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PERFORMANCE ANALYSIS AND EFFICIENCY IMPROVEMENT OF BOILER- A REVIEW

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Abstract: **The main objective of this paper is to find out the boiler efficiency calculation and method to improvement. The thermal industry is known as a major source of conventional energy in India. In the thermal power plant where chemical energy of the coal is converted into electricity. It is most demanding industry now days because of high energy demand. Boiler is the most important part for plant. Running the plant with maximum result we need high boiler efficiency. Calculating boiler efficiency as one of the most important types of performance measurement in any power plant. For calculation of Boiler efficiency basically we use Direct and Indirect method. It is a measure of how effectively chemical energy in fuel is converted into heat energy in steam going to the turbine. Finding boiler efficiency from this method from this method use for boiler efficiency, the data is collected from different department in plant like, Boiler Efficiency Department. Many researchers are find out the boiler efficiency of different plant and carried out their research for improvement of boiler efficiency. This review paper helpful to calculate the boiler efficiency and find out the different types of losses occurs in boiler. We also find that boiler efficiency is always somehow increase by implementing this method and useful for further research.**

Keywords: Boiler, Boiler Efficiency, Boiler Losses, Performance, Direct Method, Indirect Method.

I. INTRODUCTION

A. Power Plant

A power plant is defined as a machine or assembly of equipment that generates and delivers a flow of electrical or mechanical energy. Generally steam power plant, diesel power plant, gas turbine power plant, nuclear power plant are called thermal power plant. It is called thermal power plant because these convert heat into electrical energy. In the thermal power plant coal to electricity process occur, it is converting into different stages. First chemical energy converted into heat energy by burning coal, then heat energy convert into mechanical energy due to boil of water, then finally mechanical energy convert into electrical energy by the working process on turbine section. Power plant is working on the principle of Rankine Cycle.

B. Boiler

"Boiler is device which is use for power generating by the heating process of water to convert the superheated steam". In other way "boiler device is defines as a closed vessel system whereby the fuel combustion process, high pressure steam is produced from water". Basically a steam generator is known as boiler, made by high quality steel.

As per Indian boiler Act-1923, boiler means any closed vessel exceeding 22.75 L in capacity which is used expressly for generating steam under pressure and includes any mounting or other fitting attached to such vessel which is wholly or partially under pressure when steam is shut off.

C. Boiler Efficiency

Saving energy may be one of most interested themes and then one of the most important subjects for boiler. According to bureau of energy efficiency "thermal efficiency of boiler is defined as the percentage of heat input that is effectively utilized to generate steam." It is also defined as "Boiler efficiency is a ratio between the

energy supplied to the boiler capacity and the energy received from the boiler." It is expressed in percentage.

II. LITERATURE REVIEW

Literature review is part of discussion of different author's paper comparatively. In this paper we discussed about the boiler efficiency calculation and find out the better result to improve boiler efficiency and also we discussed about what the authors states.

(Rahul Dev Gupta and Sudhir Gupta, 2011) is doing case study on "Energy efficiency improvement strategies for industrial boiler". Here result shows that by controlling excess air boiler efficiency improved from 80.98% to 81.94%. So this work determines that overall boiler efficiency on account of all improvement recommendation has increased by 2% from 80.98% to 82.98%.(Amir Vosough, 2011) define "Improvement Power Plant Efficiency with Condenser Pressure". The analyses show that the condenser pressure is an important parameter that affects the output power, power potential and thermal and exergy efficiency of the cycle. The maximum energy loss was found in the condenser where 60.86% of the input energy was lost to the environment. The calculated thermal and exergy efficiency of the power cycle was found to be 38.39%, 45.85 %.(Chetan T. Patel, 2013) conducted research on "Efficiency with different GCV of coal and efficiency improvement opportunity in boiler". He derived conclusion from this paper are if higher GCV coal is used, then the efficiency should be increased. Ash and Moisture content inside the fuel will affect the efficiency. By using semi bituminous coal efficiency is 80.20% because of its high heating value and less moisture and ash content, while Indian lignite coal gives 77.51% efficiency on the same boiler because of it has a more ash and moisture contents than the semi bituminous coal. (Acharya Chirag, 2014) define analysis of "Boiler losses to improve unit heat rate of coal fired thermal power plant". It is conducted at 210 MW power plant by Direct and Indirect method. The result of this paper shows that thermal power plant heat rate is directly affected by boiler efficiency. From calculation it found that 1% decrease in boiler efficiency increases the heat rate by 1%.Heat rate is increases as boiler efficiency decreases.(Moni Kuntal Bora, 2014) carried out "Performance Analysis from the Efficiency Estimation of Coal Fired Boiler". This paper puts forward an effective methodology for the efficiency estimation of a coal fired boiler, comparison with its design value and enlists some of the factors that affect the performance of a boiler. (Sangeeth G.S., 2015) shows the "Efficiency improvement of boilers" in his research. The objective of the study was to analyze the overall efficiency and the thermodynamic analysis of boiler. It is noticed that the overall efficiency of any boiler depends upon the technical difficulties under unpredictable conditions. There are many factors, which are influencing the efficiency of the boiler. The fuel used for combustion, type of boiler, varying load, power plant age, heat exchanger fouling they lose efficiency. (J. Suresh babu, 2015) project objective is to analyze the efficiency of economizer, super heater and air pre heater by varying the various parameters in boiler section. He is conclude that by installing the economizer in the plant in the plant, the plant efficiency can increase by 10% and by implementing the super heater the efficiency can be increased by (25 - 30) %, (8-10) % in each stage of super heater.(Sarang j gulhane, 2015) carried out their research on "Scope and energy losses minimizes in the AFBC boiler". Here he find out result after discussion on paper is if we increases load then losses is reduced so plant should be run in the peak load, in 5.6 MW the boiler efficiency is 83.03% and 1.1 mw it was 76.63%.(Rakesh Kumar Sahu, 2015) define as "Energy Performance Assessment of CFBC Boiler". This project is done at 150 MW. Conclusion derived from the data related to the boiler, if higher GCV coal is used, then the efficiency should be increased and the other one is the excess air. The quantity of excess air needs to be optimized for achieving maximum efficiency of boiler. (R.Pachaiyappan, 2015) define to "Improving the boiler efficiency by optimizing the combustion air". This paper deals with the different ways to obtain the maximum heat from the flue gas travelling through the air preheater and the economizer zone to improve the boiler efficiency. After determine efficiency in this paper the performance of the air preheater has been studied on the basis of the combustion air passing through it. The correct optimization of the combustion air can increase the boiler efficiency by 2-3%. (Mr. Amitkumar, 2017) study on "Efficiency of boiler and factor affecting it". He is defining that the efficiency calculation by indirect method is the best way to account all the Boiler losses. The flue gas loss in a Boiler is always higher than any other losses so the stack temperature is to be monitored and reduced. PH level of boiler water should be maintained between 8.5-9.5 to avoid corrosion. (Gudimella Tirumala Srinivas, 2017) paper present "Efficiency of a Coal Fired Boiler in a Typical Thermal Power Plant". This paper mainly shows the boiler efficiency evaluation procedure by direct and indirect method. He obtain the result is 83.94 % by Direct method and 91.96 % by Indirect method. The direct method helps the plant personnel to evaluate quickly the boilers efficiency with few parameters and less instrumentation. (Ashutosh Kumar, 2017) present an approach for the efficiency improvement of Atmospheric Fluidized Bed Combustion Boiler. Paper addresses the various approaches for efficiency

improvement of a boiler. He find the Efficiency of boiler depends on flue gas outlet temperature i.e., APH outlet temperature and on decreasing the flue gas outlet temperature (i.e., 310°C), sensible heat loss increases by 10°C on decreasing sensible heat loss, efficiency improved by 1% of the boiler.(Md. Amanulla Farhan, 2017) discuss on the "Investigation of boiler performance in power plant" AT different unit of boiler and find out the boiler efficiency of unit-3 and unit-4 after calculation is 82.03% and 82.35% respectively. It is calculated by Indirect or Losses Method which is accurate then Direct method. (T.Manikandan, 2017) present the paper on "Performance analysis of boilers". In this project performance analysis has been carried out by reducing the excess air contain oxygen at the time of combustion process, deterioration of fuel quality and water quality also leads to poor performance of boiler. Changes in admitting of oxygen in excess air nearly 4.7%, so percentage of excess air reduced to 29.62% and gets a more than 84.806% of thermal efficiency. So 0.46% of efficiency can be increased by this analysis project. It improves the economic condition of operating that boiler nearly more than 30lakhs per annum. (P. Celen and H.H. Erdem, 2017) carried out "A case study for calculation of boiler efficiency by using indirect method". In this study the effects of increment moisture content of fuel and excess air coefficient on boiler efficiency is determined by using indirect method. Here results are obtain as Increment of moisture content of lignite resulted in reduction of lower heating value so boiler efficiency decreased from 0.92 to 0.66, The boiler efficiency decreased from 0.92 to 0.90 with the increment of excess air coefficient up to 25%, Increment of moisture content has significant effect on boiler efficiency compared to excess air coefficient.(Abhinav Sahai, 2017) calculated the efficiency of boiler and implement the method for efficiency improvement in his paper. Efficiency for different GCV has been shown in paper for FBC boiler and this paper also gives the description of calculation of efficiency for FBC boiler. After calculation he state that the dry flue gas loss in is always higher than any other loss. Therefore dry flue gas loss should be minimized by maximum heat extraction in the convective surfaces of the Boiler. Therefore by decreasing hydrogen loss & dry flue gas loss efficiency can be improved. (P. Papireddy, 2018) is conducted a research to find out the "Performance analysis of boiler in thermal power plant" of 210 MW. He is used Direct and Indirect method to calculate the boiler efficiency. He is also present the efficiency calculation of turbine, condenser and evaluation of various parameter to find losses. Here some optimization technique is mention in paper to minimize the losses. The experimental result indicate that main steam temperature and pressure, turbine cylinder efficiency should be increased and condenser vacuum, dry flue gas loss, moisture in fuel, heat rate should be decreased for better efficiency. Plant should be run at full load for maximum efficiency. (A.A. Nuraini and S. Salmi, 2018) project objective is "Efficiency and Boiler Parameters Effects in Sub-critical Boiler with Different Types of Sub-bituminous Coal". The result indicates that coal with different CV and properties will exhibit different efficiency to the boiler. The results show that sub-bituminous coal with CV 5013 kcal/ kg performs similarly to designated coal with CV of 4852 kcal/kg. The results convey that the coal type contributes to major energy losses during the combustion process in the furnace. (Wadhah H. Al-Taha, 2018) doing case study on "Performance Analysis of a Steam Power Plant". He derive from the study is top thermal and total efficiencies unit generating at full load (100%) and decrease at partial load (40%) and the lowest rate of heat net unit obstetric gets the full load (100%) and increases when the partial load (70%) and continues increase when the partial load (40%), so it can be recommended for operation at full load.(Vivek Khare, 2018) mentioned their study on "Performance Assessment of 2X250 MW Coal Based Thermal Power Plant". Here he find that The differences in the calculated efficiency from the designed efficiencies indicate the urgent need to control the parameters within the designed ratings and to evolve measures to improve the efficiency of the plant.(Ahmad Mahmoudi Lahijani, 2020) mentioned "A Review of Indirect Method in Fire Tube Steam Boilers". In this paper, the efficiency analysis of fire tube steam boilers according to pertinent parameters is presented. From the study done by author he find the result is the indirect method is the most accurate method to determine boiler efficiency and three of the most effective parameters are flue gas temperature, ambient temperature, and the fuel type effect on efficiency. (A. Kumar, 2020) is done their research on "An Exergy Analysis of a 250 MW Thermal Power Plant". The exergy analysis was carried out for the system components separately and the exergy destruction of various components in the plant was evaluated. The overall exergy efficiency of the plant was calculated to be 34.75%.

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Table 1 Overview of Literature on Performance Analysis and Efficiency Improvement of Boiler

Sr. No.	Year	Author	Methods/ Tools used for Boiler Performance
1	2011	Rahul Dev Gupta et al.	Case study- study about all the parameter affecting boiler efficiency
2	2011	Amir Vosough et al.	Energy and Exergy analysis
3	2013	Chetan T. Patel et al.	Direct and Indirect Method
4	2014	Acharya Chirag et al.	Direct and Indirect Method
5	2014	Moni Kuntal Bora et al.	Direct and Indirect Method
6	2015	Sangeeth G.S. et al.	Heat exchanger analysis with mathematical equation
7	2015	J. Suresh babu et al.	Study and calculation
8	2015	Sarang j gulhane et al.	Indirect or Losses Method
9	2015	Rakesh Kumar Sahu et al.	Direct and Indirect Method
10	2015	R. Pachaiyappan et al.	Case study and Indirect method
11	2017	Mr. Amitkumar et al.	Direct and Indirect Method
12	2017	Gudimella Tirumala Srinivas et al.	Direct and Indirect Method
13	2017	Ashutosh Kumar et al.	Direct and Indirect Method
14	2017	Md. Amanulla Farhan et al.	Indirect or Losses Method
15	2017	T.Manikandan et al.	Direct and Indirect Method
16	2017	P. Celen et al.	Indirect or Losses Method
17	2017	Abhinav Sahai et al.	Direct and Indirect Method
18	2018	P. Papireddy et al.	Direct and Indirect Method
19	2018	A.A. Nuraini et al.	Direct and Indirect Method
20	2018	Wadhah H. Al-Taha et al.	Study and Analysis
21	2018	Vivek Khare et al.	Direct and Indirect Method
22	2020	Ahmad Mahmoudi Lahijani et al.	Indirect or Losses Method
23	2020	A. Kumar et al.	Matlab calculation tool

III. METHODOLOGY

Purpose of Performance Test

- To find out efficiency of boiler
- To find out evaporation ratio

The purpose of performance test is to determine actual performance and efficiency of boiler and compare it with design values and norms.
Basically boiler efficiency is tested by this two method-

A. Direct Method or Input Output Method
B. Indirect Method or Heat Loss Method.

A. Direct Method or Input Output Method- Direct or input-output method of boiler efficiency calculation is very simple for the calculation of boiler efficiency. It is preferred by most of the boiler engineers.

Boiler Efficiency = Heat output / Heat Input X 100

Boiler Efficiency = Q X (h_g– h_f) / (q X GCV) X 100

Following input data are required for the calculation of efficiency in this case:

- Steam pressure (kg/cm^2)
- Steam temperature (°C)

- Steam flow (Q) (kg/hr)
- Quantity of fuel used (q) (kg/hr)
- Feed water temperature (°C)
- Calorific value of fuel (kcal/kg)

Where,

h_g - Enthalpy of saturated steam in Kcal/Kg of steam

h_f – Enthalpy of feed water in Kcal/Kg of water

B. Indirect Method or Heat Loss Method- The indirect efficiency of a boiler is calculated by finding out the individual losses taking place in a boiler and then subtracting the sum from 100%.
Here the steps to find out the boiler efficiency by indirect method-

1) % Heat loss in dry flue gas (L_1)
2) % Heat loss due to formation of water from H_2 in fuel (L_2)
3) % Heat loss due to moisture in fuel (L_3)
4) % Heat Loss due to moisture in air (L_4)
5) % Heat loss due to partial conversion of C to CO (L_5)
6) % Heat loss due to radiation and convection and other unaccounted losse(L_6)
7) % Heat loss due to unburnt in fly ash (L_7)
8) % Heat loss due to unburnt in bottom ash (L_8)

From all this losses calculation with different formula for each we can find efficiency in indirect method.
Boiler efficiency by indirect method =

$100- (L_1+L_2+L_3+L_4+L_5+L_6+L_7+L_8)$

IV. DISCUSSION AND CONCLUSION

This paper reviewed the literature on performance analysis of boiler in the period of 2011 to 2020. Different methods used for the analysis and improvement of boiler efficiency applied by different researchers. Literature review of performance analysis and efficiency improvement of boiler as shown in table no 1. Assessment of performance parameters plays an important role in economics of power generation. We also conclude that:

1) Gross calorific value of coal is main important parameter to define efficiency in boiler, higher GCV of coal means higher efficiency of boiler. In high GCV coal the moisture and ash contain is low so it gives proper result while burning.
2) If heat rate is increase then boiler efficiency decrease so for maximum boiler performance we need to archive desired heat rate.
3) If plant is running on peak load then efficiency is more than plant running in part load. So plant need to be run in maximum load.
4) Indirect method for boiler efficiency is more accurate then direct method because it is measuring all the losses occurring in the boiler.
5) After calculation we find out that, the dry flue gas loss in boiler is always higher than any other losses.

This review paper helpful to calculate the boiler efficiency and find out the different types of losses occurs in boiler. We also find that boiler efficiency is always somehow increase by implementing this method and useful for further research.

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