Design, Manufacture & Performance Upgradation of 16 Ton (MS) Bogie Hearth Furnace

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Abstract- This study & research work focuses on the design, Installation & optimisation of a 16 Ton capacity of Bogie Hearth Furnace used for MS round plate heat treatment for forgings of dish end of pressure vessel that is fired by LDO / Diesel as a fuel. The furnace may be run with PNG / LPG as an alternative fuel by making small changes in combustion system only. The furnace has an overall combustion Volume of 44.4 m^3. It is fitted with a chimney to allow for the escape of combustion flue gases. The combustion air blower discharge air into the furnace at the rate of 1400 m^3/hr with an air fuel ratio 11:1. This furnace was designed to consume 100 litters of LDO per Hour fuel with a rating of 40000 BTU / liter which is required to raise the temperature of 16 Ton MS round plate to 1050ºC. These MS plates are then forged in the press to manufacture the dish end of pressure vessel. The theoretical efficiency of the furnace is considered to be 30% for design calculations.
The cost of the furnace is Rs. 37,00,000 /-.

Index Terms- MS (Mild Steel), Bogie Hearth, Furnace, Combustion, Burner, Blower, Temperature, Efficiency, Air-Fuel Ratio.

I. Introduction

The direct-fired furnace where the flame is in free space above the charge & not directly on the charge was designed to manufacture Dish end for pressure vessel. The charge (Round MS plate – 3000mm diameter. X 120mm thick) was heated to the required temperature & then forged to the desired shape. Most of the local & std. available material is used to manufacture thus saving on foreign exchange.

IA Designing the furnace:

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

1. Application of the Furnace - Forging
2. Type / Size / Qty. of charge – MS round Plate / Diameter.- 3000mm / weight 08 Ton / 02 nos.
3. Capacity – 16 Ton.
4. Cycle Time – 15 hrs.
5. Temperature required – 1050ºc (After 300ºc, 50ºc rise per hour).
6. Fuel to be used – LDO / Diesel
7. Charge Volume – 6.9 m^3
8. Automation required. - Yes

IB Design / Installation / Commissioning - Description:

The Furnace is Manufactured & Installed by M/s AGNEE ENGINEERING, VASAI [Mr.Arunkumar Shetty (M-09422074436)]. The Furnace is in operation at ICEM ENGINEERING PVT. LTD., WADA, DIST. THANE, MAHARASHTRA, INDIA.

1. Design of Combustion Chamber:

Combustion chamber is designed by taking into consideration of charge volume + Combustion volume + Access volume to handle the charge smoothly.

2. Design Of Combustion System:

Combustion system is designed to fire 100 LPH with an air fuel ratio 11:1. The complete combustion system was procured from Wesman Group of Companies (Pioneer & leader in Foundry & Furnace Business in India), Some accessories procured from Honeywell - Global leader & Control panel for automation was made in-house by Agnee Engineering, Vasai.

3. Design Of Chimney: The diameter of the chimney was maintained 500 mm with damper to control & escape flue gases.
4. Design Of Trolley / Door / Other accessories – All fabrication work is carried out in-house with locally available material only.

❖ Installation Work:

- Steel shell (MS) constructed for supported for casing.
- Refractory chamber (Complete with ceramic module with density 128 for 1050ºc constructed of insulating materials to retain heat at high operating temperatures.
- Hearth (Trolley) to support or carry the steel, which consists of refractory materials supported by a steel structure, with sand sealing arrangement for heat escape.
- Chimney to remove combustion exhaust gases from the chamber.
- Charging & discharging doors through which the chamber is loaded & unloaded.
- Loading & Unloading charge is through EOT Crane.

Table: Bill of Engineering Measurement & Evaluation

Description	Total [Rs.]
Fabrication(MS plate,angles,channels etc.)	5,00,000/-
Insulation (Ceramic module 128 size)	3,50,000/-
Combustion system	5,00,000/-
Control Panel for automation & controls	3,50,000/-
Automatic Door,Trolley Machinery(Gear box , Bars etc.) , chimney, control valves,	10,00,000/-
Proprietary, Design/ Installation / Commissioning, Labour, etc..	10,00,000/-
Total [Rs.]	37,00,000/-

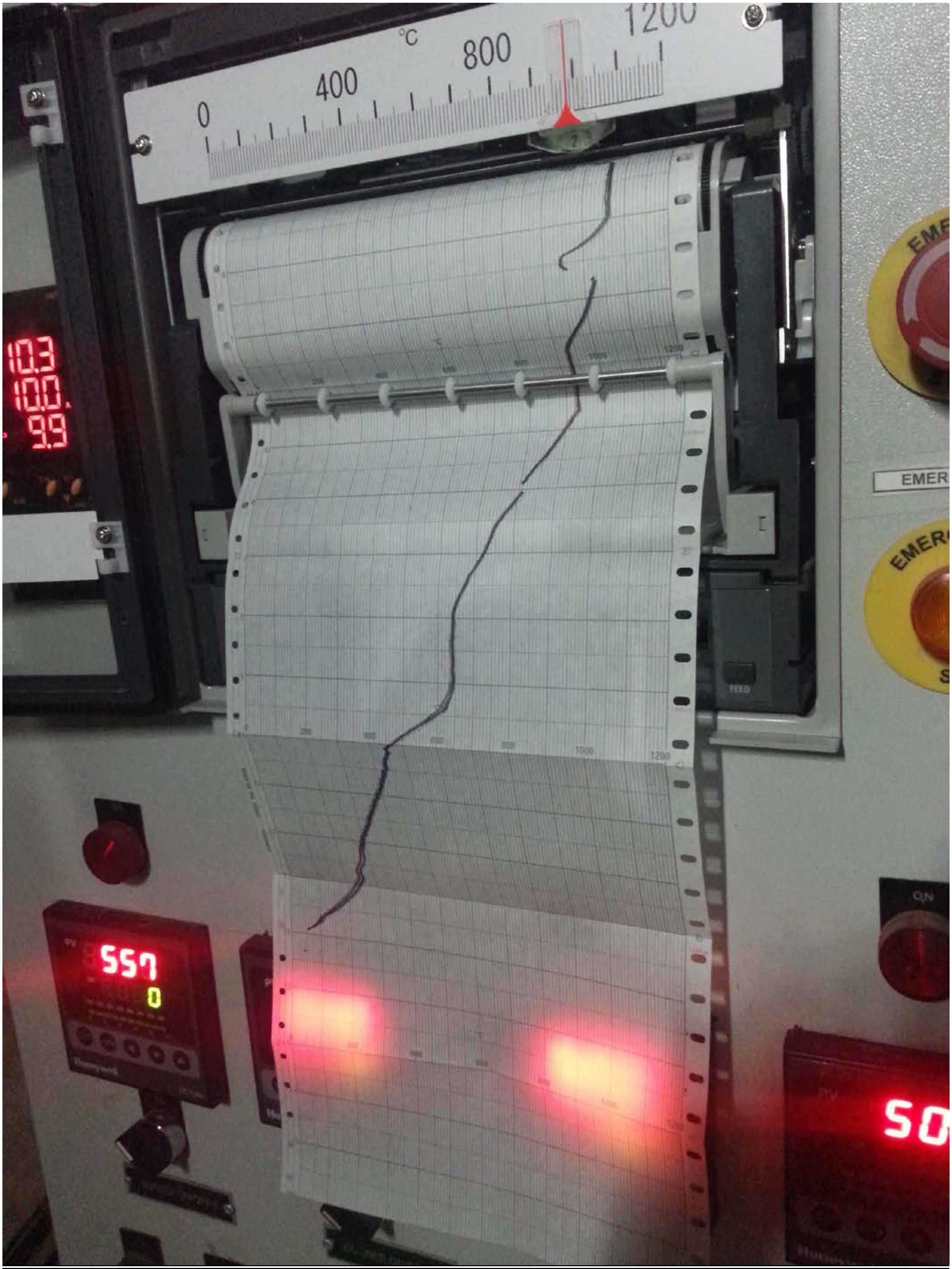
Commissioning:

The Furnace was ready to fire. Initially Oil ring main is checked for proper heating, maintaining uniform pressure & supply of Oil to the Burner. Then Blower is checked for supply of air to the Burner with the desired pressure. Leakages in both the piping line were arrested. Then supply of signals thru' control panel to all equipments are checked. After checking is over the commission is done is following steps.

1. Mechanical operations were checked.
2. Door up & down, Trolley in & out as per speed limit set.
3. All interlocking were checked for safety.
4. Ceramic Burner blocks are preheated with some solid fuels like cotton waste etc. for 10 to 15 minutes.
5. Blower started for 05 minutes to start supplying air to the Burner & necessary purging is done.
6. After checking the supply of air for 05 minutes, Oil ring main pump is started to circulate the Oil thru' ring main. During this period all Burner Oil control valves were closed. Uniform Oil pressure 25 to 30 PSI in the ring main is maintained.
7. The Burner was fired automatically by providing pilot & UV flame detector in the burner.
8. Initially the air control valve was kept on ¼ opening & by slowly opening the oil control valve, flame (Low fire) was generated inside the furnace.
9. The flame is checked for stability for 10-15 minutes & then by slowly opening & controlling both air & Oil control valve till max, flame (High fire) is generated. The flame is checked for stability for 10-15minutes.
10. The Air control valve & Oil control valve are then operated between High fire & low fire for flame stability between maximum & minimum firing.
11. **11.** The 16 Ton charge was then loaded inside the furnace & by firing all 04 Burners, the desired temperature of 1050ºc in the cycle period of 15 hrs. (After 300ºc, the rise of 50ºc/hour to be maintained till it reaches to 1050ºc).

II. OBJECTIVE OF THE WORK

The Main Objective of the work is to optimise combustion controls by automation to enhance furnace efficiency & maintaining temperature uniformity inside the furnace. The big challenge was to maintain the rise in temperature by 50ºC per hour after 300ºC uniformly so as to reach the temperature 1050ºC to maintain ±10ºC across the process from 300ºC to 1050ºC (shown in graphical representation. Refer annexure III).The same is achieved with the help of controlling various factors through automation system.



III.

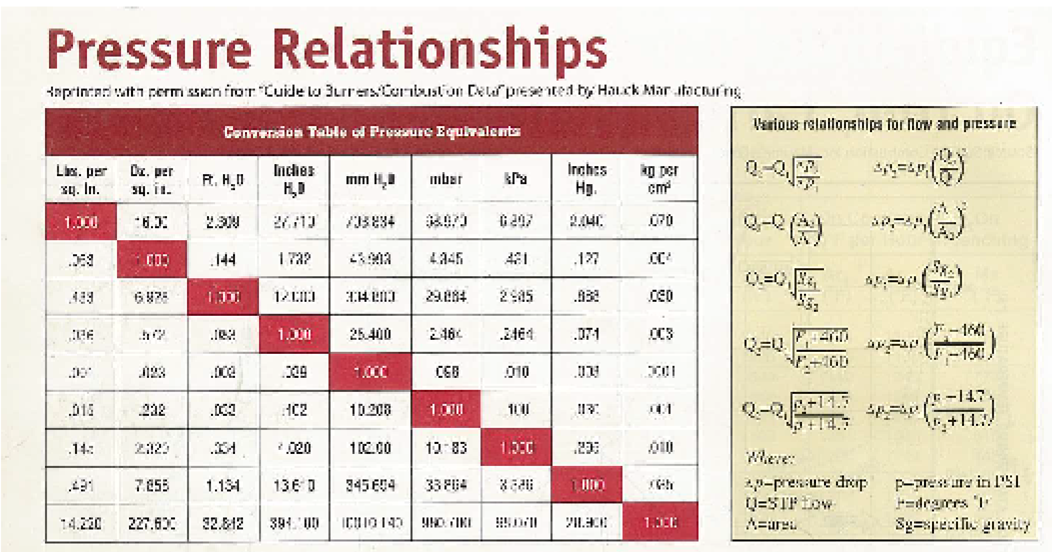
IV. PERFORMANCE UP GRADATION / CONTROLLING & OPTIMISATION

Factors affecting the performance & efficiency of furnace.

- Incomplete combustion: This is due to improper ratio of air/fuel & atomisation of fuel. Due to this the fuel get wasted & efficiency of the furnace is decreased.
- Temperature control: This is one of the important factors to be considered. The temperature inside of the furnace needs to be controlled to the desired degree to get better product quality as well as improving the furnace efficiency
- Design Of combustion chamber: The combustion chamber needs to be properly designed so that it accommodates charge, Burner flame & flue gases inside the furnaces. There should be maximum heat transfer to the charge & minimum heat losses.
- Heat Losses: At high temperature, the dominant mode of heat transfer is wall radiation. The heat losses should be minimum to the performance & increase the furnace efficiency.
- Overall equipment effectiveness: The Burner / Blower / Pumping unit / controls should work effectively to get the optimum usage & thereby upgrading the furnace performance.

❖ The following factors, which were studied & controlled to optimum level for achieving the objective of the work. Thus upgrading the furnace performance & increase in furnace efficiency.

A. *Incomplete combustion:* The Blower air pressure required at the burner should be 28" wc for light Oil & 38" for heavy Oil for better atomisation. The pressure at burner checked & by arresting various leakages in the pipeline desired air pressure at the burner is achieved. Secondly Air/ Fuel ratio for complete combustion is required 11: 1. This can be checked by producing maximum bright yellowish flame inside the furnace, which ensures that the Oil is burning completely. Exhaust gases colour should be colourless to ensure complete burning of oil. Volumetric / mass flow control is another source of maintaining proper air- fuel ratio for perfect combustion. This is done by either putting flowmeter or pressure gauge in the oil line & air line. The pressure vs. flow relationship formula as shown below.



Pressure Relationships

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Conversion Table of Pressure Equivalents

Lbs. per sq. in.	Oz. per sq. in.	Ft. H_2O	Inches H_2O	mm H_2O	mbar	kPa	Inches Hg.	kg per cm^2
1.000	16.00	2.309	27.710	703.834	68.970	6.897	2.040	.070
.063	1.000	.144	1.732	43.993	4.345	.431	.127	.004
.433	6.928	1.000	12.000	304.800	29.894	2.985	.882	.030
.036	.577	.083	1.000	25.400	2.484	.2484	.074	.003
.001	.023	.003	.039	1.000	.098	.010	.003	.0001
.015	.232	.033	.402	10.208	1.000	.100	.030	.001
.145	2.320	.334	4.020	102.00	10.183	1.000	.295	.010
.491	7.855	1.134	13.610	345.694	33.864	3.386	1.000	.035
14.220	227.600	32.842	394.100	10010.140	980.700	98.070	28.960	1.000

Various relationships for flow and pressure

$$Q_2=Q_1\sqrt{\frac{\Delta p_2}{\Delta p_1}} \qquad \Delta p_2=\Delta p_1\left(\frac{Q_2}{Q_1}\right)^2$$

$$Q_2=Q_1\left(\frac{A_2}{A_1}\right) \qquad \Delta p_2=\Delta p_1\left(\frac{A_1}{A_2}\right)^2$$

$$Q_2=Q_1\sqrt{\frac{Sg_1}{Sg_2}} \qquad \Delta p_2=\Delta p_1\left(\frac{Sg_2}{Sg_1}\right)$$

$$Q_2=Q_1\sqrt{\frac{F_1+460}{F_2+460}} \qquad \Delta p_2=\Delta p_1\left(\frac{F_2-460}{F_1-460}\right)$$

$$Q_2=Q_1\sqrt{\frac{p_2+14.7}{p_1+14.7}} \qquad \Delta p_2=\Delta p_1\left(\frac{p_1-14.7}{p_2+14.7}\right)$$

Where:
Δp=pressure drop; p=pressure in PSI
Q=STP flow; F=degrees °F
A=area; Sg=specific gravity

By controlling Air-Fuel Ratio inside the burner, efficiency of the furnace was increased by 05% while the furnace was loaded & in operation.

B.Temperature Control: The most commonly control process parameters which are measured & monitored /controlled are temperature & pressure.

Temperature control of a fuel-fired furnace is done by:

i. Volumetric flow control of fuel & air to the burners.
ii. Mass flow control of fuel & air to the burners.

Temperature control system consists of the following elements:

A] Temperature sensors
B] Controllers
C] Fuel & air flow measuring equipment
D] Fuel & air control equipment

SENSORS:

A] 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 and linearity of output [over a wide span of temperature], thermocouples are widely used for measurement of temperature.

The composition & maximum use temperatures for various standard thermocouples are given in the table below.

Type	Composition	Useful Temperature range [ºc]
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 – Equipments used are Rotameter, 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 flow of fuel & air through control valves.

Four types of control actions are

1. ON/OFF [Two position]
2. Proportioning [Throttling]
3. Proportioning plus integral [Automatic reset]
4. 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.

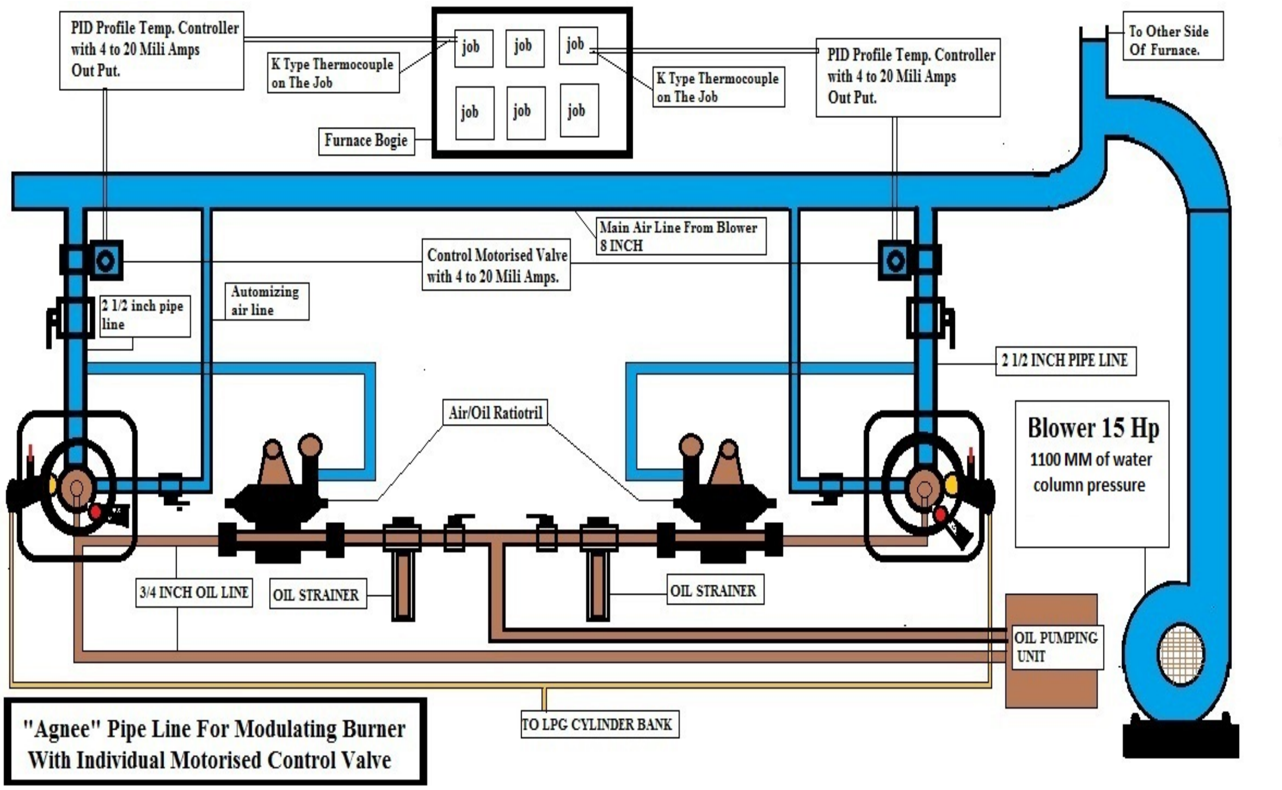
Mechanically operated diaphragm type fuel flow control valves commonly known as ratio regulating valves are widely used in volumetric flow control circuits.

Pressure control scheme of a furnace works on a principle similar to temperature control scheme.

The entire temperature control system of controlling volumetric flow of air & fuel thru' modulation was bought from

Wesman-North American combustion system, which is proven technology all over the world for many years.

The piping schematic is shown in Annexure II attached herewith.



The requirement of the job was the temperature to be controlled in such way that there is temperature rise of 50ºc /hour after 300ºc till it reaches 1050ºc which was a major task & required certification from authorised body like NABL- National Accreditation Board for Testing & Calibration Laboratories (+10% to –10% allowed). This was achieved by proper control of fire with individual setting of burner, by increasing the no. of thermocouples to 20 nos. adjusting the position of thermocouples & trolley w.r.t. flame position & maintaining proper insulation of combustion chamber the desired result achieved. This was a research work & completed with certification of authorised regulatory body NABL.

By controlling the temperature inside the furnace, efficiency of the furnace was increased by 08% when the furnace was loaded with full capacity & in operation.

C. Heat Losses: At high temperature, the dominant mode of heat transfer is wall radiation. The heat losses should be minimum to the performance & increase the furnace efficiency.

This is done by maintain the proper insulation in refractory lining - Ceramic module 128 density for temperature 1050ºc to get required refractoriness & minimum heat losses from the furnace wall. Further heat leakages thru’ door, furnace wall opening were arrested to upgrade the furnace performance.

Finally control of exhaust flue was 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 1/8 passage & results were checked which shown 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 was increased by 12% while the furnace was loaded with job & in operation.

Final Result:

The fuel consumption at the initial stage without automation & control say for example was about 100 LPH (Liters per Hour). This fuel consumption brought down to 75 LPH with automation & necessary control of factors as mentioned above thereby saving & increase in furnace efficiency of 25%. The Furnace is in operation at M/s ICEM ENGINEERING PVT. LTD., WADA, DIST. THANE.

V. CONCLUSION

This study & research work has proved beyond reasonable doubt that, given the perfection to various parameters, right environment & necessary support, local raw materials can be efficiently used to design a heating equipment that can provide the basis upon which our heavy scale jobs can be forged easily. Further 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.

VI. SCOPE OF FUTURE STUDY

For better quality & cleanliness of the space it is suggested that the furnace can be used for other fuel options i.e. LPG / PNG.
The firing can be done much smoothly. The Heating & pumping station is not required. Atomisation of fuel is not required in case of PNG / LPG. The safety equipment is must when using LPG / PNG.

VII. RECOMMENDATION

There is always scope of further development. In order to improve on the design, it is recommended to add recuperator which intake temperature of hot flue gases escaping from the furnace to the atmosphere & gives it to the combustion air for preheating. This will further enhance the efficiency by 10 to 15%. This Furnace is strongly recommended for heating of heavy jobs to be forged subsequently the furnace can be used for small capacity by controlling the firing depending on requirement. The Furnace is so designed that it can take a maximum load upto 25 Ton as well as load of 16 Ton well efficiently by effective combustion controls.

ACKNOWLEGEMENT

I wish to thank you to the Principal, HOD-Mechanical, Project guide of Yadavrao Tasgaonkar College Of Engineering & Management for extending their co-operation to submit my Study on the subject:

DESIGN, MANUFACTURE & PERFORMANCE UPGRADATION OF 16 TON (MS) BOGIE HEARTH FURNACE

I also thanks to
M/S AGNEE ENGINEERING, VASAI
[Mr. Arunkumar Shetty – Proprietor (M-9324154436)] ,

The Furnace Manufacturer &
M/S ICEM ENGINEERING PVT. LTD.
[Mr. Vishal Tibrewala – MD (M-9820071385)] ,
The end user who extended their co-operation to complete my Study during my visit to their place. This study contains overall Design, Manufacture & performance upgradtaion of 16 Ton (MS) Bogie Hearth Furnace used for forgings of Dish end of pressure vessel.

Furnace Photograph –

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