International Journal for Ignited Minds (IJIMIINDS)

Design and Analysis of Waste Heat Recovery System to Improve the Performance of Blast Furnace

K Nagaraja Rao[a], Chandrashekar Hiregoudar[b] & M. Jeethendra[c]

[a]*PG* student,Department of PG studies RYMEC, Bellary, Karnataka.
[b]*Asst* Prof, Department of PG studies RYMEC, Bellary, Karnataka.
[c]Asst General Manager, JSW Steels Vidyanagar, Bellary, Karnataka.

ABSTRACT

In the present work waste heat recovery system is designed to integrate the heat of waste gas in the blast furnace stoves process. For this reason a case study of distinctive Blast furnace stoves is measured. The waste gas from a Blast furnace stoves exits at a temperature of around 350 to 400^{0}C. A lot of sensible heat is lost with these gases. This heat is utilized to preheat the air entering to stoves. Further, the waste gas at reduced temperature is used to pre heat BF gas & Combustion air. Consequently, considerable energy savings is achieved which increases the efficiency of the process manifold. The objective of this project is to design a suitable heat recovery system for above cases which can efficiently remove the sensible heat and put it to use.

Keywords - *Waste Heat, Recovery, Waste Heat Utilisation, Design*.

1. INTRODUCTION

The task activity will utilize waste heat generated during combustion of fuels at stoves, for preheating of combustion air and Blast Furnace gas. By this project activity, the flue gas temperature of Blast Furnace stoves reduces from 400^{0}C to 189^{0}C With this task action, the waste vitality conveying medium is recouped and consequently lessening extra fuel utilization in stoves. The recovery of flue gas from recuperates system i.e. massive structure with holding of number of mild steel pipes are using to extract heat from outgoing gases, however the recuperates are exerts heat from waste gas by horizontal pipe lines due chemical reaction in mild steel pipes it get damage quickly.

The Blast Furnace is envisaged with three numbers of stoves. The stoves are heated by mixture of in-house generated BF gas and Coke oven gas. The stoves maintain a dome temperature of 1375^{0}C, when stove attain dome temperature of 1375^{0}C, the fuel (BF gas and Coke oven gas) gas consumption will be cut off and cold blast air which is generated in Power Plant blowers (high pressure compressors) at pressure of 3.0 bar 140^{0}C pass through the stove and becomes hot blast air and goes to Blast Furnace through tuyeres and melt iron oxides and produce hot metal.

The stove will transfer heat for period of 30-35 minutes and another stove which is in firing (heating) mode will be switched on and the process operates continuously. Two Stoves will be on heating mode(use fuel for generating heat) and one stove will be blast mode(transfer heat from regenerative chaqure bricks to blast air). During the heating operation of Blast furnace stoves, the flue gases after generation of heat will exit through chimney. In normal circumstances, the waste gases exit from the blast furnace stoves at temperature e of >350^{0}C and estimated volume of waste gases is 385200 m^3/hr and heat is lost to atmosphere.

1.1 Preface of Waste Heat Recovery System.

The reduction or reuse of waste heat provide as exceptional opportunity for saving with in industrial commercial and institutional facilities are use in this system. (Source: Waste heat recovery Energy management series for industry commerce and institutions)

Heat Exchange Equipment:

1) Shell and Tube Heat Exchanger
2) Waste Heat boilers Heat Exchanger
3) Fin Tube Heat Exchanger
4) Spiral Heat Exchanger
5) Concentric Heat Exchanger

6) Plate Heat Exchanger
7) Run –Around system Heat Exchanger
8) Heat wheels Heat Exchanger
9) Heat pipes Heat Exchanger.

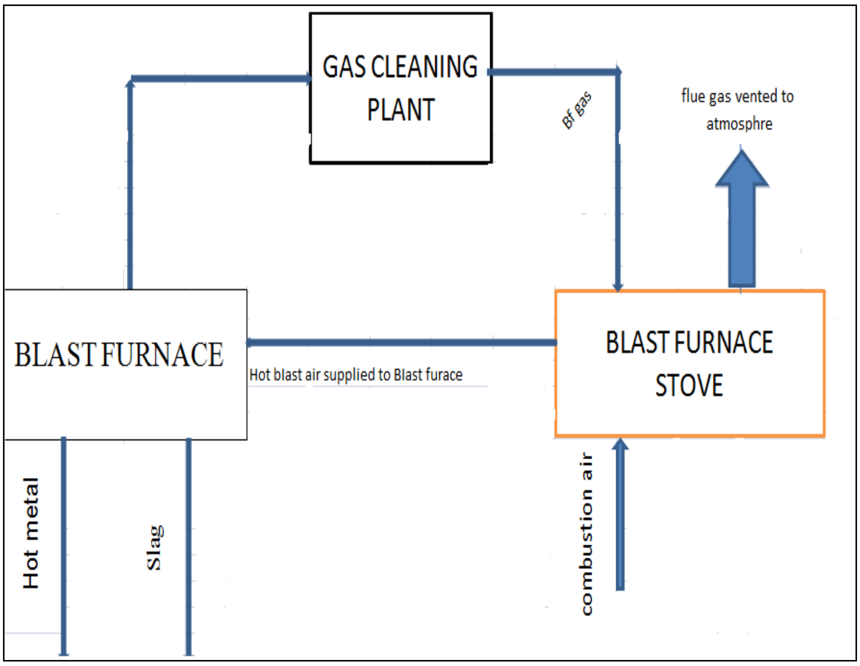
2. METHODOLOGICAL

The type of energy flow includes heat flow which will be supplying additional energy to Blast furnace stoves. The type of equipment to be installed under project activity includes two numbers of heat exchangers and associated ducting systems, valve, pipes and control system. The control system includes auto operation to bypass the waste heat recovery system in case of emergency or irregular conditions, the heat recovery system will be bypassed and waste heat will be directly released to atmosphere

The project includes flue gas ducting, heat exchange pipes, heat exchanging liquid. The heat recovery system consisting of heat pipe modules is particularly well suited to transfer the heat between waste gas and combustion air and BF gas utilized into hot stoves. The heat is transferred to the cold combustion media by a great number of heat pipes; each of them is operating independently and requires no additional energy. The wall temperatures at the waste gas side are kept higher than the dew point temperatures to avoid acid condense formation and consequent corrosion.

The type of energy flow includes heat flow which will be supplying additional energy to Blast furnace stoves. The type of equipment to be installed under project activity includes two numbers of heat exchangers and associated ducting systems, valve, pipes and control system. The control system includes auto operation to bypass the waste heat recovery system in case of emergency or irregular conditions, the heat recovery system will be bypassed and waste heat will be directly released to atmosphere

The project includes flue gas ducting, heat exchange pipes, heat exchanging liquid. The heat recovery system consisting of heat pipe modules is particularly well suited to transfer the heat between waste gas and combustion air and BF gas utilized into hot stoves. The heat is transferred to the cold combustion media by a great number of heat pipes; each of them is operating independently and requires no additional energy. The wall temperatures at the waste gas side are kept higher than the dew point temperatures to avoid acid condense formation and consequent corrosion.



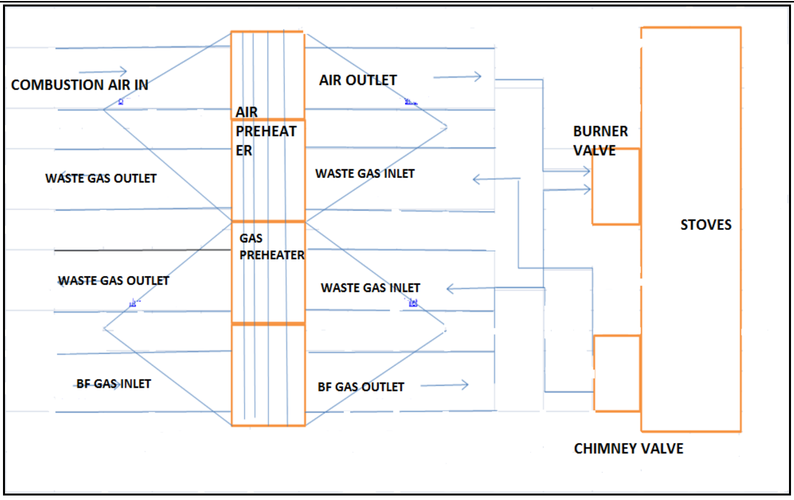


Fig 1: Schematic Layout of Gas Cleaning Plant.

3. EQUATIONS AND CALCULATIONS

1. Cold blast volume : 2660 Nm^3 /hrs
2. Required Hot blast temperature : 1200^0C
3. BF gas pressure : 650 MMWC
4. Bf gas temperature : 40^0C
5. Combustion air temperature : 40^0C
6. Bf gas compositions : CO = 18.00%

CO2= 18.60%, O2= 02.00%, H2= 02.50%, N2= 55.00%, CH4= 01.90%

a. Blast furnace gas required for stove combustions.

$$= \frac{(200 - \text{cold blast temperature})}{\text{Calorific value of BF gas x } 0.75} \text{ x } 4691.80$$

$$= \frac{(200 - 150)}{720 \text{ x } 0.75} \text{ x } 4691.80$$

$$= 435.0368 \text{ KJ} \qquad (1)$$

b.

$$= \frac{2674973}{\text{Calorific value of BF gas x } 0.75}$$

$$= 4953.653 \text{ KJ} \qquad (2)$$

c.

$$= \frac{2495311}{\text{Calorific value of BF gas x } 0.75}$$

$$= 4620.946 \text{ KJ} \qquad (3)$$

d.

$$= 0.94 \text{ x } [20890 \text{ x } (200 - \text{Cold blast temp})]$$

$$= 0.94 \text{ x } [20890 \text{ x } (200 - 150)]$$

$$= 981830 \text{ KJ} \qquad (4)$$

Bf gas required = Adding values obtained from 1 +2+3

= 434.368+4953+4620.946

= 10008.97 KJ

Heat required can be obtained by adding values of 4

= 981830 + 21262040

= 22623870 KJ

Heat required for Stoves Heating.

=Cold blast volume X Required Hot blast temp – (Cold blast temp+273) X 0.993

= 159600 X 1200 – (150+273) X 0.993

= 2096727444 KJ

Bf gas required for heating.

$$= \frac{\text{Heat required}}{\text{Heat required X gas required}}$$

$$= \frac{2096727444}{22623870 \text{ X } 10008.97}$$

$$= 92751.80 \ \frac{\text{Nm}^3}{\text{hr}}$$

Volume of Combustion air required,

= (Bf gas CO/200) + (Bf gas H2/200) + (Bf gas CH4/50) – Required (O2/100)

= (20.8/200) + (2.5/200) + (1.90/50) – (2/100)

= 0.1345 m^3

Air volume required for combustion.

= O_2 required for combustion X 4.3

= 0.1345 X 4.3

= 0.6404

O_2 volume required for STP,

$$= \frac{\text{O2 volume required X 760 } (273 + 0)}{(\text{Bf gas pressure} + 273) \text{X } 47.62}$$

$$= \frac{0.1665 \text{ X } 760 \ (273 + 0)}{(47.79 + 273) \text{X } 47.62}$$

$$= 12.632 \ \text{m}^3$$

Combustion air required for heating.

= Bf gas required for heating X Air volume required for combustion

$$= 0.6404 \text{ x } 92751.80$$

$$= 53397.74 \text{ N m}^3$$

$$= \frac{\text{Combustion air required for heating}}{\text{Bf gas required for heating}}$$

$$= \frac{53397.74}{92751.80}$$

$$= 0.60$$

Volume of CO_2,

$$= \left(\frac{\text{Bf gas Co}}{100} + \frac{\text{Bf gas CH}_4}{100} + \frac{\text{Bf gas CO}}{100}\right)$$

$$= 0.423 \ \text{m}^3$$

Then volume of air required will be,

$$= \text{Air required for combustion x 1} \left(\text{excess air } \frac{10}{100}\right)$$

$$= 0.6404 \text{ x } 1 \left(\frac{10}{100}\right)$$

= 0.7044

Volume of N_2,

$$= \frac{\text{Bf gas } N_2}{100} + \text{volume of air required x } 0.79$$

$$= \frac{55}{100} + 0.7044 \text{ x } 0.79$$

$= 1.1064\ m^3$

Volume of O_2,

$= O_2$ volume required for combustion x excess air

$$= 0.1345 \text{ x} \frac{10}{100}$$

$= 0.01345\ m^3$

Total volume of production of combustion,

= Volume of CO_2+ Volume of N_2 + Volume of O_2

= 0.423+1.1064+0.01345

$= 1.54285\ m^3$

Waste gas analysis will be,

$$\%\ CO_2 = \frac{\text{Volume of } CO_2}{\text{Total volume of production of combustion x } 100}.$$

$$= \frac{0.423}{1.54285} \text{ x } 100$$

$CO_2 = 27.41\ \%$

Percentage of N_2,

$$\%\ N_2 = \frac{\text{Volume of } N_2}{\text{Total volume of production of combustion x } 100}$$

$$= \frac{1.1064}{1.54285} \text{ x } 100$$

$N_2 = 72\ \%$

Percentage of O_2,

$$\%\ O_2 = \frac{\text{Volume of } O_2}{\text{Total volume of production of combustion x } 100}$$

$$= \frac{0.01345}{1.54285} \text{ x } 100$$

$O_2 = 0.87\ \%$

To find out the total waste gas (Flue), Following parameters are considered.

Volume of Gas burned in side stove = 45250 Nm^3/hr

Volume of combustion air = 38950 Nm^3/hr

Waste gas volume: Volume of Bf gas x 1.54

= 47250 x 1.54

= 72765 rounding up to 75000 Nm³/ hr/ stove

Two stoves are in heating & one stove in supplying hot air to Blast furnace

= 75000 x 2(Stoves)

= 150000 Nm³/ hr.

SN	Equipment	Description	Quantity
1	Gas pre heater	For pre heating blast furnace Gas	1
2	Air pre heater	For combustion air	1

Table 1: The Main Equipment Used in the Waste Heat Recovery.

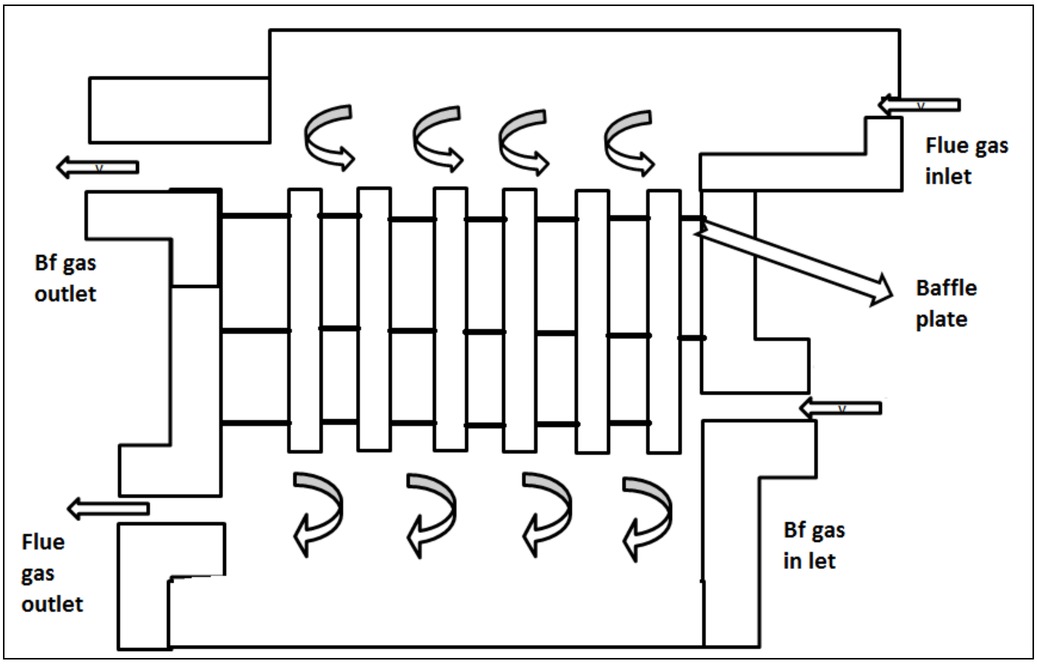


Fig 2: Gas Pre Heater.

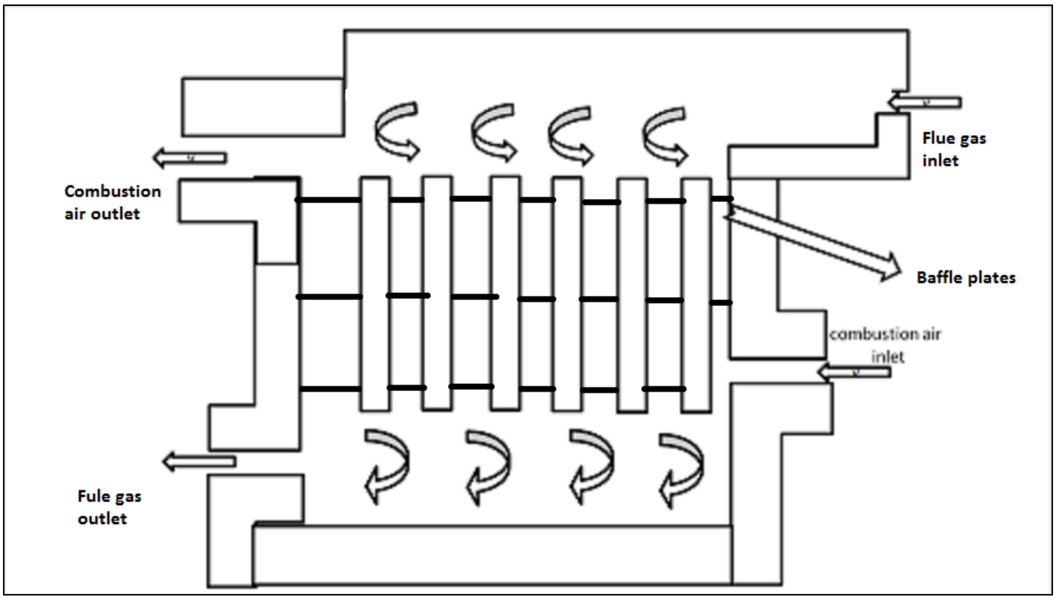


Fig 3: Air Pre Heater.

4. SELECTION OF GAS PRE HEATER

4.1 Selection of Gas Pre Heater

Heat ex-changers are used for transforming energy from one source to another the heat bearing source can be used directly. Heat exchangers are available number designs and configuration. We are selecting Heat pipes.

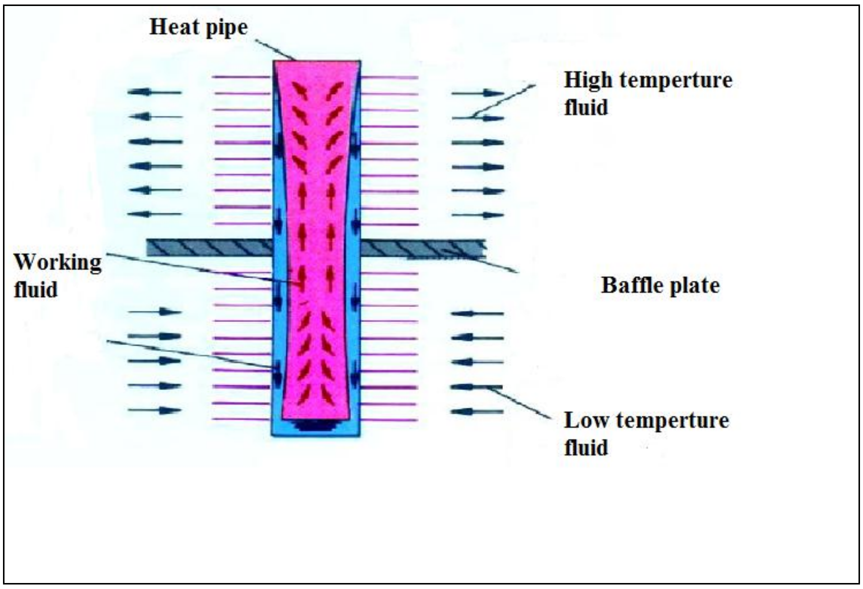


Fig 4: Working Principle of Gas Pre Heater.

4.2 Design of Heat Pipe (Technical Constraint)

1. Steel structure material should be IS 3602. Thickness of the material should be 6 MM.
2. Inside tube diameters will be 20 mm diameter.
3. Fin tube material should be Q195L. Fin thickness at flue end and gas end 1.2 MM and air end 1.0MM.
4. Heat insulation of flue gas with the heat pipe fully.
5. For gas preheated and shall be welding the tube to the separation plate to avoid leakage from gas to flue gas.
6. Manual venting to be located at the bottom of the shell.
7. Differential pressure transmitter and temperature transmitter are required at inlet and outlet cone hood of the flue gas and air.
8. During manufacturing 20 bar leakage test to carried out.
9. Expansion joints are required at inlet and outlet end at both gas and air preheated.
10. For welding in gas line in running condition, it is required to put nitrogen purging valve.
11. All the gaskets are using cam profile gaskets between the top cover plate and the heat pipe.
12. For air pre heater between air side and flue gas ensure the leakage is no, more than 3%.

5. CONCLUSION

Consequences by using waste heat recovery system.

This project activity is utilizing the waste heat of Blast furnace stoves for preheating of combustion air and fuel gases and results in saving of Blast Furnace gas.

The technology used in the project activity is environmentally safe. The usage of this technology has no negative impacts on the ecosystem as it leads to the reduction of the greenhouse gases which would have otherwise been emitted from the alternative use of fossil fuel. By the implementation of this technology the project proponent will introduce a cleaner and energy efficient technology for enabling utilization of waste heat in process waste gas steams which otherwise would have been lost. Hence, the project activity will lead to the replication of this technology in similar industries thereby initiating a positive step towards utilization of waste heat.

Waste energy is used to generate electricity. Waste energy is used to provide mechanical energy that would have been supplied by electrical motor in the baseline. Determine baseline emissions for generation of thermal energy and mechanical energy if steam is used in baseline to drive a turbine.

This project activity is utilizing the waste heat from the stoves of Blast Furnace to generate electricity by using saved Blast Furnace at Thermal Power Plant without burning any fossil fuels. The methodology is applicable to project activities implemented for using waste heat into useful energy. Hence this methodology is applicable.

The project activity consists of installing waste heat recovery system to recover waste heat from exit gases of Blast furnace stoves. With this project activity, the fuel gas (Blast Furnace gas) consumption to Blast Furnace stoves reduced and surplus BF gas is sent to Captive Power Plant where in it displaces Boiler coal.

REFERENCES

1. Ma, Zheshu, Dong Yang, and Qiang Guo. "*Conceptual Design and Performance Analysis of an Exhaust Gas Waste Heat Recovery System for a 10000TEU Container Ship*", Polish Maritime Research, 2012. Publication.
2. The waste heat recovery handbook by Robert Goldstick, Albert Thumann Edition Illustrated publisher: Fairmount Press, 1983 Original from, the University of Michigan Digitized 6 Dec 2007.
3. Blast furnace calculations and tables for Furnace Managers and Engineers: Containing Rules and formulas for finding the dimensions and Output capacity of any furnace, as well as Regular outfit of stoves , Heating surface, Volume of air, Tuyere Area, ETC per ton of iron per day of 24 Hours By John L. Stevenson Publisher: C: lockwood and son, 1906. Original from: the University of califormia.
4. Heat pipes Theory, Design and applications Sixth Edition By D.A. Reay David Reay & Associates, Whitly bay UK P.A Kew Heriot –watt University Dubai Campus, Dubai R.J. McGlen Thermacore, Ashington, UK.
5. Maarten Geerdes, Renard Chaigneau, Ivan Kurunov, Oscar Lingiardi, John Ricketts Modern Balst Furnace Iron Making Third Edition, 2015 Published By IOS Press under imprint Deflt University Press.
6. The ideal hot blast temperature – Why and How Proceedings of Symposium on "*The Ideal Hot Blast temperature Why & How*" by Mc Master University. Dept of Material Science and Enginnering Editor Wei-Kao Lu. Publisher: the University of Wisconsin –Masison Digitized: 6 Oct 2009.
7. Proceeding of the International Conference on Environmental Management in Metallurgical Industries (EMMI-2000) 14-16 DECEMBER, 2000, Editors: Prof. R. C. Gupta Associated Editors: Prof. S.N. Gupta, Prof. J.P Pathak Dr. Sunil Mohan 2000, Allied Publishers LTD.
8. Thirumarim, M., T. Kannadasan, and E.Ramasamy. "*Performance Analysis of Shell and Tube Heat Exchanger Using Miscible System*", American Journal of Applied Sciences, 2008. Publication.
9. Duarte Rocha, Bruno, and René Reyes Mazzoco. "*Development of a Closed-Loop Heat-Pipe for Heat Recovery With Mini- Channels Enhancing Evaporation*", ASME 2008 6th International Conference on Nanochannels Microchannels and Minichannels, 2008. Publicat ion.
10. Heat pipe Design Hand book Issue 74; Issue 34402 of N74 -22569- United States National Aeronautics and Space Administration Volume 134264 of NASA contractor report, United States National Aeronautics and Space Administration Publisher: The Corporation 1972.
11. Energy Management series for industry, Commerce and Institution: Boiler plant system volume 6 of Energy Management series for industry Commerce and Institution Canada Energy, Mines and Resources Canada. Publisher: Supply and services, 1985.
12. Modern Blast Furnace Iron making: An Introduction Maarten Geerdes, Hisko Toxopeus, Cor van der Vliet. Editors Maarten Geerdes, Hisko Toxopeus, Publishers: IOS press, 2009.