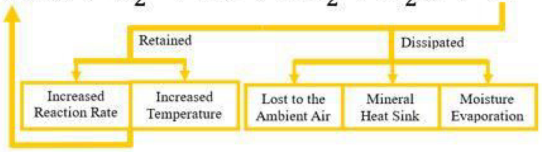

Fig 6.1 Oxidation of Coal

The full oxidation of Carbon to Carbon dioxide is an exothermic reaction that gives out a heat emission of around 21-42 Kilo Joule per gram of coal, consideringpure Carbon coal.

7. Conclusion

VSP being an integrated plant deals with different processes in steel making up to dispatch of various finished products and by-products. We came to know how raw material such as iron ore, limestone, dolomite, coal etc. are handled and processed into steel and different merchant mill products by different material handling systems. It is the largest and technological unique coke oven batteries in the country at the time of commissioning. They have 7-meter-tall coke ovens batteries. Selective crushing of coal is done to improve the coke quality. 100% dry quenching of coke using nitrogen gas in done in the batteries.

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