# Investigation & Analysis of the Heat Loss in Boiler for Improving the Boiler Efficiency

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## ABSTRACT

***By analyzing flue gases, gathering data on fuel usage, and calculating steam production, boiler efficiency is calculated. analyse in depth the aforementioned parameters and compare the data acquired with normative data. A boiler adjustment is conducted in order to improve the boiler's efficiency. Boilers' inefficient fuel-to-steam conversion is caused by excessive stack loss, poor convective heat transfer, and convection loss values. By using flue gas analysis to reduce the amount of fuel used in the above 2.8 TPH low pressure fire tube boiler oil fueled boiler for each tonne of produced steam, the project aims to increase boiler efficiency.***

***Keywords: Air-fuel ratio, Flue gas, CO parameter, Flue-gas emission, Fuel Atomization, Oil Spray Nozzle, $O_2$ Percentage, Stack Temperature.***

## INTRODUCTION

Modern package boilers are designed to produce steam, efficiently and reliably, twenty-four hours a day and seven days a week without interruption. To achieve the best performance of boiler operation, it is essential that the boiler is operated correctly and maintained regularly. It is equally important that the boiler operators and maintenance personnel are well trained to carry out regular checks and make adjustments and repairs.

The investigation is carried on package modular boiler of three-pass design. The first pass is the furnace and the second and third passes are two nests of smoke tubes. At the end of the furnace, bend tubes are provided which reverse the flue gas and directs it to second pass tubes. The flue gas outlet is positioned at the rear side of the boiler, just after the third pass.The smoke tube nest is a combination of plain and stay tubes without any restriction inside. Stay tubes are strength welded to the tube plate and are meant for support to tube plates as well as heat transfer. Plain tubes are especially for heat transfer. The above boiler is design and construction confirm to IBR 1950 with latest amendments.

## LITERATURE SURVEY

L Uneus et.al [1] found different operating modes for the boiler in the data set using principal component analysis as the data evaluation approach. Daulet Zhakupov et.al [2] done sensitivity analysis on co-firing of local biomass and Ekibastuz coal demonstrated the optimal operating temperature for fluidized bed reactor at 1148 K with the recommended biomass-to-coal ratio is 1/4, leading to minimum emissions of CO, NO, and SO2.Mukesh Shyamkant Desai et.al [3] determined the way to increase boiler efficiency. This review article is useful for determining the boiler's efficiency and learning about the many forms of losses that can occur. Yadav Harsh et.al [4] Investigated how various characteristics, including return water temperature, condenser temperature, and many other parameters linked to temperature issues, might affect how the boiler functions. Monitoring boiler performance has the purpose of regulating the plant's heat rate. In this essay, the operating efficiency of a boiler is determined, and significant losses are computed. Shailendra Sinha et.al [5] used heat balance sheet to depict the losses and investigations for a 3-tonne capacity coalfire tube boiler have been conducted in this project. Two scenarios—(i) coal supplied to the boiler at room temperature and

(ii) coal heated to 110 $^0$C before supply—are considered in the preparation of the heat balance sheet. Utilising reheated coal causes the moisture content to drop, aiding in efficient fuel burning. It has been discovered that warmed fuel increases boiler efficiency. With the use of warmed fuel in the current scenario, boiler efficiency is found to rise by 4 to 5%. B. Veerabhadra Reddy et.al [6] made a two-dimensional model of the economizer coil using the Computational Fluid Dynamics (CFD) method. When compared to carbon steel, the performance of the economizer portion made of mild steel is superior. The fluid flow field within an economizer tube under the actual boundary conditions has been analysed using the CFD tool. The fluid flow temperature, pressure, and velocity are increasing. As a result, the boiler's performance will improve. Asmaa S. Hamouda [7] created a device to calculate boiler efficiency using a java web application, a straight forward mathematical model of a steam boiler. The results showed that every 10% increase in surplus air caused a 0.37 percent decrease in boiler efficiency when a water tube boiler was powered by natural gas. The efficiency of a fire tube boiler using liquid fuel (solar) decreases by 5% for every 10% increase in excess air and by 1-2% for every 10% (20°C) increase in flue gas temperature.V. K. Soni et.al [8] the calculation of significant losses and the estimation of the boiler's present operational efficiency for the 210 MW Vindhyachal Super Thermal Power Plant in India. then determine what is causing performance to suffer. Identify the primary causes of heat losses using Fault Tree Analysis (FTA), and then suggest the best course of action to minimise significant losses. The purpose of performance monitoring is to continuously assess any degradation, or decline in steam boiler performance. These data enable extra information that aids in the detection of issues, the enhancement of boiler performance, and the formulation of cost-effective maintenance schedule selections.

**Table 1 : Composition of furnace oil and specifications Furnace Oil Confirm toIS: 1593-1982**

| **Composition** | **(% v/v)** |
|---|---|
| C | 84.00 |
| $H_2$ | 11.00 |
| S | 3.50 |
| N | Nil |
| $O_2$ | Nil |
| $H_2O$ | 1 |
| Ash | 0.5 |
| NCV of Fuel | 9650 Kcal/Kg |
| Ash % Weight Max | 0.1 |
| Flash Point $^o$C | 66 min |
| Kinematic Viscosity | 125 to 180 Cst at 50℃ |
| Pour point ℃ | 27 Max |

## METHODOLOGY OF THE PROBLEM

For the experimental boiler with a capacity of 2.8 TPH, the fuel is transported from the storage tank to the burner with preheating temperature and oil viscosity that aids free flow through the nozzle and mixing with air in the right proportions with an air-fuel ratio of 1:14. Additionally, an $O_2$ analyzer is positioned in the provision provided in the stack for the gathering of data on $O_2$, $CO_2$, CO, and stack temperature for stack analysis. With this information, the air regulator unit is adjusted to reduce the extra $O_2$. The boiler's efficiency will drop by 1% if it is not maintained under optimum temperature.

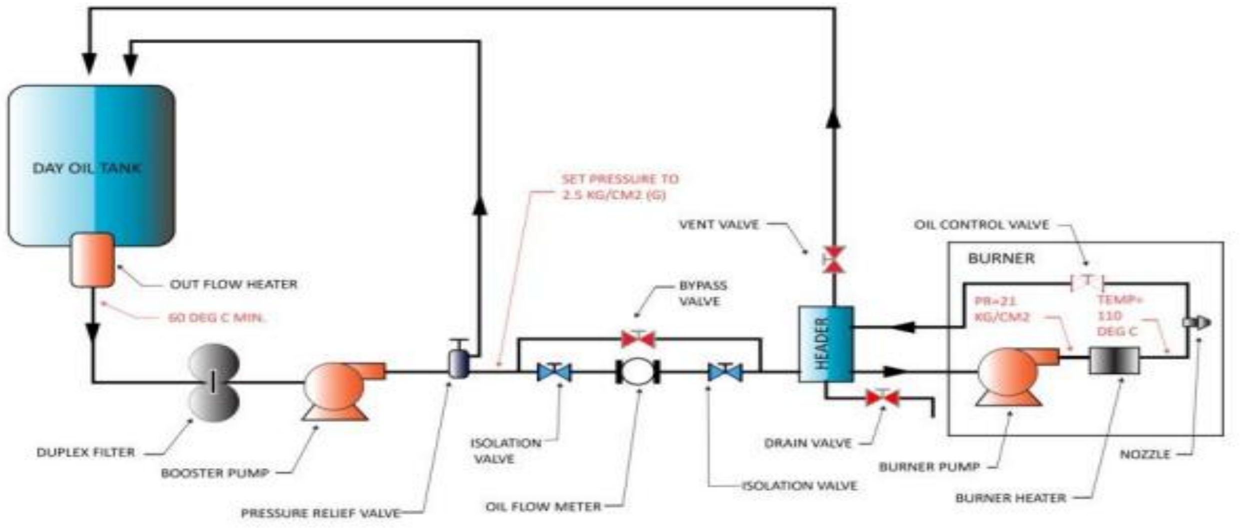



*Figure 1 :Fuel atomization process*


*Figure 2: Gas analyzer connected to boiler stack*

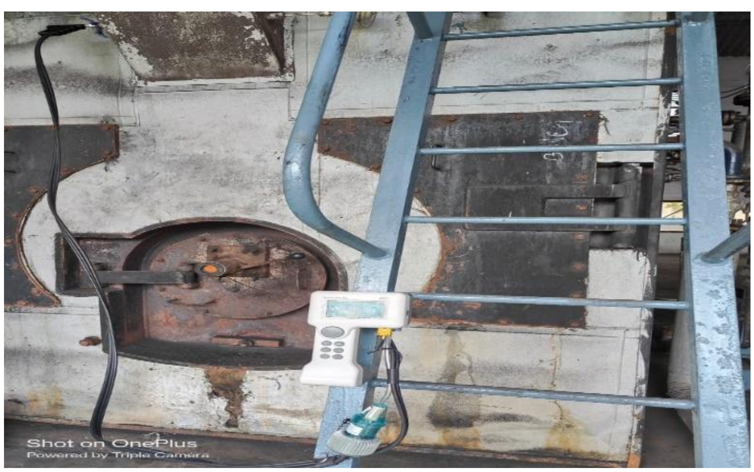



*Figure 3: Running boiler performing stack analysis*


*Figure 4: front end of boiler*

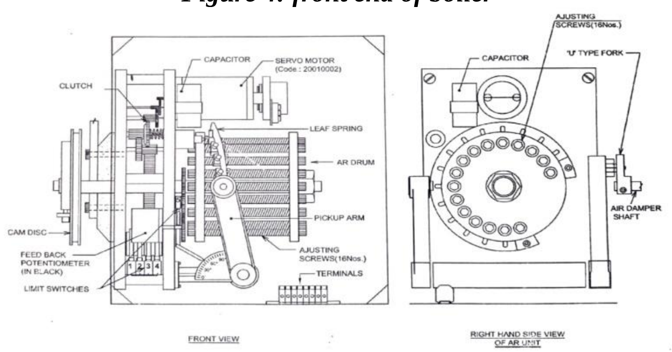



*Figure 5: Image reference from M/s. Combustion Concepts private limited, Pune*

**Losses in boilers:**

Stack loss, Enthalpy loss, Radiation loss, and Blowdown loss are among the losses. The analyzer's recorded data can be used to fine-tune the boiler so that it produces more steam while using less fuel. Oxygen in the stack, stack temperature, steam flow (density-adjusted), fuel flow, steam temperature, feed-water temperature, ambient temperature, and TDS of boiler water serve as the foundation for determining the boiler's efficiency and operating conditions and preserving the boiler's maximum efficiency. The regular monitoring of all the aforementioned parameters can enhance boiler performance.

A boiler flue gas analysis report typically provides the following information:

1. Oxygen ($O_2$) Content: The amount of oxygen in the flue gas is a sign of how effectively fuel is burned. Incomplete combustion is indicated by low oxygen concentration.
2. The amount of carbon monoxide (CO): CO is a poisonous gas produced during incomplete combustion. Flue gas with a high CO content indicates inefficient combustion and calls for adjusting the combustion process.
3. Carbon Dioxide ($CO_2$) Content: $CO_2$ is a combustion byproduct, and the amount of it in the flue gas indicates how well fuel is burned. Complete combustion is indicated by a high $CO_2$ concentration.
4. Nitrogen Oxides ($NO_x$) Content: $NO_x$are a class of air pollutants created during combustion at high temperatures. High $NO_x$ concentrations in the flue gas are a sign of inefficient combustion and possible environmental effects.
5. Sulphur Dioxide ($SO_2$) Content: When sulfur-containing fuels are burned, $SO_2$ is formed. High $SO_2$ concentrations in flue gas can have detrimental effects on human health and contribute to air pollution.
6. Stack Temperature: The flue gas's temperature as it leaves the boiler is known as the stack temperature. A high stack temperature may be a sign of ineffective heat transfer or flue obstructions.
7. Additional characteristics: A boiler flue gas analysis report may also include additional characteristics such as stack pressure, flow rate, and moisture content. These variables may reveal more details about the operation of the boiler and the combustion process.

**Calculation of flue gas parameter $CO_2$:**

$$CO_2 = [CO_2]_{max} * (1- ([O_2]_{min}/21))$$

$[O_2]_{min}$ - *It is the measured oxygen concentration*

$[CO_2]_{max}$ - *It is the maximum possible concentration of carbon* dioxide which can be produced with the fuel in use.

Calculation of Excess air:
$\lambda = 1 + (O_2 / (21 - O_2))$
*Lambda (λ) is the air in excess*
*Air n index calculation:*
$n = 21/ (21- [O_2]_{min})$
where n is the air index
$CO_{(o)} = [CO]_{min} * n$
Here multiplying the air index by the value of CO measured the value of undiluted CO is obtained, reported at the condition $O_2$ = 0%.

**Analysis:**
The oxygen measurement probe is mounted on the stack of the boiler and it measures the % $O_2$ in the flue gas. This is an important parameter for efficiency calculations. The % $O_2$ in the flue gas indicates the operating excess air level of the boiler and hence the health of combustion.

- Typical values of Evaporation ratio for different type of fuels are as follows:
- Biomass fired boilers: 2.0 to 3.0
- Coal fired boilers: 4.0 to 5.5
- Oil fired boilers: 13.5 to 14.5
- Gas fired boilers: 11.0 to 13.0

Boiler Evaporation Ratio
There are two methods of assessing boiler efficiency.

The Direct Method: Where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.

The Indirect Method: Where the efficiency is the difference between the losses and the energy input.

**Boiler Efficiency**
Evaluation Method
1. Direct Method
2. Indirect Method

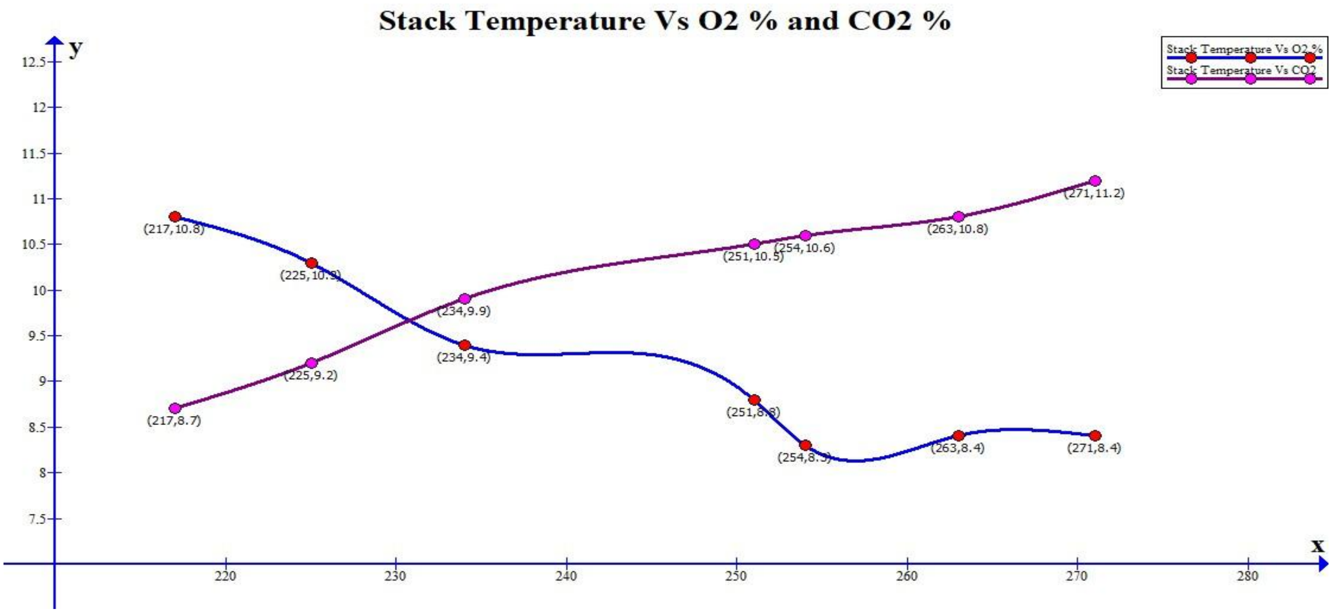
**Performance Evaluation of Experimented Boiler**
Type of boiler: Oil fired Boiler
<u>Heat input data</u>
Qty of furnace oil consumed :100 kg/hr.
GCV of furnace oil :10200 KCal/Kg
Heat output data
• Qty of steam generated: 2.5 TPH
• Steam pressure/temperature:10.0 kg/cm2(g) / 180°C
• Enthalpy of steam (sat) at 10 kg/cm2(g) pressure: 665 KCal/Kg
• Feed water temperature: 85 °C
• Enthalpy of feed water: 85 KCal/Kg
Efficiency Calculation by Direct Method
Boiler efficiency (Ƞ): = Q x (H – h) x 100/ (q x GCV)
Where Q = Quantity of steam generated per hour (kg/hr)
H = Enthalpy of saturated steam (kcal/kg)
h = Enthalpy of feed water (kcal/kg)
q = Quantity of fuel used per hour (kg/hr.)
GCV = Gross calorific value of the fuel (kcal/kg)
Efficiency(Ƞ) = 2.5TPHx1000Kg/Tx(665–85)x100/0.175TPHx1000Kg/Tx 10200
= 81.23 %
Evaporation Ratio = 2.5 Ton of steam/0.17 Ton of furnace oil
= 14.29

**RESULTS AND DISCUSSION OF BOILER (BEFORE TUNING)**

The **Table 2** shows the variations of $O_2$, CO and $CO_2$ for different return oil pressures as the inlet pressure is constant throughout the experiment before tuning of the boiler.

*Table 2: Boiler Stack Analysis Before Tuning*

| Inlet oil Pressure Kg/cm$^2$ | Return oil Pressure Kg/cm$^2$ | $O_2$ % | CO | $CO_2$ | Stack Temp.in $^OC$ |
|---|---|---|---|---|---|
| 20 | 3.5 | 10.8 | 162 | 8.7 | 217 |
| 20 | 4.5 | 10.3 | 104 | 9.2 | 225 |
| 20 | 5.5 | 9.4 | 98 | 9.9 | 234 |
| 20 | 6.5 | 8.8 | 104 | 10.5 | 251 |
| 20 | 7.5 | 8.3 | 106 | 10.6 | 254 |
| 20 | 8.5 | 8.4 | 115 | 10.8 | 263 |
| 20 | 8.8 | 8.4 | 119 | 11.2 | 271 |




*Graph 1: Stack Temperature Vs $O_2$ % and $CO_2$ % Variations before tuning*

The **Graph1** shows the graph between Stack temperature and $CO_2$ %and Stack temperature and $O_2$ % before tuning. The stack temperature with increase in $CO_2$ results in direct fuel loss which increases the cost of the operations for generating the steam. The increase in excess air in the boiler which emits white flue gas with excess $O_2$ %.

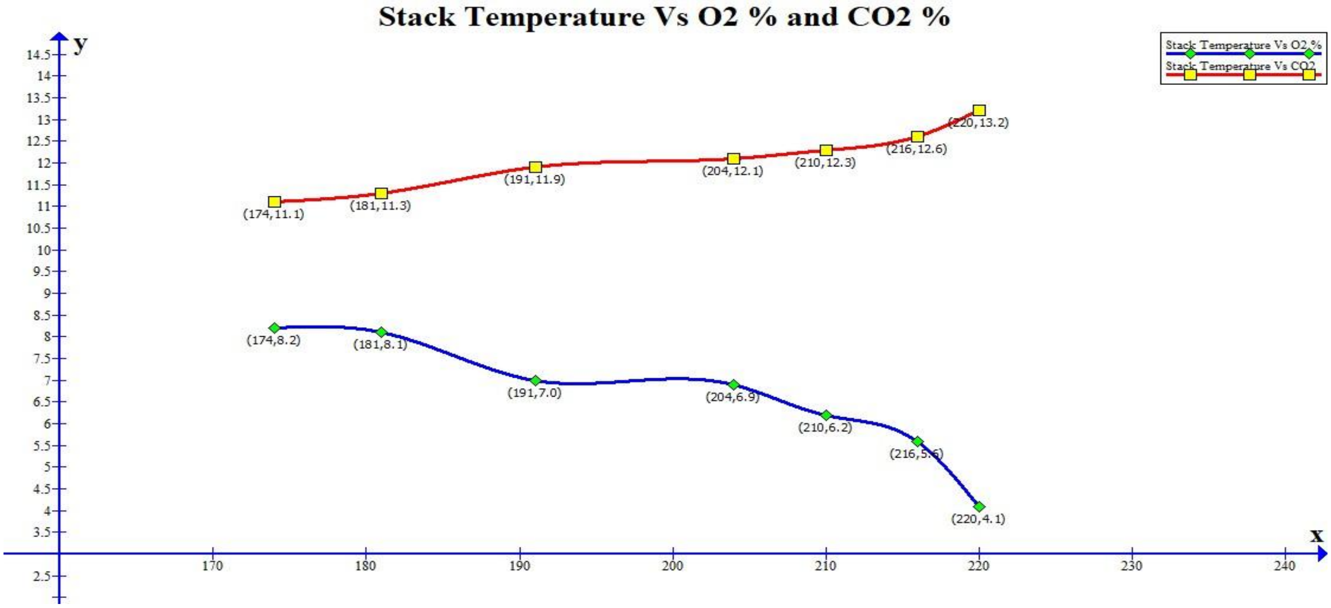
**Results and discussion of Boiler (After Tuning)**

The **Table 3** shows the variations of $O_2$, CO and $CO_2$ for different return oil pressures as the inlet pressure is constant throughout the experiment after tuning of the boiler.

*Table 3 : Boiler Stack Analysis After Tuning*

| Inlet oil Pressure Kg/cm$^2$ | Return oil Pressure Kg/cm$^2$ | $O_2$ % | CO | $CO_2$ | Stack Temp.in $^OC$ |
|---|---|---|---|---|---|
| 20 | 3.5 | 8.2 | 56 | 11.1 | 174 |
| 20 | 4.5 | 8.1 | 90 | 11.3 | 181 |
| 20 | 5.5 | 7.0 | 100 | 11.9 | 191 |
| 20 | 6.5 | 6.9 | 111 | 12.1 | 204 |
| 20 | 7.5 | 6.2 | 125 | 12.3 | 210 |

| | | | | | |
|---|---|---|---|---|---|
| 20 | 8.5 | 5.6 | 124 | 12.6 | 216 |
| 20 | 10.0 | 4.1 | 128 | 13.2 | 220 |




***Graph 2 : Stack Temperature Vs $O_2$ % and $CO_2$ % Variations after tuning***

The Graph 2 shows the graph between Stack temperature and CO2 % and Stack temperature and O2 % after tuning. The stack temperature decreased with increase in O2 results in direct fuel gain which decreases the cost of the operations for generating the steam.

## CONCLUSIONS

In the investigation described above, boiler flue gas parameters were analyzed, and the necessary precautions were made to reduce fuel consumption by reducing the amount of excess air ($O_2$) in the stack by adjusting the air damper in accordance with the results from the online flue gas analyzer. The purpose of this accomplished project has been achieved. i.e., the boiler stack's temperature is lowered from 270 °C to 220 °C. A nearly 50 °C reduction in the stack means fuel savings and increase in the boiler efficiency by 2.5%.

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