

## **RAW MATERIAL**

### **General**

The major Raw Materials required for production of Sponge Iron by the rotary kiln process are: sized graded Iron Ore and Non-Coking coal. Limestone, in small quantities, is also required to scavenge the sulphur.

### **IRON ORE**

The quality requirement of Sized ore for sponge iron production can be classified into:-



**1) Physical requirements:-**

Strength and granulometry are the two important physical requirements. The ore should be hard, and possess high strength. The optimum tumbler strength of the ore should be 90 percent minimum. Depending on the reducibility, closely calibrated ores in the size range of 5 to 20 mm generally used.

**2) Metallurgical requirements:-**

The ore should be highly reducible, thermally stable and have a low tendency for sticking and disintegration during heating and reduction.

**3) Chemical requirements:-**

Apart from the removal of oxygen, no other major chemical change takes place in direct reduction. The gangue material in sponge iron, originating from Iron Ore, namely, silica and alumina and the sulphur and phosphorous contents adversely affect the economics in subsequent steel making operation. Therefore, the ore should be high in iron content and low in gangue,

**Physical Specification -**

|               |   |           |
|---------------|---|-----------|
| Size          | - | 5-20 mm   |
| Oversize      | - | < 5 % max |
| Undersize     | - | < 5% max  |
| Tumbler Index | - | + 90      |
| Silica        | - | < 3%      |
| Contamination | - | < 5%      |

(Porous, Laterite etc)

### **Chemical Specification**

|  |   |       |
|--|---|-------|
| Fe (Total)   | - | 65%   |
| Si O <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> | - | 5%    |
| Sulphur  | - | 0.01% |
| Phosphorous.                                       | - | 0.05% |
| Moisture.  | - | 1%    |

### **COAL**

Non-coking coal is used as reductant in the rotary kiln process.



### **Physical Specification -**

|               |       |   |         |
|---------------|-------|---|---------|
| Size          | Lumps | - | 5-20 mm |
|               | Fines | - | 0-5 mm  |
| Contamination |       | - | < 3%    |

(Shale & Stones etc)

### **Chemical Specification**

|                 |   |        |
|-----------------|---|--------|
| Fixed Carbon    | - | 45%    |
| Volatile Matter | - | 25-30% |
| Ash             | - | 20%    |
| Moisture.       | - | 8%     |

The major quality requirements of coal for Sponge iron production are-

- 1) Non-coking characteristics
- 2) Low ash content
- 3) Low sulphur content
- 4) Good reactivity
- 5) High ash fusion temperature
- 6) Medium volatile matter

#### **1). Non-coking character:-**

Non-coking coal is required in sponge iron production, since the coking reaction leads to formation of rings inside the kiln. Practically permissible caking index is 3 maximum for rotary kiln operations.

#### **2) Low ash contents:-**

High ash leads to under utilization of the kiln volume available for reduction. It also increases the consumption of fixed carbon, since additional energy is consumed in heating the inert ash

mass to reaction temperature. An ash content of 20 percent maximum is the practicable limit for normal operation.

**3) Low sulphur content:-**

To control the sulphur in sponge iron, the sulphur in coal should be one percent maximum.

**4) Good reactivity:-**

An important step in solid state reduction is the forward reaction, whereby carbon dioxide generated from burning of coal reacts with coal to regenerate carbon monoxide, the coal, therefore, should possess sufficient “reactivity” so that the bounded reaction proceeds at sufficient rate. Bituminous and sub-bituminous coal exhibits very good reactivity suitable for production of sponge iron.

**5) Ash fusion temperature:-**

Coals with low ash fusion temperature leads to sticky mass, and consequent unstable kiln operation by forming accretions inside the kiln, and reducing the reduction rate by formation of slag layer on surface of the ore. Hence coals with ash fusion temperature above 1400°C are desirable for rotary kiln operation. Ash fusion temperature is governed by its chemistry.

**6) Volatile matter:-**

Coals with optimum volatile content are required for coal based rotary kiln process. Coal with very low volatile matter result in very low reactivity of char, and thus give rise to poorly metallised product. Very high volatile coals, though they yield highly reactive char, are also not preferred. Generally for rotary

kiln process volatile matter should be in the range of 25 to 30 percent.

### **DOLOMITE/LIMESTONE**



Limestone is used as a de-sulphuriser in the production of sponge iron.

Typical specification of limestone is given below –

| <b>CHEMICAL COMPOSITION</b> | <b>PERCENTAGE MIX</b> |
|-----------------------------|-----------------------|
| MgO<br>(Minimum)            | 22%                   |
| CaO<br>(Maximum)            | 28%                   |

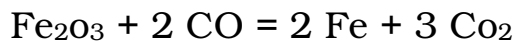
### **MANUFACTURING PROCESS**

Coal based Direct reduction process is classified based on the reducing agent namely solid.

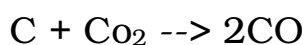
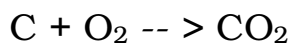
Most solid reduction process use non-coking coal as reducing agent due to abundantly available non-coking coal.

The process proposed to be adopted is the rotary kiln proposes using Non-coking coal and iron ore.

Iron are undergoes the following reduction reaction in all the processes



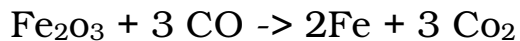
As shown in above reactions, carbon monoxide is reducing gases. These reducing gases can be obtained by controlled combustion of coal, according the boudouard reaction produces carbon monoxide.



As maintained earlier direct reduction is the conversion of oxide feedstock to the metallic state with such conversion taking place

entirely in the solid state (at no time does the material become molten).

The carbon monoxide (co) produced as above reduces iron oxide to metallic iron.



However, the reduction from oxide to metal does not occur in one step, but by gradual removal of oxygen giving, rise to various intermediary oxides.

The reduction sequence can be expressed as follows:



For sulphur removal in the ore, dolomite/ limestone is used and the reactions are as follows:



### **Reaction mechanism**

The reaction occurring inside the bed of iron ore and coal are heterogeneous in nature. Two sets of reaction take place.

Set 1: Between coal, carbon dioxide and oxygen

Set 2: Between iron ore particles and co.



Each particle/ lump of ore may be considered as a porous. reaction between the particle and the gaseous reactant can be visualized to occur in 5 successive steps

|        |  |
|--------|--|
| step 1 | Diffusion of gaseous reactant through the film surrounding the particle to the surface of the solid.                           |
| step 2 | Penetration and diffusion of the reactant through the blanket of the reacted outer layer to the surface of the unreacted core. |
| step 3 | Reaction of gaseous reactant with solid at this reaction surface.  |
| step 4 | Diffusion of gaseous products through the reacted layer to the exterior surface of the solid.                                  |
| step 5 | Diffusion of gaseous products through the gas film back to the main body of the gas.   |

Since the reaction takes place in several steps and each in succession, any of them having the least rate could be the rate controlling. Be it diffusion or reaction, the rate should be primarily a function of the following three parameters.

- a) Concentration of reactants at active interface temperature.
- b) Active area of reaction.

The rotary kiln process chosen for the unit considers reduction of iron ore (5-20 mm) with solid carbonaceous material like coal heated up to a temperature of 950-1000<sup>o</sup>c in rotary kiln and then

cooled in a rotary cooler with external water cooling system. The products are screened and magnetically separated.

Sponge iron being magnetic gets attracted and gets separated from non- magnetic char.

The iron ore and coal crushed and screened to respective sizes are fed to rotary kiln through feed tube in pre-determined ratio. The rotary kiln is slightly inclined at an angle 2.5 deg and rotated by ac variable speed motor at a steeples variable speed ranging form 0.2-1.0 rpm.

Due to inclination and rotary motion of the kiln, the material moves form feed end to discharged end in about 7-8 hrs.

The fine coal is blow form the discharge end to maintain the required temperature and the carbon concentration in the bed. The kiln has 8 shell air fans mounted on the top which blow air in the respective zones to maintain the required temperature profile.

The material and the hot gases move in the counter current direction, as a result the iron ore gets pre- heated and gradually reduce by the time if reaches the discharged end.

The hot reduced material is transferred to rotary cooler via the transfer chute. The cooler is also inclined at 2.5 ° and rotates of a steeples variable speed of 0.3 to 1.2 rpm driven by an ac variable

speed motor. Water is sprayed on top of shell to cool indirectly the inside material.

The material gets cooled to 100 deg c and discharged on the belt conveyor but the double pendulum valve, which acts as a seal for prevention of atmospheric air into the kiln cooler system. The cooler discharge is sent to the product separation system where material is screened to various size fractions and magnetically separated.

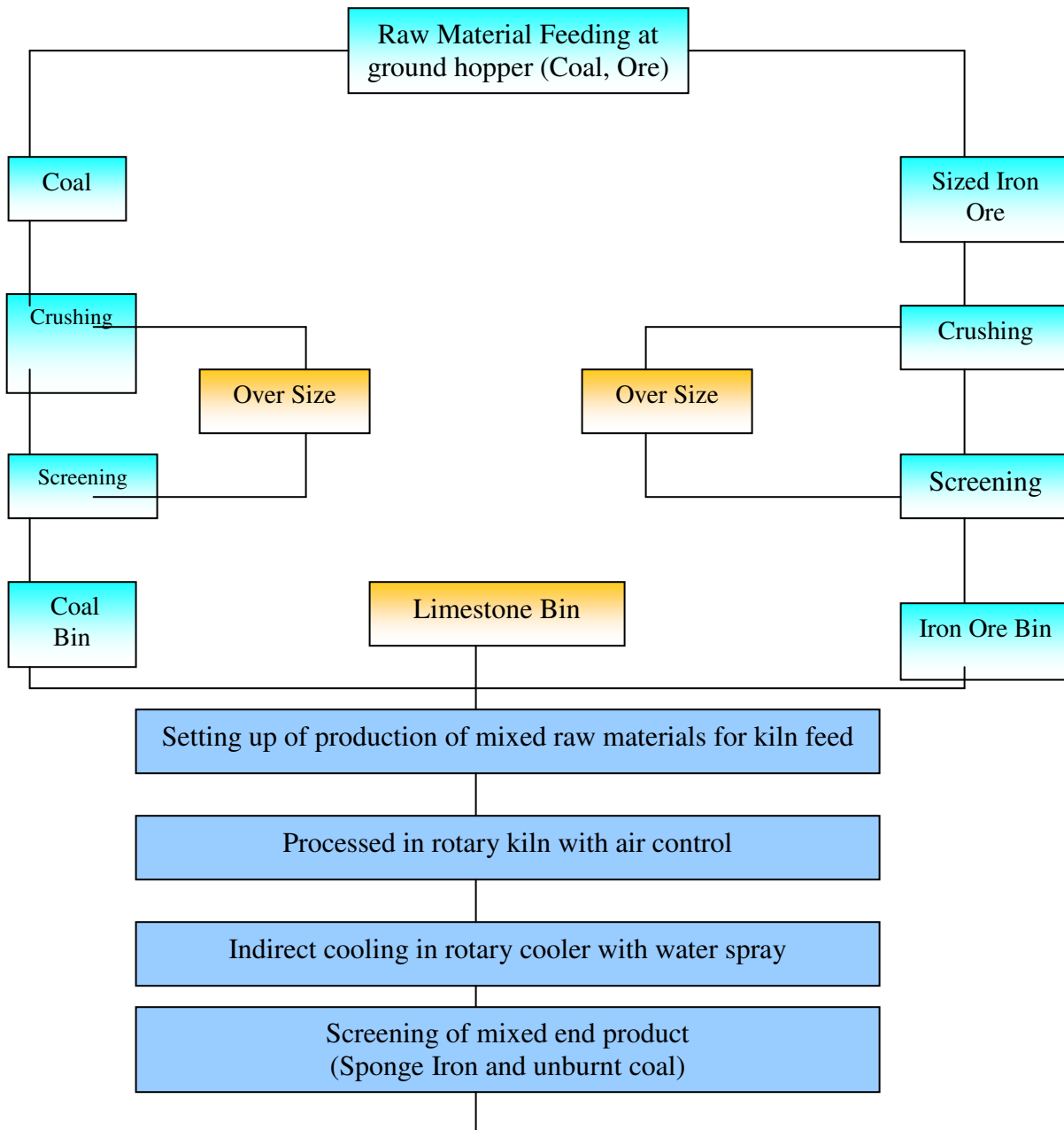
Gases flowing in counter current direction to material go to the dust settling chamber where heavier particles settle down and latter dust particles are arrested in pollution control equipment like an esp.

The gases which flow in the counter current direction of the material go to the dust settling chamber (DSC) where the heavier particles settle down. These particles are continuously removed by the wet scrapper system.

The gases then pass to the after burner chamber (ABC) where the residual carbon or co is burned by the excess air available. The gases are of high temperature and have a lot of heat energy which can be utilized for the power generation through the waste heat recovery boiler.

The hot gases after the heat recovery boiler gets cooled to 200°C, the gases then are passed through an ESP and the clean gases are let off to the atmosphere at 80 °C through the chimney.

### **PROCESS FLOW CHART FOR MANUFACTURE OF SPONGE IRON**



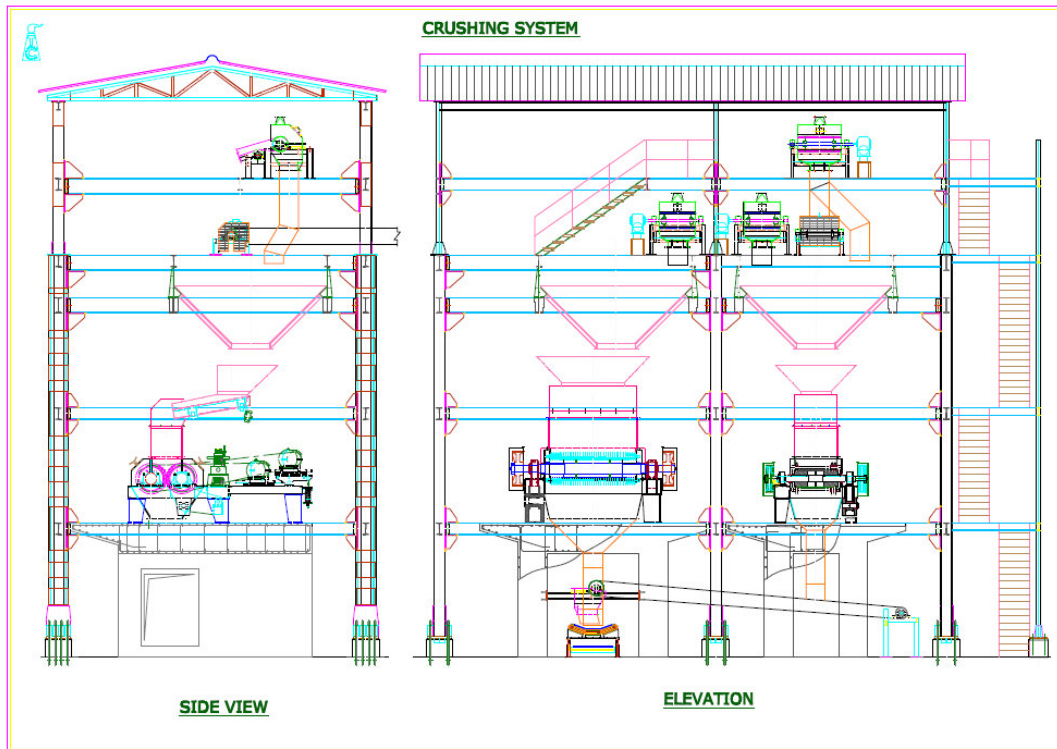
## **MAJOR PLANT FACILITIES**

### **1- RAW MATERIAL PREPARATION SYSTEM -**

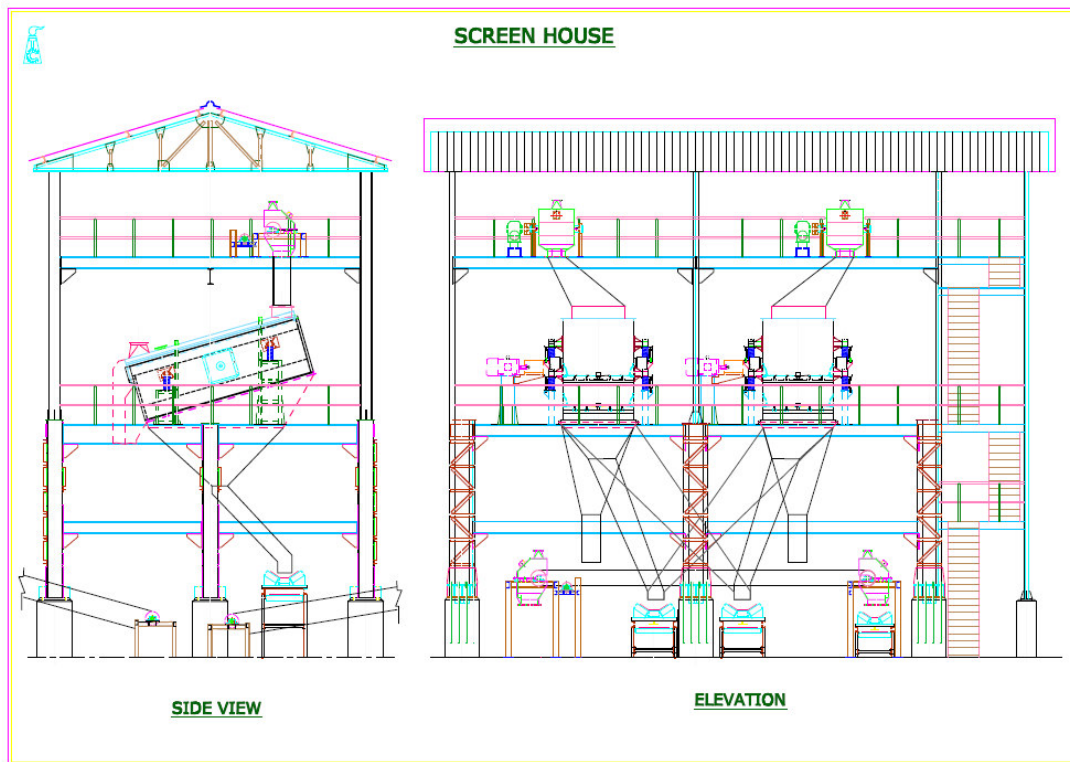
Raw material system mainly consist Vibro Feeder, Crusher and Screen.

Iron ore crushing is not required since sized material has to be purchased. Iron ore of size 5 mm to 20 mm is being used for the production of Sponge iron. Iron ore is being fed to the Ground hopper, from where it conveyed to the Screen with the help of Vibro Feeder, where Oversize i.e. + 20 mm and Undersize i.e. – 5 mm is being removed by screening. The oversize material is conveyed to the Oversize crusher to get sized material.

Coal of having size 200 mm is being crushed with the help of Primary and secondary Crushers and screening to be done through Primary and Secondary screen.



The screens are having different size decks for getting required size of coal i.e. 5-20 mm for Feed coal and 0-5 mm for Injection coal lumps and fines.

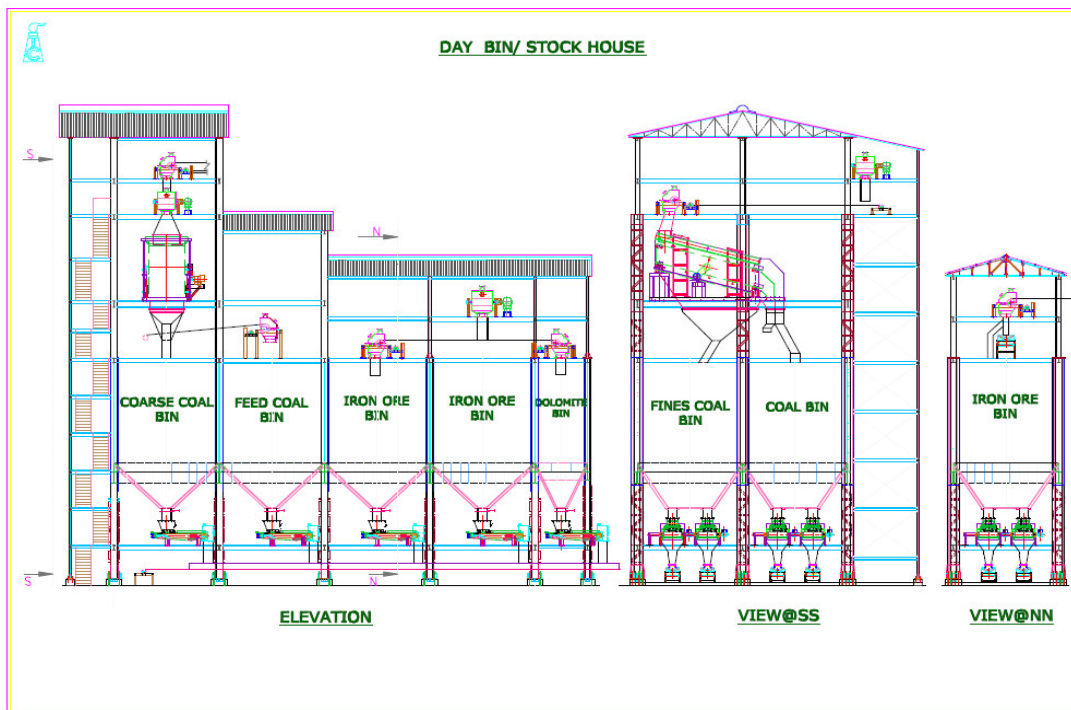


Dolomite crushing and screening is not required and purchased size 3-8 mm is directly fed to Day Bin through Conveyor.

All the raw materials from their discharge points are the fed to the Day bin through conveyors.

## **2- RAW MATERIAL STORAGE SYSTEM -**

It consist storage bins which are called as Day Bins. For different Raw material separate storage bins are provided. The bins are being designed for the storage of raw material for minimum of one day capacity.



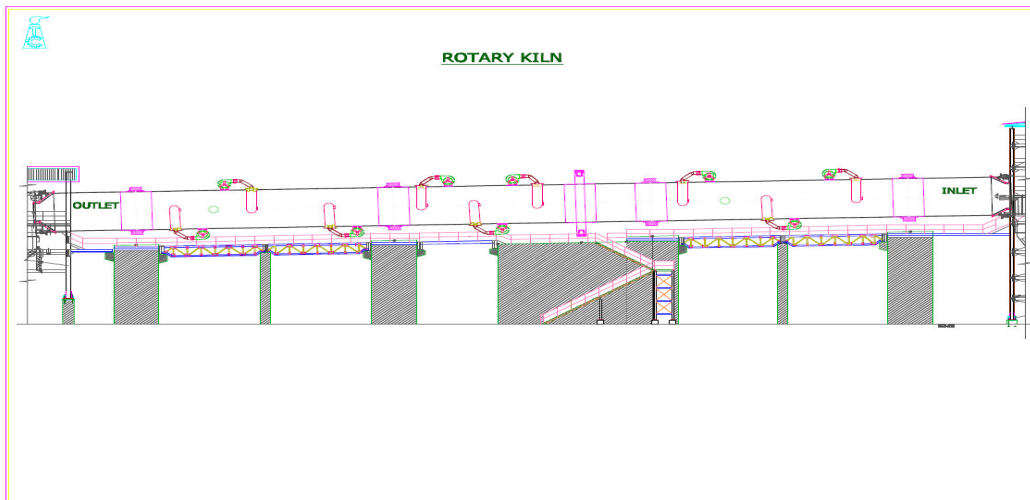
## **3. RAW MATERIAL FEEDING SYSTEM -**

Weigh feeders are provided below each bin to draw various raw materials in the required proportion from the bins and deliver to the conveyors for feeding into the Kiln.



#### **4. ROTARY KILN SYSTEM -**

The Rotary Kiln process is a well-established process for production of coal based sponge iron. Rotary kiln of certain dia and length is provided for reduction of Iron Ore into sponge iron using non-coking coal as reductant and Dolomite as sulphur scavenger; however the Diameter and Length are to be designed based on the Plant Capacities.



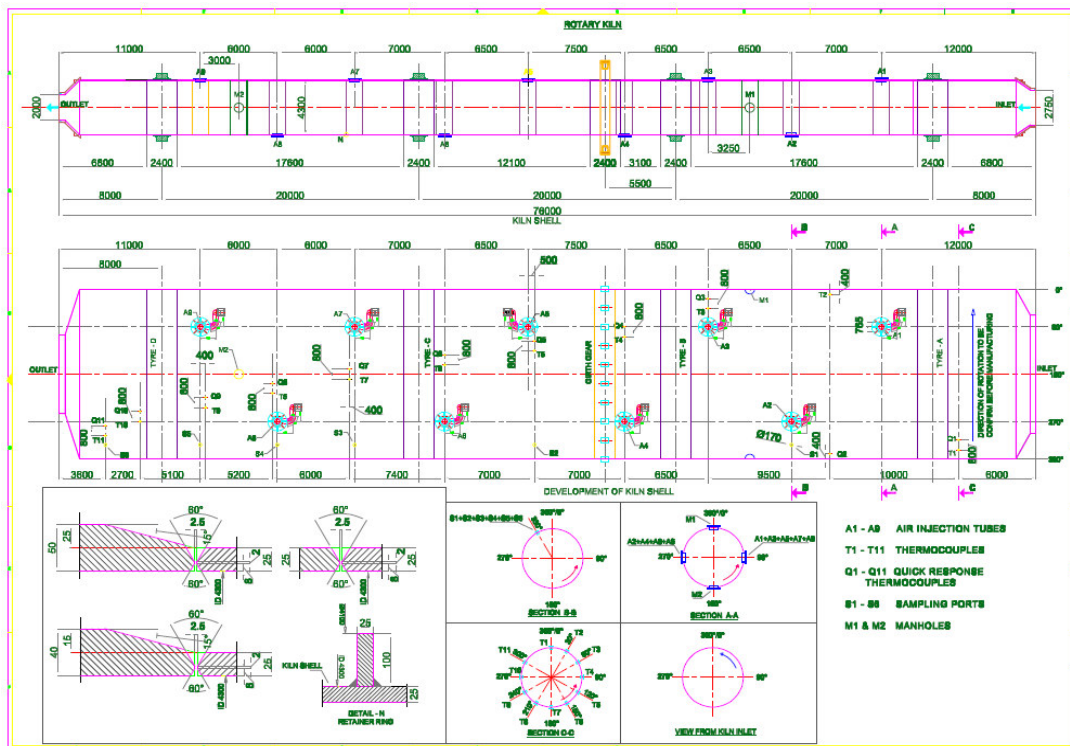
The kiln will be lined with high alumina castable refractories throughout its length with dams at feed end and discharge end.

The kiln is mounted with a slope of 2.5% down words from the feed end to the discharge end. A central burner located at the discharge end is used for initial heating of the kiln.

The kiln feed from the charging end consist of screened Iron Ore, Coal, and Dolomite. Air is supplied to the kiln through air ports provided on kiln periphery along the kiln length. This

ensures a controlled combustion resulting in a very even temperature profile.

A part of required coal will be thrown from discharge end pneumatically into the kiln. Necessary rotary feeder, compressor, piping, and valves will be provided for the injection system.



A number of air tubes are provided along the length of the kiln. The desired temperature profile is maintained by controlling the volume of combustion air through these tubes. Air is introduced through these tubes axially in the free space over charge.

The rotary kiln is broadly divided into two zones namely, the pre-heating zone and the reduction zone.

The pre-heating zone extends over 40 to 50 percent of the length of the kiln. In this zone, the moisture in the charge is driven off, and the volatile matter in the coal, liberating over a temperature range of 600 to 800 degree centigrade, is burnt with the combustion air supplied through the air tubes in the free space above the charge.

Heat from the combustion raises the temperature of the lining and the bed surface.

As the kiln rotates, the lining transfers the heat to the charge. Charge material, pre-heated to about 1000 °C enters the reduction zone. Temperature of the order of 1050 to 1100 °C is maintained in the reduction zone, which is the appropriate temperature for solid-state reduction of iron oxide to metallic iron. Thermocouple installed along the length of the kiln shell determines the thermal profile of the kiln.

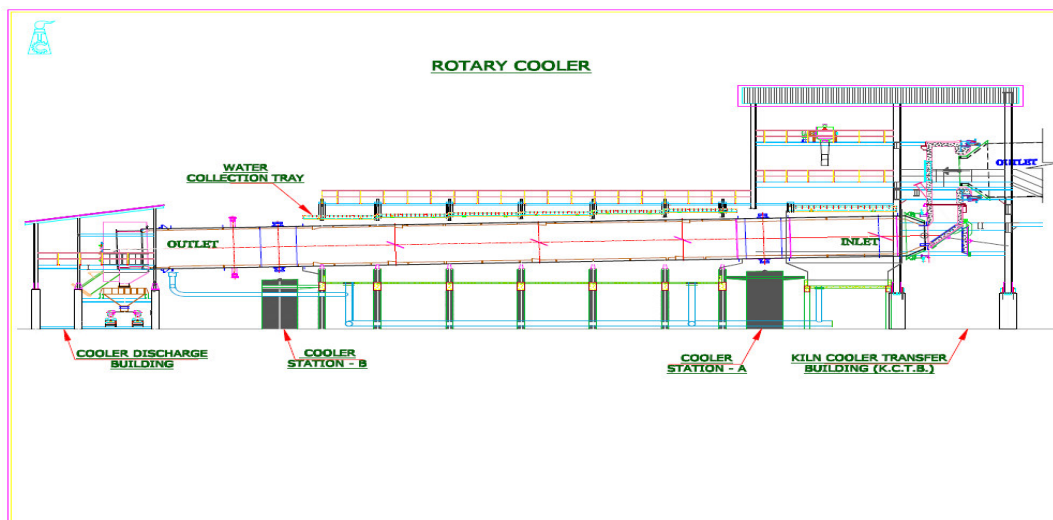
The temperature inside the kiln is controlled by regulating the amount of combustion air admitted into the kiln through ports with the help of fans mounted on the kiln shell and by controlled coal injection.

The iron oxide of the ore is reduced to metallic iron by carbon monoxide generated in the kiln from coal.

The reduced material from the kiln is then passes to Rotary Cooler though transfer chute for Cooling.

## **5. ROTARY COOLER SYSTEM -**

The reduced product is discharged into a rotary cooler along with coal ash, calcinated limestone and residual char, where they are cooled to below 110° C indirectly by spraying water on the outer surface of rotary cooler.



At the discharge end, the cooler will act as a screening section, which separates all the accretions larger than 50 mm from the reduced material.

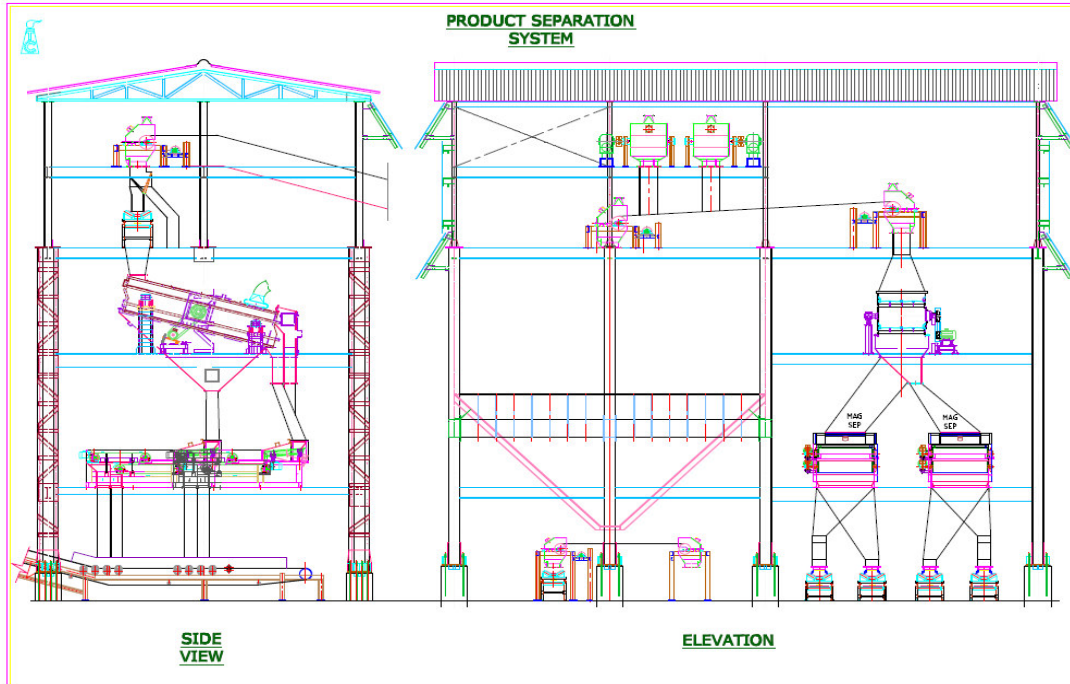
These lumps are discharged separately via lump gate. Rest of the material is discharged on a conveyor via double flap valve.

The product is then conveyed to the Product separation system through conveyor.

## **6. PRODUCT SEPARATION SYSTEM -**

It consist Vibrating Screen and Magnetic Concentrators.

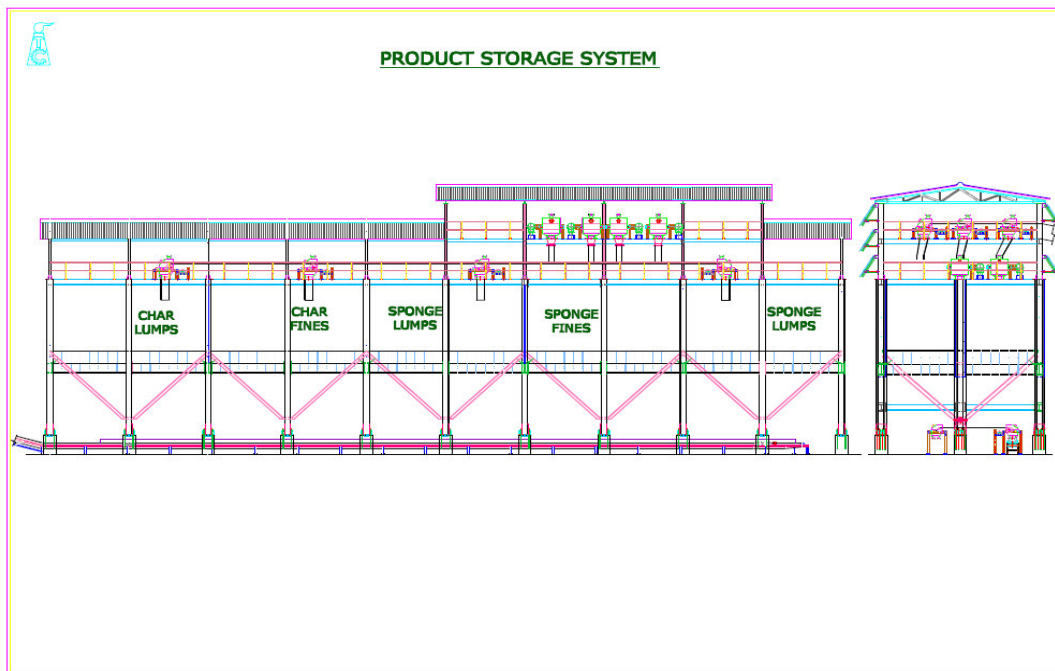
The cooled product is conveyed to the product separation building through belt conveyors. The products from the cooler discharge contain sponge iron, char and spent dolomite. In the product separation building, the product will be first screened in a double deck screen having 4mm and 20mm screens.



The screened product is being fed to magnetic separators for separation of magnetic and non-magnetic portions.

## **7. PRODUCT STORAGE SYSTEM -**

It consist storage bins known as Product Storage Bins. For Sponge Iron Lumps (4-20 mm) and Sponge iron Fines (0-4 mm) different storage bins are provided. Char generated in the plant is stored separately for use as fuel in the power plant.



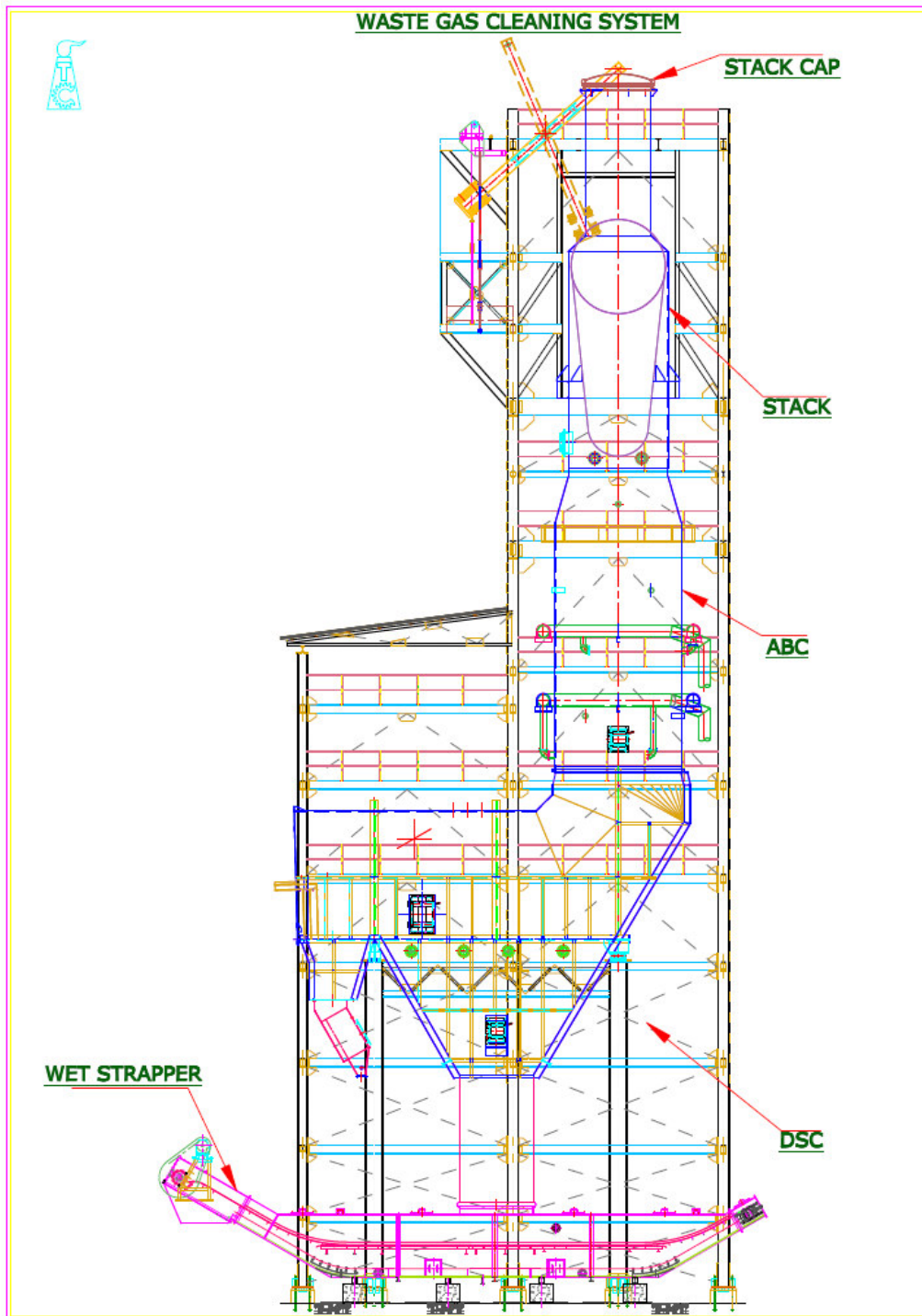
The bins are being designed for the storage of product for one day capacity.

## **8. PRODUCT LOADOUT SYSTEM -**

Volumetric Conveyors are provided below each storage Bin. The discharge of all volumetric conveyors is given in a common conveyor through which the product has to be dispatched.

## **9. WASTE GAS CLEANING SYSTEM -**

The flue gases are coming out from kiln is cleaned upto maximum level in this system.



### **1. Dust settling chamber (D.S.C.)-**

The flue gas coming out from the rotary kiln is passed through a dust settling chamber to settle down the dust by making slurry with water. The bottom of the dust settling chamber is immersed in the Wet Scrapper water, which is working as the



sealing to avoid the gas leakage and false air entry. Maximum amount of dust is settled in this chamber.

The dust collected by the Wet Scrapper will be fed to the waste heat recovery boiler after drying.

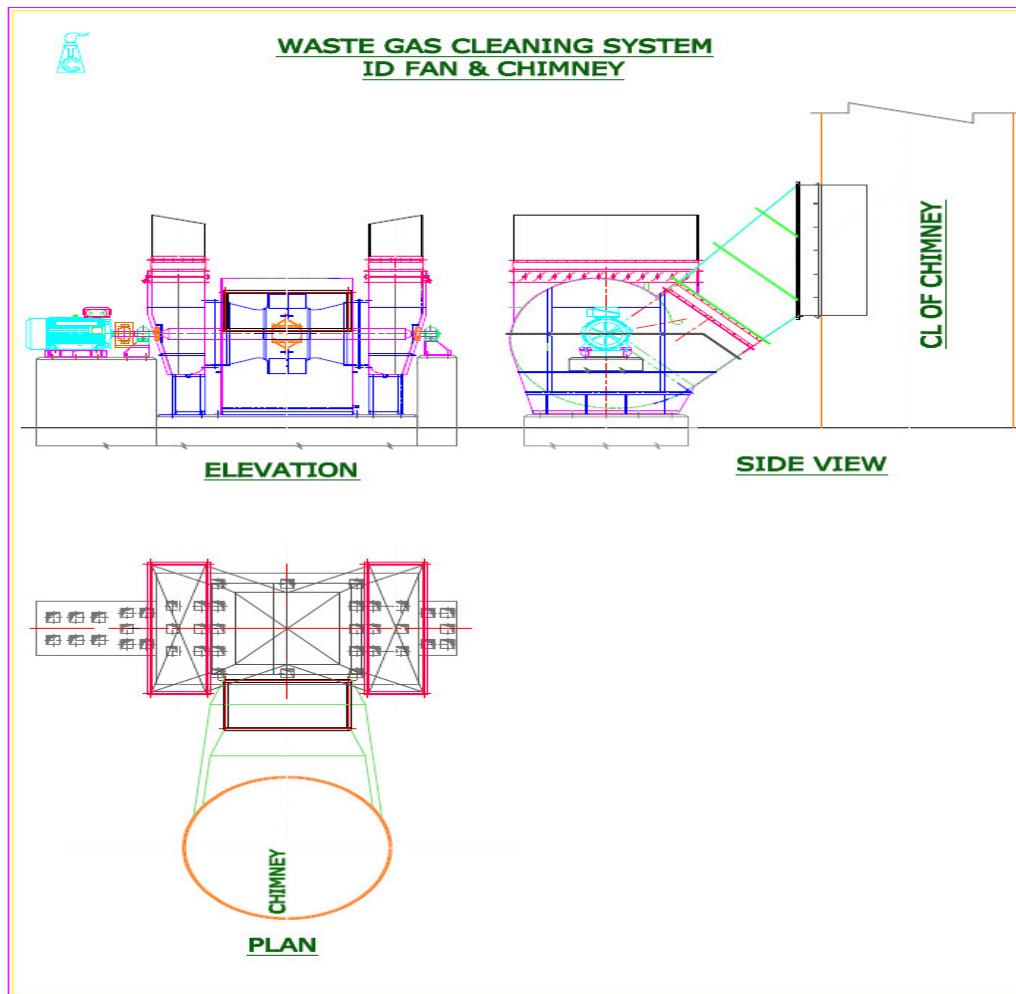
## **2. After burning chamber (A.B.C.)**

The gas passes through the after burning chamber in which the combustion of carbon monoxide and un burnt carbon takes place by giving required air.

The main aim after burning chamber is to reduce the carbon monoxide content in waste gas.

## **3. Wet Scrapper**

The dust settled at the dust settling chamber is collected by a wet scrapper in the form of slurry, which can be fed to the waste heat recovery boiler after drying.



#### **4. Induced Draft Fan (I.D.Fan)**

The gas passes from Electrostatic Precipitator (E.S.P.) to Chimney by the Induced Draft fan, which is located between E.S.P. and Chimney.

#### **5.Chimney**

The cleaned gases are being liberated in atmosphere through Chimney. The design of chimney is based on the parameters set by Pollution control board.

#### **10. UTILITY SYSTEM -**

Air compressor is being provided for the supply of air to operate pneumatic cylinders and jack hammers. For supply of cooling water, Cooling Towers and Water Pumps are provided.

## **11. POLLUTION CONTROL SYSTEM -**

### **1. Bag Filter system -**

In Raw material preparation system, Raw material feeding system, Product discharge system and product storage system the Bag Filter are provided.

The bag house, or dry dust collector, is an enclosed housing containing fabric filter bags which are suspended inside the unit.

The dust laden air is pushed or pulled through the filter bags, forming a dust cake to separate the particulate from the clean air.

The bags are cleaned with pulsing with compressed air.

It is extremely efficient and is typically able to clean without stopping the production process.

The collected dust will be used in the after burning chamber for complete combustion of carbon particles.

### **2. Electro-static Precipitator (E.S.P.)**

The flue gases are passed through an electro static precipitator from Dust Settling Chamber (DSC) in which, the gas is cleaned up to maximum level possible.

