Scientific Journal of Impact Factor (SJIF): 4.14

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 3, Issue 6, June -2016

Analysis and Efficiency Improvement in Co-generation Power Plant

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Abstract -*In the existing background, majority of the electricity produced throughout the world is from steam power plants. Therefore, it is very important to ensure that the plants are working with maximum efficiency. Analysis of the power plant has been manage to increase the efficiency and reliability of power plants. The overall efficiency of a power plant surround the efficiency of some various components of a generating unit. To Minimizing heat losses is the greatest factor affecting the loss of power plant's efficiency, and there are many areas of potential heat losses in a power plant. Efficiency of previous power plant's becomes dissipated over time, and minimize power plant efficiency results in more* CO_2 *being emitted per unit of electricity generated.*CO_2 *emissions can be lowered by improving the efficiency of coal fired power plants. Expanding the temperature & pressure in a steam turbine increases the efficiency of the Rankin steam cycle used in power generation. The options most often considered for increasing the efficiency of power plant's involve some equipment refurbishment, plant improvements, and better operations and maintenance plan. The aim of this paper is to find out the amount and source of unrecoverable heat generated in boiler of 18 TPH boiler in 2 MW captive power plant so that any operation in system which having largest energy destruction can be identified that help to Improve efficiency of power plant.*

Keywords -*Boiler,Efficiency, Rankin Cycle, Coal,Emissions,Refurbishment, Energy.*

Abbreviations – *Qo= Heat output,Qi = Heat input, Q = Quantity of steam produced per hour (kg/hr),q = quantity of fuel per hour (kg/hr),hg = steam enthalpy (kcal/kg), hf = feed water's enthalpy (kcal/kg)GCV of coal = gross calorific value of coal (kcal/kg), Cp = specific heat of flue gas (0.23 Kcal/kg*^{0}*C)Tf = temperature of flue gas (*^{0}*C), Ta = ambient temperature (*^{0}*C), Ts = surface temperature (*^{0}*C), m = mass of dry flue gas (kg/kg of fuel),* H_2 *= percentage of* H_2 *in fuel = kg of* H_2 *in 1kg of fuel, Cp = specific heat of superheated steam (0.45 Kcal/kg* ^{0}*C), 584 = latent heat of water in Kcal/kg, M= % of moisture present in fuel = kg of moisture in 1kg of fuel, Cp= specific heat of super-heated steam (0.45 Kcal/kg* ^{0}*C), AAR = actual air required (kg/kg of fuel), Mbw = mass of blow down water (Kg/hr), Hbw = enthalpy of blow down water at drum pressure (Kcal/kg), Hfw = enthalpy of the feed water (Kcal/kg), Ma = mass of total ash generated/kg of fuel, SBC = Steffen Boltzmann constant (5.67 ** 10^{-6}*),* $\mathcal{E}$ *= emissivity factor of surface, A = total surface area (m*^{2}*), C = 1.97,2.56,1.32,2.30forvertical surface, for upward facing horizontal surface, for downward facing surface, for horizontal cylindrical surface respectively.*

I. INTRODUCTION

The need of performance of the boiler, like efficiency and evaporation ratio reduces with time, due to poor combustion, heat transfer fouling and the poor operation and lastly the maintenance. Deterioration of fuel quality and water quality also leads to bad performance of the boiler. Efficiency testing help us to find out how far the boiler efficiency drifts away from the better efficiency. Any observed unusual deviations could therefore be investigated to pinpoint the problem area for necessary corrective action to take. Hence it is necessary to find out the current level of efficiency for performance analysis, which isrequirement for energy conservation action in industry.To calculate the efficiency of the boiler there are some methods and by using this method we can calculate the efficiency of the boiler.And it will help to increase the efficiency of the power plant.The company is looking for ways not only to improve efficiency of power plant assets but it also to growconcerns regarding the environmental impacts of power generation without compromising their marketcompetitiveness.This report focuses on the efficiency improvements in power plants, and discusses technologies, and other modifications to facility operations which provide the potential to increasepower plant efficiency and reduce CO_2 emissions.

II. LITRETURE REVIEW

A Thermal power plant in which water is heated turns into steam and spins a steam turbine. This turbine is coupled with generator. So, the generator is rotated. After steam passes through the turbine, the steam is condensed in a condenser. After condensing, it is recycled to where it was heated; this is known as Rankin cycle.

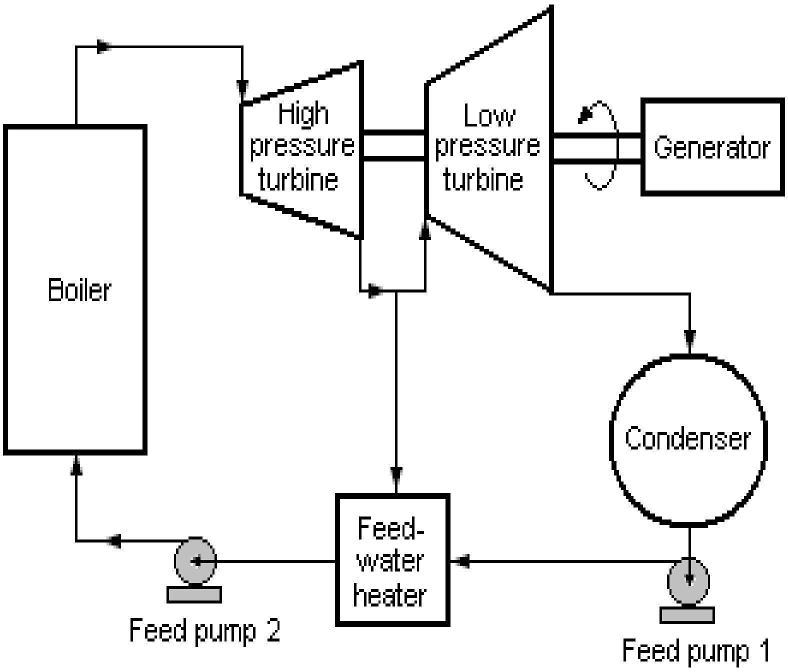

Figure 1. Rankin Cycle used in power plants

Performance of the boiler efficiency and evaporation ratio reduces with time, due to poor combustion, heat transfer fouling and bad operation and then maintenance. Deterioration of fuel quality and water quality also leads to bad performance of the boiler. Efficiency testing help us to find out how far the boiler efficiency drifts away from the better efficiency. Any observed unusualdeviations could therefore be investigated to pinpoint the problem area for necessary corrective action. Hence it is necessary to find out the current level of efficiency for performance evaluation, which is a pre requisite for energy conservation action in industry. [2]

2.1. Name- Energy Assessment of boiler

Reference – Bureau of energy efficiency. The purpose of the performance test is to determine actual performance and efficiency of the boiler and if we compare it with design values or norms. It is an indicator for tracking day-to-day and season-to-season dissimilarity in boiler efficiency and energy efficiency improvements.

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Energy &Exergy analysis are used to examine the performance of the system Earlier, most of the power plants are designed by the energetic performance criteria based on the first law of thermodynamics but the loss of useful energy cannot be justified by first law of thermodynamics, as we know it does not distinguish between quality & quantity of energy. Energy analysis presents only quantities result while energy performance presents qualitative result about actual energy consumption. Exergy is maximum theoretical helpful work that may be received from energy in a system of ideal machines. It is clear that exergy is not kept in a single process, but may be destroyed due to irreversibility.[1]

In the Rankin cycle, the vapor may be superheated at constant pressure from some points without difficulty. In a Carnot cycle using superheated steam, the superheating will have to be done at constant temperature along path of cycle. During this process, the pressure has to be dropped. This means that heat is moved to the vapor as it undergoes expansion doing work. This is difficult to achieve in practice.

III. CALCULATION

3.1. Methods Of Efficiency Calculation

Basically Boiler efficiency can be tested by the following methods:

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

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

3.1.1. Direct Method Testing

Description

This is also known as 'input-output method' due to the fact that it required only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. This efficiency can be evaluated using the formula:

Measurements Required for Direct Method Testing :

Heat input-

Both heat input and heat output must be studied. The measurement of heat input requires knowledge of the calorific value of the fuel and the flow rate in terms of mass or volume, according to the nature of the fuel.

For gaseous fuel -

A gas meter of the accepted type can be used and the measured volume should be corrected for temperature and pressure. A sample of gas can be collected for calorific value verification, but it is usually acceptable to use the calorific value announced by the gas suppliers.

For liquid fuel -

In this used heavy fuel oil is very viscous, and this property varies sharply with temperature. The meter, which is usually placed on the combustion appliance, should be regarded as a rough indicator only and, for the test purpose, a meter measured for the particular oil is to be used and over a realistic range of temperature should be installed. Similarly better is the use of an accurately calibrated day tank.

Calculation

Boiler efficiency = $\frac{Heatoutput}{Heatinput}$

Boiler efficiency η% = $\frac{Qo}{Qi} \times 100$

$= \frac{Q \times (hg - hf)}{q \times GCVoffuel} \times 100$

3.1.2. Indirect Method Trial

Description

The efficiency can be calculated easily by measuring all the losses occurring in the boilers using the propositions to be described. The drawback of the direct method can be overcome by this method, which calculates the different heat losses related with boiler. The efficiency can be arrived at, by subtracting the heat loss fractions from 100. The mainly important advantage of this method is that the errors in measurement do not make significant changes in efficiency. Thus if the boiler efficiency is 90% , an error of 1% in direct method will result in significant change in efficiency. That is 90 + 0.9 = 89.1 to 90.9. In this method, 1% error in measurement of losses will result in.

The following losses were appropriate to all the fuel used, weather it is solid, liquid or gas fired boiler.

L1 – loss due to dry flue gas
L2 – loss due to hydrogen present in fuel
L3 – loss due to moisture in fuel
L4 – loss due to moisture present in air
L5 – loss due to CO formation
L6 – loss due to not burned fuel in fly ash
L7 – loss due to not burned fuel in bottom ash
L8 – loss due to radiation and convection (known as surface loss)

Boiler efficiency (η%)= 100 –$Totallosses$
= 100 − ($L1$ + $L2$+$L3$ + $L4$ + $L5$ + $L6$ + $L7$ + $L8$)

Formula for Computing Various Losses

1. L1=Heat loss due to Dry flue gas loss
$= \frac{m*Cp\ (Tf-Ta)}{GCV} * 100$

2. L2=Heat loss due to evaporation of water formed due to H_2 present in fuel
$= \frac{9*H2*[584+Cp\ (Tf-Ta)]}{GCV} * 100$

3. L3= Heat loss due to evaporation of moisture present in fuel
$= \frac{M*[584+Cp\ (Tf-Ta)]}{GCV} * 100$

4. L4= Heat loss due to moisture in combustion air
$= \frac{AAR*humidityfactor\ *Cp\ (Tf-Ta)}{GCV} * 100$

Humidity factor = % of water in dry air
$= \frac{kgofwaterindryair}{kgofdryair}$

5. L5= Heat due to un-burnt in fly ash
$= \frac{Ma*GCVofflatas\ h}{GCVoffuel} * 100$

6. L6= Heat loss due to un-burnt in bottom ash
$= \frac{Ma*GCV\ of\ bottom\ ash}{GCV\ of\ fuel} * 100$

7. L7= Blow down loss
$= \frac{Mbw*(hbw-hfw)}{GCVoffuel} * 100$

8. L8=Heat loss due to radiation & convection
= 1 to 2% for small capacity boiler
= 0.2 to 1.2 for large capacity boiler

% surface heat loss = radiation loss + convection loss
% radiation loss = $\frac{SBE*\epsilon*A*Ts\ 4-Ta4*860}{GCvoffuel\ *1000}$
% convection loss = $\frac{C*A*Ts-Ta\ 1.25*860}{GCVoffuel\ *100}$

Sum of all heat losses
% total losses = sum of all heat losses
= 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8

Estimate boiler efficiency
%η B = 100 – (1 + 2 + 3 + 4 + 5 + 6 + 7 + 8)
% η B = 100 − (% total losses)

IV. COAL

4.1. Types of Indian and International Coals[3]

Characteristics	Indian	Indonesian	South African
Total Moisture%	10-20	10-30	8
Ash %	25 – 50	10-15	15-17
Carbon %	30-55	60	70-80
Hydrogen %	2-4	4.5	4.5
Nitrogen %	0.7-1.15	1	2- 2.5
Sulphur %	0.3-0.8	About 1%	1-2 %
Oxygen %	4-8	12	8-9 %
GCV kcal/kg	2800-5000	5500	6500

Table 1.Indian and international Coals

The main reason to select the Indian coal is to save transportation cost.

4.2.Types of Indian Coals

Depending upon its grade from highest to lowest following, The coal found in India mainly classified as Anthracite Coal, Bituminous Coal, Lignite (Brown Coal), Peat etc. They are discussed below-

4.2.1. Anthracite Coal–

It is the best quality of coal and contains over 85 per cent carbon. It is very hard, compact and jet black coal having a semi-metallic luster. This coal ignites slowly and burns with a nice short blue flame. In India, it is found mostly in Jammu and Kashmir and in very small quantity.

4.2.2.Bituminous Coal -

This is the most widely coal used and it contains 50% to 85% carbon percentage. It is very thick, compact, and brittle and it is usually found in black colour. A good bituminous coal is collected ofa alternate dull and bright bands. Its calorific value is very high due to high proportion consist of carbon and low moisture content. Most of the bituminous coal is found also in Jharkhand, Orissa, West Bengal, Madhya Pradesh and including inChattisgarh.

4.2.3. Lignite (Called as Brown Coal) –

It also known as brown coal, lignite is a lower grade coal and it contains around 35% to 50% of carbon. It shows the intermediarystage in the change of woody material into coal. Its colour differ from dark to black brown. It is found in Palna of Rajasthan, in Tamil NaduNeveli, Lakhimpur in Assam and Karewa in the Jammu and Kashmir.

V. RESULTS

After calculating the efficiency of the boiler with using the coals that is first calculated by 1st used coal and then calculated by now using coal. By doing so from that calculation we can draw the some graphs related to efficiency.

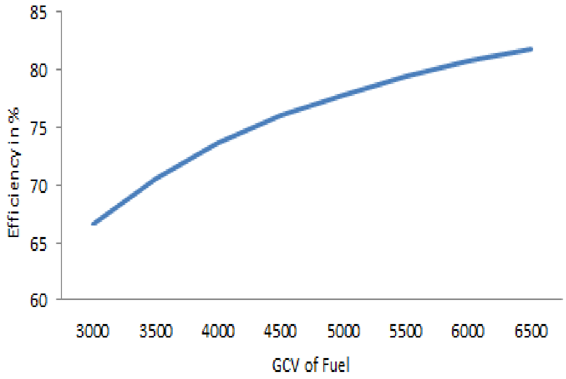

Figure2. GCV Vs Efficiency

This is graph which shows relation between Efficiency of plant and GCV of the fuel used in plant.From above graph we conclude that Efficiency is directly proportional to GCV of fuel. When the GCV of fuel is increased then the efficiency is also increased.

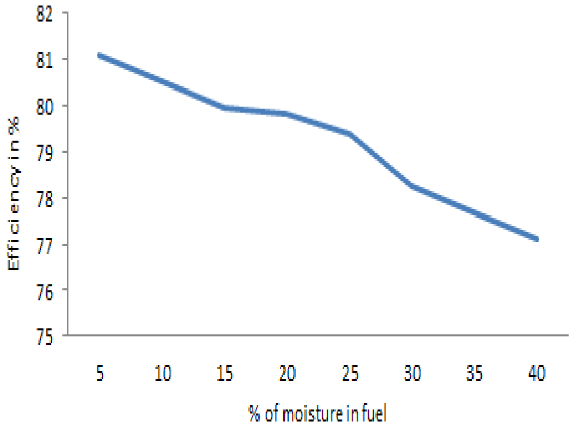

Figure 3. Moisture in Fuel Vs Efficiency

This is graph of relationship between the Efficiency and % of moisture present in fuel. Graph shows that efficiency is more stable at 79-80% when % of moisture present in fuel is between 15-20%.When the % of moisture in fuel when it decreases then also efficiency is decreases.

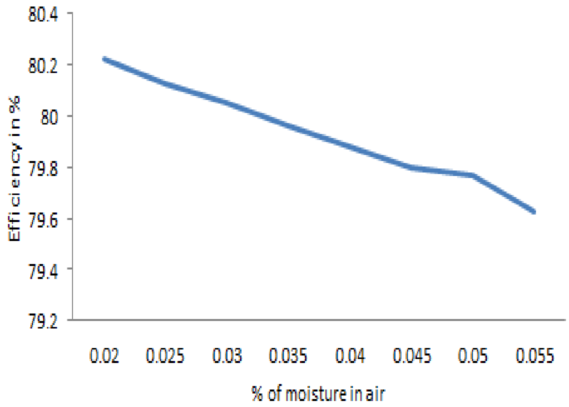

Figure 4. Moisture in Air Vs Efficiency

This is graph of relationship between the Efficiency and % of moisture present in air. Graph shows efficiency is more stable at approx.79.8% when the % of moisture present in air is 0.045-0.05%. If the % of moisture in air is existing in greater quantity then the efficiency also reduces.

VI. CONCLUSION

Therefore the conclusion is derived from the data related to the boiler, if higher GCV coal is used, then the efficiency should be increased. Ash and Moisture content inside the fuel will affect the efficiency. From the Indirect Method mathematical model, the efficiency should be easily calculated. Efficiency calculated by Direct and Indirect Method are approximately same. When we calculate the efficiency of both coals which is lignite and semi - bituminous the efficiency is increased by using the semi bituminous coal. So semi - bituminous coal is best to use in power plant for better efficiency. The main advantage of the semi - bituminous coal is that we can save transportation cost and it helps to increase the profit of company. By using Indian lignite coal total expenditure per year is Rs. 618280 and by using semi bituminous coal expenditure will be Rs. 628560 approximately for running 2 MW cogeneration plant.But with increase in efficiency we will get profit approximately up to Rs. 13000 – 14000 or more per year in final production.Fuel saving is achieved for semi -bituminous coal as compared to lignite coal is good.

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