Redesigning a Boiler Chimney System to Enhance Boiler Efficiency Against Fouling.

[1]Sourabh Awati, [2]Akshay Patil, [3]Vaibhav Narwade, [4]Sujit Arage, [5]Prof.R.M.Deshmukh
Department Of Mechanical Engineering, JSPM Narhe Technical Campus, Pune.

Abstract- *Chimney plays very important role in the exhaust of flue gases from boiler to the atmosphere. An initial design of chimney heat recovery heat exchanger was provided. The design had a completely fabricated exchange core but an incomplete ducting system .This report is based on the work undertaken to complete and test the gas to gas heat recovery system. This system will design specifically for boiler chimney and therefore the systems ducting will design to conform to the general boiler stack. In the completion of the design, the major factor to consider is to design against fouling. The system is therefore design with means of reducing fouling such as provision for easily replaceable particulate filter and quick washing system.*

Keywords- fouling, particulate filter, quick washing system

1. INTRODUCTION

A) industrial waste heat[3]

This is heat lost in industries through ways such as discharge of hot combustion gases to the atmosphere through chimneys, discharge of hot waste water, heat transfer from hot surfaces. This energy loss can be recovered through heat exchangers and be put to other use such as preheating other industrial fluids such as water or air. This project focuses on recovering heat that is lost through boiler chimney flue gas.

The advantages of heat recovery include:

i). Increasing the energy efficiency of the boiler.

ii). Decreasing thermal and air pollution dramatically. [3]

B) Challenges to recovering low temperature wasteheat (hodge b.k, 1990)

Corrosion of heat exchanger surface: as the water vapor contained in the exhaust gas cools some of it will condense and deposit corrosive solids and liquids on the heat exchanger surface. The heat exchanger must be designed to withstand exposure to these corrosive deposits. This generally requires using advanced materials, or frequently replacing components of the heat exchanger, which is often uneconomical. Large heat exchanger surface required for heat transfer; since low temperature waste heat will involve a smaller temperature gradient between two fluid streams, larger surface areas are required for heat transfer. This limits the economy of heat exchangers. Finding use for low grade heat: recovering heat in low temperatures range will only make sense if the plant has use for low temperature heat. [10]

2. PROBLEM STATEMENT

The industrial boilers are working on very high temperature & pressure. And the some flue gasses forms in the boiler which required exhausting in atmosphere. Because of this the boiler chimneys are provided to the boiler. Through the chimney that gasses are exhausted to the atmosphere. But some fouling are forms in the chimney. And after some period that chimneys will get blocked. And in existing chimney system hasn’t any provision to clean the particulate filters. There for this will reduce the efficiency of boiler and increase the chances of accident.

Now our project is to redesigning of the boiler chimney against fouling creation. Our attempt in the way to reduce the fouling forms in the chimney. For this we provide such design which allows the particulate filter cleaning after some period. The design has to allow for quick maintenance without interfering with the boiler operations.

OBJECTIVE

1. To redesign the boiler chimney against fouling.
2. To enhance the efficiency of boiler by reducing the fouling creates in chimney.
3. To fabricate the chimney
4. Testing of the model under forced convection condition.
5. The gases from a furnace were used to simulate industrial flue gases.

METHODOLOGY

The project will finish in the following manner.

1. Visit to the industry
2. Identification of problem
3. Idea of project
4. Collection of data
5. Literature survey
6. Design of CAD model
7. Material selection
8. Completing of the fabrication.
9. Research on ways of minimizing fouling. Incorporating the ways arrived at in 1 above into the system design.
10. Testing of the model under forced convection condition. The gases from a furnace were used to simulate industrial flue gases.

3. LITERATURE REVIEW

Moni Kuntal Bora1 and S. Nakkeeran[1] This paper is convergent on the diverse aspects of the operation of Boiler efficiently. Efficient operation of boiler is likely to play a very big role in following years to come. Industries all over the world are going through increased and powerful competition and increased automation of plants. The suspension cost of such system is expected to be very high. To get away with this challenge, it is clearer by this paper. We have to use the advanced technology and management skills in all spheres of activities to perform its effective role in the turnover of the company.

Rahul Dev Gupta, Sudhir Ghai1, Ajai Jain[2] The above Paper says that idea for findings of boiler house efficiency improvement study carried out in a large boiler house unit of a pulp and paper mill has been presented. The causes of poor boiler efficiency were various heat losses such as loss due to unburnt carbon in refuse, loss due to dry flue gas, loss due to moisture in fuel, loss due to radiation, loss due to blow down, and loss due to burning hydrogen, etc. The various heat losses were analyzed and a set of recommendations were made to the plant management for implementation, so that efficiency of boiler can be increased. Five important recommendations were implemented by plant management, and it has been seen that there is tremendous increase in boiler efficiency. This work, with only five recommendations implemented, has resulted in net increase of 2% in overall boiler efficiency. In addition, it is observed that carefulness in the operation of boiler can help a great deal in energy efficiency improvement in boiler.

[3] Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperatures while keeping them from mixing with each other. Heat transfer in heat exchangers involves convection in each fluid and conduction through the wall separating the two fluids. In order to account for the contribution of all the effects of convection and conduction, an overall heat transfer coefficient (U), is used in the analysis. Heat transfer rate depends on the temperature differences between the two fluids at the location and the velocity of the fluids (time of interaction) between the fluids.

4. FOULING

INTRODUCTION

The deposition of any unsought material on heat transfer surfaces is named fouling. Fouling might considerably impact the thermal and mechanical performance of warmth exchangers. Fouling could be a dynamic development that changes with time. Fouling will increase the thermal resistance and lowers the heat transfer constant of warmth exchangers. Fouling additionally impedes fluid flow, accelerates corrosion and will increase pressure drop across heat exchangers.

Fouling tendencies depends on the sort of warmth money handler and also the fluids. throughout the look stage bound concerns might facilitate minimize fouling skilled within the field: If doable, assign the a lot of fouling fluid to the tube aspect style for a fouling fluid rate of five ft/sec on the tube aspect and three ft/sec on the shell aspect attempt to keep the fluid rate constant yield quick access for cleanup

In water service, make sure the tube wall temperature isn't too high to make salt deposits or render treatment chemicals ineffective don't throttle water flows in winter time

TYPES OF FOULING

1. Macro-fouling

Macro fouling is caused by coarse matter of either biological or inorganic origin, as an example industrially created refuse. Such matter enters into the cooling water circuit through the cooling water pumps from sources just like the open ocean, rivers or lakes. In closed circuits, like cooling towers, the ingress of macro fouling into the cooling basin is feasible through open canals or by the wind. Sometimes, components of the cooling internals detach themselves and area unit carried into the cooling water circuit. Such substances will foul the surfaces of warmth exchangers and will cause deterioration of the relevant heat transfer constant. they will additionally produce flow blockages, spread the flow within the parts, or cause fretting harm.

Examples

- Manmade refuse;
- Detached internal components of components;
- Tools and alternative "foreign objects" accidentally left when maintenance;
- Mussels; Algae;
- Leaves, components of plants up to entire trunks.

2. Micro-fouling

Scaling or precipitation fouling, as crystallization of solid salts, oxides and hydroxides from water solutions, as an example, carbonate or atomic number 20 sulfate; Particulate fouling, i.e., accumulation of particles, generally mixture particles, on a surface; Corrosion fouling, i.e., unchanged growth of corrosion deposits, as an example, iron ore on steel surfaces; reaction fouling, as an example, decomposition or chemical change of organic matter on heating surfaces; curing fouling - once parts of the flowing fluid with a high-melting purpose freeze onto a sub-cooled surface; Bio-fouling, like settlements of bacterium and algae; Composite fouling, whereby fouling involves quite one foulant or fouling mechanism.

3. Precipitation fouling

Scaling or precipitation fouling involves crystallization of solid salts, oxides and hydroxides from solutions. These area unit most frequently water solutions, however non-aqueous precipitation fouling is additionally noted. Precipitation fouling could be a quite common downside in boilers and warmth exchangers operative with H_2O and sometimes ends up in lime scale.

Through changes in temperature, or solvent evaporation or degasification, the concentration of salts might exceed the saturation, resulting in a precipitation of solids (usually crystals).

The following lists a number of the industrially common phases of precipitation fouling deposits ascertained in apply to create from liquid solutions:

Calcium carbonate (calcite, mineral sometimes at t > ~50 °C, or seldom vaterite);
Calcium sulfate (anhydrite, hemihydrate, gypsum);
Calcium salt (e.g., beerstone);
Barium sulfate (barite).

5. WHY FOULING OCCURS?

Fouling from chemical reactions in the fluid stream which results in the deposition of material on the heat exchanger surface occurs when biological organisms grow on heat transfer surfaces. It is a common fouling mechanism where untreated water is used as the coolant.

Fouling is a general term that includes any kind of deposits of extraneous material that appears on the heat transfer surface during the lifetime of the heat exchanger.

Fouling reduce heat transfer across the exchanger surface hence reduces efficiency of the heat exchanger. The fouling deposits also reduce flow cross-section area causing a pressure deferential across the heat exchanger which in turn increasing on the fan power required. It might also eventually block the heat exchanger.

Different kinds of fuel produce different degrees of fouling most fuel produce just soft black soot that get deposited on the exchanger surface.

This can easily be removed by brushing and sand washing. However lower grade fuel oil (principally no.6.oil or resid) contain large quantities of alkaline sulfates and vanadium pentoxide that causes scaling due to their lower fusion temperatures.

The forms of fouling may therefore include

- Particulate fouling.
- Scaling/precipitation.
- Chemical/corrosion fouling.
- Solidification.

Forms Of Fouling

Scaling/precipitation:

Scaling/precipitation occur as a result crystallization of dissolved substance on to the heat transfer surface. These deposits can be removed by scratching or by cleaning via chemical treatment. This is the most common type of fouling. Scaling/precipitation can be reduced by treating the fluid flowing past the heat exchanger before it reaches the heat exchanger surface.

Particulate fouling

This result from the accumulation of the solid particle suspend in the process fluid onto the heat transfer surface. Such solid particles can be removed by use of filters to treat the process fluid before it reaches the heat exchanger surface.

Chemical /corrosion fouling

In this case, the surfaces are fouled by accumulation of the products of chemical reactions on the surfaces. This form of fouling can be avoided by coating the heat exchanger surfaces by glass. Heat exchanger surfaces can also be fouled by growth of algae in warm fluids (chemical fouling) which can be prevented by chemical treatment.

Solidification fouling

The crystallization of a pure liquid or one component of the liquid phase on a sub cooled heat transfer surface. The mechanism of fouling is complicated and no reliable techniques are available but there are means of reducing fouling. The methods mostly used to reduce fouling include use of filters and increasing the fluid flow to ensure turbulent flow.

6. DESIGN AGAINST FOULING

It was our duty to consider the effect of fouling upon the heat exchanger performance during the desired operation lifetime and make provisions in our design for sufficient extra capacity to ensure that the exchange will meet process specifications up-to shut down for cleaning. We were also to consider the mechanical arrangements that are necessary to permit easy cleaning.
In our design, the following measures have been taken to reduce the rate of fouling.
I. Provision for particulate filters.
II. Introduction of turbulent flow upstream of the exchanger core.

Provision of particulate filters

At the entry of the flue gas duct is attached, a cone shaped duct to whose narrower end can be attached diesel particulate filter. The particulate filter is designed to remove fuel particulate matter (soot) from the fuel gases. The efficiency of the filter is inversely proportional to the pressure that is build up due to resistance to gas flow. It is therefore difficult to achieve 100 percent efficiency through filtration, as there must be a compromise between efficiency and pressure buildup. The best filters are therefore broad band filters that can filter particles of diameters between 0.2-150µm. The filters can easily be removed through a door on the side of the side duct for cleaning.

Introduction of turbulent flow upstream of the exchange core

The cone shape element at the gas-duct entry causes turbulence as it suddenly opens into the larger gas duct .this causes turbulence. This turbulent flow of air picks with it some of the particles that stick on the exchanger surface due to its drag effect. This helps to reduce on fouling. The above filtration and turbulence only minimizes rate of fouling. But the fouling still takes place. This therefore implies that the exchanger will require maintenance (cleaning). There are various ways that could be used in cleaning the exchanger. In the design we consider using the following methods.

1. Blowing
2. Washing

The system was designed with a slit on the wall of the flue gases duct downstream of the exchanger. This allows the overhead water washing.

Pressurized water mixed with abrasives e.g. fine sand is used to remove soot that cannot be removed by blowing air past the exchanger. The abrasives help in scrubbing the surface.

Before washing, the particulate filter is removed and replace with a lid to prevent water from entering the broiler.

During washing the waste water drains out of the system through the outlet ducts at the base of the flue gas inlet duct.

1. Design Considerations

In the designing of the exchanger following factors were put to consideration.

1. The exchanger surface has to be the most efficient and suitable for gas-gas heat exchange.
2. The design has to consider the fouling effect of the flue gases.
3. The design has to allow for quick maintenance without interfering with the boiler operations.
4. The ducting design has to conform to the boiler chimney design.

Based on the above factors, the exchanger was designed to be of compact plate type. Various designs for the exchange core were considered including cylindrical type (ducts).The plate type was found to be more efficient and simpler in design. It was also more suitable for gas - to gas heat exchange as it offers higher surface for heat transfer.

2. Overall Heat transfer Coefficient

In analysis of heat transfer in heat exchangers, various thermal resistances in the path of heat flow from the hot to cold fluid are combined.

Heat is first transferred from the hot fluid to the wall by convection, through the mass by conduction and from the wall to the cold fluid by convection. Any radiation effects are usually included in the convection heat transfer coefficients.

The total thermal resistance, R, for the whole system is given by:-

R= thermal resistance of inside flow + thermal resistance of the systems material + thermal resistance of outside flow

$$R = \frac{1}{A_i h_i} + \frac{1}{A_o h_o} + \frac{t}{kA_m}$$

Where hi, ho= heat transfer coefficients for inside and outside flow respectively

k= Thermal conductivity of the exchanger material

R= Total thermal resistance from inside to outside flow

t= Thickness of the heat exchanger material

$A_m = \frac{A_o - A_i}{\log(\frac{A_o}{A_i})}$=logarithmic mean area, m2

Ai, Ao= Inside and outside surface areas of the heat exchanger surfaces respectively. Expressing the thermal resistance R as an overall heat transfer coefficient based on either the fluid inside or outside surface of the heat exchanger surface areas:-

$$U_o = \frac{1}{A_o R} \quad \text{And} \quad U_i = \frac{1}{A_i R}$$

If the wall thickness is small and its thermal conductivity is high the material resistance may beneglected and hence the overall heat transfer coefficient becomes:-

$$U_t = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}}$$

In applications of heat exchangers, accumulation of deposits mostly from combustion, on the heat exchanger surface causes additional thermal resistance, a condition known as fouling. Effects of fouling are introduced in the heat transfer coefficient in the form of a fouling factor. The total thermal resistance then became:-

$$R = \frac{1}{A_i h_i} + \frac{F_i}{A_i} + \frac{t}{kA_m} + \frac{F_o}{A_o} + \frac{1}{A_o h_o}$$

Where Fi and Fo are the fouling factors on the inside and outside surfaces respectively.

CONCLUSION

The objective of this project was completion and testing of boiler chimney heat recovery heat money handler system that might be accustomed recover heat lost through flue gases. A plate kind heat money handler was employed in the look. The systems model was completed and tested underneath forced Convection conditions.

REFERENCES

[1] Moni Kuntal Bora and S. Nakkeeran, “Performance Analysis From The Efficiency Estimation of Coal Fired Boiler” ISSN 2320-5407 International Journal of Advanced Research (2014), Volume 2, Issue 5, 561-574

[2] Fouling of Heat Exchangers (Chemical Engineering Monographs) 1st Edition by T. R. Boat book

[3] http://www.hcheattransfer.com/fouling1.html

[4] Lon E. Bell “Cooling, Heating, Generating Power, and Recovering Waste Heat with Thermoelectric Systems” VOL 321 12 SEPTEMBER 2008

[5] Rahul Dev Gupta, Sudhir Ghai1, Ajai Jain.

[6] Kirtikanta sahoo, “analysis of self supported steel Chimney as per indian standard” Department of Civil Engineering National Institute of Technology Rourkela Orissa -769008, India May 2012

[7] Leonardo E Carrión, Rodrigo A Dünner And Iván Fernández–Dávila, “seismic analysis and design of industrial chimneys”

[8] Rahul Dev Gupta, Sudhir Ghai1, Ajai Jain, “Energy Efficiency Improvement Strategies for Industrial Boilers: A Case Study”

[9] Fargione, J.; Hill, J.; Tilman, D.; Polasky, S.; Hawthorne, P. Land clearing and the biofuel carbon debt. Science 2008, 319, 1235–1238.