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# Design, Manufacture &Commissioning Of 02 Ton Pit Type Furnace For Mill Scale Reduction Process.

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**ABSTRACT-** The present study focuses on the design, installation &optimization of a 02 Ton capacity of Pit type Furnace used for Mills Scale reduction that is fired electrically. The furnace may run with Oil / PNG / LPG as an alternative fuel by making necessary changes in combustion system only. The furnace has an overall combustion volume of 2.209m³. It is fitted with SS cylindrical pot with number of trays with spacers between two trays on the centrally located shaft to hold the charge in powder form for processing. Heating & reduction process carried out electrically to form pure iron powder at a temperature of 950˚C which is used in Powder Metallurgy. This furnace was designed to consume 100 KW to reach the temperature in 06 hrs. cycle per batch of 02 ton charge.
**Index Terms:** Mill Scale, Reduction, Pit type, Furnace, Combustion, KW (Kilowatt), Temperature, SS (Steel) Charge(Iron Oxide).

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## I. INTRODUCTION:

Mill scale is generally referred as scale only& regarded as waste. This Mill scale is generally consists of iron oxides & magnetite (FeO, $Fe_2O_3$, and $Fe_3O_4$) which in turn reduced to Fe by means of reduction process in this pit type furnace. Reduction process is the process where the Charged Pot is heated up to 500˚C and at this temperature a Mixture of 75% Hydrogen & 25% Nitrogen Is Purged in to the chamber continuously till 950˚C & soak time of 60 Minute. The moment 75% $H_2$& 25% Nitrogen is purged in to the charged pot reduction process starts. The excess Hydrogen Is burnt at the opening Port Of Furnace Lid: The Inlet Valve of $H_2$& $N_2$ is closed &the burning Port valve is closed & the charged pot is removed & kept for cooling. In this cooling process the expanded nitrogen contracts & the system will go in vacuum state.

Once the Charged pot is opened you will find the Mill scale oxide which has reduced and formed in 96 to 98 % purity Fe.

The indirect-fired furnace where the charge is in free space of combustion chamber which is heated by means of electric coils fitted on the periphery. The combustion chamber (around – 1250mm diameter X 1800 mm height & thickness 6 mm) is so designed that it accommodate the charge comfortably with compact size. The charge was heated to the required temperature & then reduced to iron powder by means of reduction process. Most of the local & std. available material is used to manufacture thus saving on foreign exchange.

## II. DESIGNING THE FURNACE:

To start design activity, following data collected from the customer. (Questionnaire Form)

- i Application of the Furnace - Reduction of Iron Oxide.
- ii Type / Size of charge – Iron oxides / powder form
- iii Capacity – 02 Ton.
- iv Cycle Time – 06 hrs.
- v Temperature required –950ºc.
- vi Fuel to be used –Electricity.
- vii Charge Volume – 2.2m³
- viii Furniture load - 01 Ton
- ix Automation required. - Yes

## III. DESIGN / INSTALLATION / COMMISSIONING - DESCRIPTION

The Furnace is Manufactured & Installed by M/s Agnee Engineering, Vasai.

**Design of Combustion Chamber:** Combustion chamber is designed by taking into consideration of SS310 pot to accommodate the charge + Combustion volume + Access volume to handle the pot smoothly.

i. Design of Combustion System: Combustion system is designed as per wattage of heating elements required. Heating elements fixed on the periphery of combustion chamber & Control panel for automation was made in-house by Agnee Engineering, Vasai.
ii. Design Of piping: The piping to pass the mixture of Nitrogen (25%) & Hydrogen (75%) through cylinder & to escape the same is done with regular SS 310 piping.
iii, Design Of mounting / Door / Other accessories – All fabrication work is carried out in-house with locally available material only.

**Installation Work:**

i. Steel shell (MS)–6 mm thick used as outer shell of the furnace as a cold face of the furnace.
ii. Refractory walls of the furnace -Two layers of ceramic module300 mm outer & 50 mm inner(SS cage in between for holding ) with density 160 kg/m3 .for 950ºc hot face constructed of insulating materials to retain heat in the combustion chamber at high operating temperatures.
iii. SS 310 pot to support or carry the iron oxides for reduction with centrally located shaft to hold the trays & spacers in between.
iv. Charging & discharging door at the top through which the charge is loaded & unloaded.
v. Loading & Unloading charge is through EOT Crane.

The power rating required for the furnace is calculated with the universal formula of heat input required.

$$\text{Heat Input} = \frac{\text{Mass} \times \text{Sp. heat (MS)} \times \text{Temperature}}{\text{Furnace efficiency} \times \text{Cycle time}}$$

$$= 3\times2.2\times0.12\times1742/(3.412\times6) = 67.39 \text{ KW}^*$$

$$= 67.39\times\text{Factor of safety } (1.5)$$

$$= 101.085 \text{ KW}$$

*Std. numerical values in required units.

Hence 100 KW rating heating elements are incorporated on the periphery of the hot face of the combustion chamber to heat up the charge electrically.

**Commissioning:** The Furnace was ready to start. Initially all equipment checked for proper heating, maintaining uniform pressure & supply of nitrogen & hydrogen through cylinder. Then heating element functioning is checked for supply of current to generate the heat inside the combustion chamber. Leakages in the piping line were arrested. Supply of signals through control panel to all equipment is checked. After checking is over the commission is done is following steps.

i. All mechanical &electrical operations were checked.
ii. Door opening & charge is placed inside the pot to start the process. Door closed.
iii. Current through heating coils to start heating & raise the temperature up to $500^0$C inside the combustion chamber. Supply of nitrogen & hydrogen through cylinder will automatically start when the combustion chamber temperature reaches 500 $^0$C.
iv. All interlocking were checked for safety.

Reduction process is a process where the charged pot is heated up to $500^0$C and at this temperature a Mixture of 75% Hydrogen & 25% Nitrogen Is Purged in to the chamber continuously till 950 $^0$C & soak time of 60 minute. The moment 75% Hydrogen& 25% Nitrogen is purged in to the charged pot reduction process starts. The excess Hydrogen is burnt at the opening port of furnace lid. The inlet valve of H2 & N2 is closed. The burning Port valve is closed. The charged Pot is removed & kept for cooling.

v. In this cooling process the expanded nitrogen contracts and the system will go in vacuum state .
vi. $2^{nd}$ Charged Retort is placed in the heating furnace for $2^{nd}$ batch of reduction.

## IV. OBJECTIVEOFTHEWORK:

The Main Objective of the above work is to optimize combustion controls by automation to enhance furnace efficiency & maintaining temperature uniformity inside the furnace. The big challenge was to create inert atmosphere inside the pot for process uniformly so as to achieve desired reduction & obtained the iron powder after the cycle is completed. The same is achieved with the help of controlling various factors through automation system.

**Temperature Control:** The most commonly control process parameters which are measured & monitored /controlled are temperature & pressure in all kind of furnaces.

Temperature control system consists of the following elements: A] Temperature sensors
B] Controllers
C] Heating Elements for heating the Furnace Electrically.
D] Control equipment of Automation

**Sensors:**
**Temperature:**

i) Bi-metallic strips: Uses the difference in coefficient of thermal expansion of two different metals. The principle is used in simple thermostats.
ii) RTD: Resistance of most metals increase in a reasonably linear way with temperature. Resistance measured is converted to temperature.

iii) Thermocouples: The thermocouple is based on the thermoelectric effect/e.m.f. generated when two conductive wires of different metals at different temperatures are connected to form a closed circuit. In classical physics this is known as siebeck-peltier effect. Because of the wide range of temperatures covered, good sensitivity to change of temperatures

Table1.1:Thermocouple

| Type | Composition | Useful Temperature range [ °c ] |
|---|---|---|
| J | Iron - Constantan | -180 to +760 |
| T | Copper - Constantan | -200 to +350 |
| K | Chromel - Alumel | -180 to +1200 |
| R | Pt-Pt/Rh 13% | 0 to 1400 |
| S | Pt-Pt/Rh 10% | 0 to 1450 |
| B | Pt/Rh6% -Pt/Rh30% | 0 to 1700 |

**B] Fluid flow measurement:**

Differential pressure method: Most widely used method of measuring fuel/air flow in furnace. Common instruments Orifice plate, Venturi tubes etc.

Direct flow measurement: Equipment used are Rota meter, Turbine meter, Vortex flow meter etc. Under very special case ultrasonic flow meter may be used.

**Controllers:**

In closed loop temperature control the temperature is measured by using a suitable sensor. The controller compares the temperature signal to the desired set point & actuates the final control element. The final control element varies the amount of heat added to the process by varying power supply to heating elements.

Four types of control actions are

- ON/OFF [Two position]
- Proportioning [Throttling]
- Proportioning plus integral [Automatic reset]
- PID [Rate]

**Control Valves:**

Control elements popularly used are automatic flow control valves. The valves may be motorized /pneumatically operated & work in conjunction with controller signal. Mechanically operated diaphragm type fuel flow control valves commonly known as ratio regulating valves are widely used in volumetric flow control circuits. Pressure control scheme of a furnace works on a principle similar to temperature control scheme. The entire temperature control system is done though a linking of thermocouple inside the combustion chamber, PID controller & power supply to the heating elements.

The requirement of the job was to achieve the desired temperature& creating the inert and linearity of output [over a wide span of temperature], thermocouples is widely used for measurement of temperature.

The composition & maximum use temperatures for various standard thermocouples are given in the table1.1.

While carrying out the process, inert atmosphere created inside the pot so as to achieve iron powder by necessary reduction.

By controlling the temperature inside the furnace, efficiency of the furnace was increased when the furnace was loaded with full capacity & in operation.

Heat Losses: At high temperature, the dominant mode of heat transfer is wall radiation. The heat losses should be minimum to increase the furnace efficiency. This is done by maintaining the proper insulation in refractory lining - Ceramic module 160 kg/m3 density for temperature 950ºc to get required refractoriness & minimum heat losses from the furnace wall. Further heat leakages thru' doors, furnace wall opening were arrested by sealing to upgrade the furnace performance.

For oil/gas firing, control of exhaust flue needs to be done by placing the damper in the passage of exhaust flue & controlling the same by closing the passage of exhaust flue. Initially the damper closed the ¼ passage & results to be checked which can shows the improvement in fuel saving. The action repeated by closing the damper till maximum improvement is done.

By arresting leakages through various openings, controlling the Damper of exhaust gases, Proper Insulation etc., efficiency of the furnace can be optimized while the furnace is loaded with job & in operation.

## V. FINAL RESULT:

The Reduction process is satisfactorily completed to reduce mill scale to 96 to 98 % pure Fe.

## VI. CONCLUSION:

This research &study of the conditions of mill scale reduction, a by-product of iron and steel formed during the hot rolling of steels, with a reducing gas (carbon monoxide) in order to produce iron powder having characteristics required by powder metallurgy. The reduction was carried out at temperature (950°C) with time of 180 min in an inert atmosphere. The produced iron powder can be characterized by the chemical analysis, x-rays diffraction, optical microscopy and scanning electron microscopy.

These methods of investigation confirm the presence of iron, graphite and iron carbide ($Fe_3C$) as the products of reactions. A reduction annealing under hydrogen makes it possible to decrease carbon and oxygen content of the reduced iron powder.

Further this study & research work has proved beyond reasonable doubt that, given the perfection to various parameters, right environment & necessary support, local raw materials with IS certification can be efficiently used to design &manufacture a heating equipment rather than just importing that can provide the desired output. Also local material will make easy availability of components, which hitherto could have been imported from overseas, thereby saving foreign exchange. Its comparative cost advantage when compared with imported ones gives additional credit.

**Scope Of Future Study**

Better quality product needs study &understanding of operating temperature, cycle time, and impurity content. It is suggested to trial of using the furnace with other fuels.

## RECOMMENDATIONS

There is always scope of further development. In order to improve on the design, it is recommended to the end user to monitor the operation of furnace continuously.

Fig. 1.1 – Loading & unloading the charge.

Fig. 1.2 – Excess Hydrogen burnt through Furnace lid.

Fig. 1.3- Control Panel

**Factors For Optimization**

Design of combustion system, temperature control, incomplete combustion(for Oil/Gas fired furnace), design of combustion chamber, design of wall thickness, design of chimney, heat losses, overall equipment effectiveness are major consideration while designing any furnace.

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