Overall efficiency in the improvement of an industrial boiler using COAL ACTIVATOR

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Abstract
The main objective of this project is to find out the boiler capacity and its development. The thermal industry is considered to be the major source of conventional energy in India. The chemical energy of coal is converted into electricity in a thermal power plant. It is now the most in demand industry due to high energy demand. The boiler is a very important part of the power 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. We also improve boiler efficiency by using coal activator.
The art of converting plastics into useful fuels was scaled up a few decades ago, but this side is far less likely. Plastic contains most of the organic polymers made up of carbon and other elements. Various processes such as gasification and pyrolysis are used to convert plastics into smaller hydrocarbon units such as naphtha. This is named as a "COAL ACTIVATOR". This paper aims to provide the best options that will help reduce fuel (Coal) prices in the future.

Keywords: Boiler, Boiler Efficiency, Boiler Losses, Performance, Coal Activator, Direct Method and Indirect Method.

Introduction

Saving energy may the 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. And the boiler fuel (coal) is mixed with coal activator to improve the efficiency.

Companies around the world and people started producing fuel from waste plastic. Only 8% of waste plastic is recycled in the U.S., in 15% Western Europe, and very few in developing countries, this recycling of plastic keeps it vast the amount of plastic from landfills and from the oceans. Over 500 billion pounds of new plastic made every year and almost 33% of it is single use and thrown. Since less plastic is recycled, we need it reframe plastic waste versus landfill as a less used resource destination. According to the United Nations Environment Program, global plastic consumption has gone up from 5.5 Million tons in the 1950s and 110 million tons in 2009. Due to technical limitations or inconvenience of recycling, only a portion of that material will reappear in the new plastic products. This leads to extra-normal amounts dumped in landfills for thousands of years. Pacific ocean is the largest landfall in the world: The Great Pacific Garbage Patch.

Department of Plastics The American Chemical Council asked the Earth Institute Earth Engineering Center to explore recovery paths the energy inherent in non-recycled plastics. As a result report released in August 2011, The amount of energy in millions of tons the equivalent of 36.7 million tons of plastic in US landfills Coal, 139 million barrels of oil or 783 billion cubic feet Natural gas. If all this plastic turns into a liquid fuel, which can power all cars in Los Angeles for a year. And in fact now there are technologies that can put it all together good use of this waste plastic. As mentioned earlier, plastic is a the long chain is made of a hydro-carbon short chain hydro-carbons such as naphtha, oil, diesel, kerosene, etc.

Literature Review

Literature review is part of discussion of different author's paper comparatively. In this paper we have discussed the boiler efficiency calculation and found a better result to improve the boiler efficiency and we have also discussed what the authors say. **(Rahul Dev Gupta and Sudhir Gupta, 2011)** is doing case study on **"Energy efficiency improvement strategies for industrial boiler"**. The result here shows that the control of excess air boiler efficiency has been improved from 80.98% to 81.94%. So this work determines that the total boiler efficiency has increased from 80.98% to 82.98% by 2% due to all the improvement recommendations.

(Amir Vosough, 2011) define **"Improvement Power Plant Efficiency with Condenser Pressure"**. The analyzes show that condenser pressure is an important parameter that affects the output power, power potential and thermal and exhaust capacity of the cycle. The maximum power loss is found in the condenser, where 60.86% of the input energy is lost to the environment. The calculated thermal and energy 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 concluded from this paper that if high GCV coal was used, the efficiency should be increased. Affects the ash and moisture capacity inside the fuel. The use of semi-bituminous coal is 80.20% due to its high heat value and low moisture and ash content, while Indian lignite coal provides 77.51% efficiency over the same boiler as it contains more ash and moisture than semi-bituminous coal. **(Acharya Chirag, 2014)** define analysis of **"Boiler losses to improve unit heat rate of coal fired thermal power plant"**. It is operated directly and indirectly at the 210 MW power plant. The result of this paper shows that the thermal power plant heat rate is directly affected by the boiler capacity. From the calculation it was found that a 1% decrease in boiler efficiency increases the heating rate by 1%. The heating rate increases as the boiler capacity decreases. **(Moni Kuntal Bora, 2014)** carried out **"Performance Analysis from the Efficiency Estimation of Coal Fired Boiler".** This paper puts forward an effective method for estimating the efficiency of a coal based boiler, comparing it with its design value and listing some of the factors that affect boiler performance. **(Sangeeth G.S., 2015)** shows the **"Efficiency improvement of boilers"** in his research. The aim of the study is to evaluate the overall capacity and thermodynamic analysis of the boiler. It can be observed that the total capacity of any boiler depends on technical difficulties in unforeseen circumstances. There are many factors that affect the efficiency of the boiler. Fuel used for combustion, boiler type, various loads, power plant age, heat exchanger fouling they lose capacity.**(J. Suresh babu, 2015)** The project aims to evaluate the efficiency of the economizer, superheater and air preheater by changing the various parameters of the boiler section. He concluded that by installing an economizer in the plant, plant efficiency can be increased by 10% and efficiency can be increased by (25 - 30)%, (8-10)% on everything by running a superheater. Phase of the superheater. **(Sarang j gulhane, 2015)** carried out their research on **"Scope and**

energy losses minimizes in the AFBC boiler". Here he found the result after discussion on paper, we have to run the plant at peak load as the losses will decrease if we increase the load, the boiler capacity at 5.6 MW is 83.03% and 1.1 MW it is 76.63%. **(Rakesh Kumar Sahu, 2015)** define as **"Energy Performance Assessment of CFBC Boiler"**. The project will be done with 150 MW. The conclusion from the data related to the boiler is that if high GCV coal is used then the capacity should be increased and another additional air. The excess air volume must be optimized to achieve the maximum efficiency of the boiler. **(R.Pachaiyappan, 2015)** define to **"Improving the boiler efficiency by optimizing the combustion air"**. This paper deals with various ways to get maximum heat from flue gas traveling through the air preheater and economizer zone to improve boiler efficiency. After determining the efficiency in this paper the performance of the air preheater is studied based on the combustion air passing through it. Proper optimization of combustion air increases boiler efficiency by 2-3%.

(Mr. Amit kumar, 2017) study on **"Efficiency of boiler and factor affecting it".** He defines the best way to calculate efficiency by indirect method to calculate all boiler losses. Stock temperature should be monitored and reduced so that the flue gas loss in the boiler is always greater than other losses. The pH level of the boiler water should be maintained between 8.5-

To prevent corrosion 9.5. **(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 process through direct and indirect method. He gets 83.94% result by direct method and 91.96% by indirect method. The direct method helps plant staff to quickly assess the efficiency of boilers with certain parameters and minimal instrumentation. **(Ashutosh Kumar, 2017)**Demonstrate how to improve the efficiency of an atmospheric fluidized bed combustion boiler. The paper suggests various approaches to improve the efficiency of the boiler. He found that the efficiency of the boiler depends on the flue gas outlet temperature, i.e., as the APH outlet temperature decreases and the flue gas outlet temperature (i.e., 310 C) decreases, the heat loss increases by 10 C with optimal heat loss and efficiency increases. 1% of the boiler. **(Md. Amanulla Farhan, 2017)** discuss on **the "Investigation of boiler performance in power plant"** Find out the different units of the boiler and after calculating the boiler efficiency of Unit-3 and Unit-4 are 82.03% and 82.35% respectively. It is calculated by the indirect or loss method, which is more accurate than the direct method. **(T.Manikandan, 2017)** present the paper on **"Performance analysis of boilers".** Performance analysis was carried out on the project as the presence of excess air oxygen during combustion process, deterioration of fuel quality and water quality also led to poor performance of the boiler. The changes in the allowance of oxygen in the excess air are about 4.7%, so the percentage of excess air is reduced to 29.62% and achieves a thermal efficiency of more than 84.806%. So the efficiency can be increased by 0.46% by this analysis project. This will improve the financial status of those who operate the boiler for more than Rs 30 lakh 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 the additional air coefficient on the increase in moisture content of the fuel and the boiler efficiency are determined using the indirect method. As the percentage of moisture in the lignite decreases, the boiler efficiency decreases from 0.92 to 0.66, the boiler capacity decreases from 0.92 to 0.90, the additional air coefficient increases by 25%, and the increase in humidity has a significant effect on the boiler efficiency compared to the additional air coefficient. **(Abhinav Sahai, 2017)** The efficiency of the boiler was calculated and the method of improving the efficiency in his paper was implemented. The efficiency of various GCVs is shown in the paper for the FBC boiler and this paper also provides an explanation of the calculation of efficiency for the FBC boiler. After the calculation he stated that the loss of dry flu gas is always greater than the other loss. Therefore dry flue gas loss should be minimized by maximum heat extraction at the convection surfaces of the boiler. Therefore by reducing the hydrogen loss & Dry flue gas damage 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 uses direct and indirect method to calculate the boiler capacity. He also calculated the efficiency of the turbine, the condenser and the evaluation of various parameters to find the losses. Here are some optimization techniques mentioned in the paper to reduce the risks. The experimental result suggests that the main steam temperature and pressure should increase the turbine cylinder capacity and reduce the condenser vacuum, dry flue gas loss, moisture in the fuel, and heat rate for better efficiency. The 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 Subcritical Boiler with Different Types of Sub-bituminous Coal"**. The result indicates that the coal boiler with different CV and characteristics exhibits different efficiencies. The results show that sub-bituminous coal with CV 5013 kcal / kg works as specified coal with 4852 kcal / kg CV. The results show that the type of coal contributes to major energy losses during the combustion process in the furnace. **(Wadhah H. AlTaha, 2018)** doing case study on **"Performance Analysis of a Steam Power Plant".** He produces at full load (100%) the maximum thermal and total efficiency unit and decreases at partial load (40%) and the heat net unit receives the lowest rate of maternity full load (100%) and increases partial load (70%) and partial The increase continues during load (40%), so it is 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 finds that differences in calculated capacity from the designed capacities indicate an urgent need to control the parameters in the generated ratings and to formulate 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 the relevant parameters is presented. From the study conducted by the author he found that the indirect method is the most accurate method to determine the boiler efficiency and the three most effective parameters are the effect of the fuel type on the flue gas temperature, ambient temperature and efficiency. **(A. Kumar, 2020)** is done their research on **"An Exergy Analysis of a 250 MW Thermal Power Plant".** Energy analysis for system components was conducted separately and energy destruction of various components in the plant was evaluated. The total energy efficiency of the plant is estimated at 34.75%. **(Satyam Purseth, Jayprakash Dansena)** says the **"Performance Analysis And Efficiency Improvement of Boiler"** This paper reviews the literature on boiler performance analysis between 2011 and 2020. Different methods used for analysis and improvement of boiler efficiency used by different researchers.

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.

Boiler Types and Classifications

There are virtually infinite numbers of boiler designs but generally they fit into one of two categories:

Fire tubeor "fire in tube" boilers; contain long steel tubes through which the hot gasses from a furnace pass and around which the water to be converted to steam circulates. (Refer Figure 2.2). Fire tube boilers, typically have a lower initial cost, are more fuel efficient and easier to operate, but they are limited generally to capacities of 25 tons/hr and pressures of 17.5 kg/cm2.

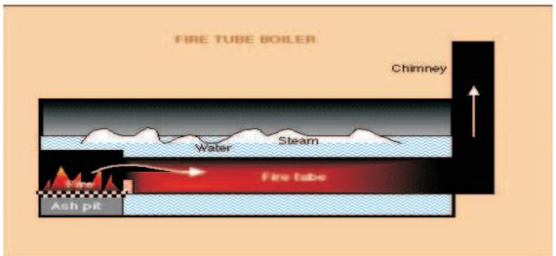


Figure 2.2 Fire Tube Boiler

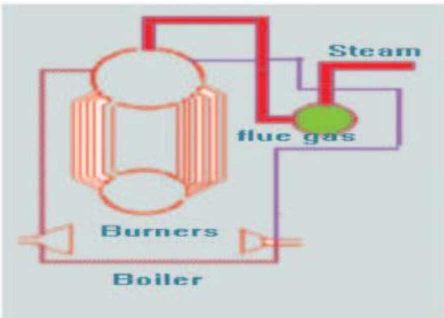


Figure 2.3 Water Tube Boiler

Water tube or "water in tube" boilers in which the conditions are reversed with the water passing through the tubes and the hot gasses passing outside the tubes (see figure 2.3). These boilers can be of single- or multiple-drum type. These boilers can be built to any steam capacities and pressures, and have higher efficiencies than fire tube boilers.

Packaged Boiler The packaged boiler is so called because it comes as a complete package. Once delivered to site, it requires only the steam, water pipe work, fuel supply and electrical connections to be made for it to become operational. Package boilers are generally of shell type with fire tube design so as to achieve high heat transfer rates by both radiation and convection (Refer Figure 2.4).

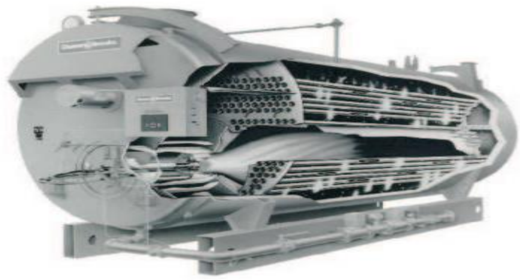


Figure 2.4 Packaged Boiler

The features of package boilers are:

✓Small combustion space and high heat release rate resulting in faster evaporation.

✓Large number of small diameter tubes leading to good convective heat transfer.

✓Forced or induced draft systems resulting in good combustion efficiency.

✓Number of passes resulting in better overall heat transfer.

✓Higher thermal efficiency levels compared with other boilers.

These boilers are classified based on the number of passes – the number of times the hot combustion gases pass through the boiler. The combustion chamber is taken, as the first pass after which there may be one, two or three sets of fire-tubes. The most common boiler of this class is a three-pass unit with two sets of fire-tubes and with the exhaust gases exiting through the rear of the boiler.

Stoker Fired Boiler

Stokers are classified according to the method of feeding fuel to the furnace and by the type of grate. The main classifications are:

1. Chain-grate or traveling-grate stoker
2. Spreader stoker

Chain-Grate or Traveling-Grate Stoker Boiler

Coal is fed onto one end of a moving steel chain grate. As grate moves along the length of the furnace, the coal burns before dropping off at the end as ash. Some degree of skill is required, particularly when setting up the grate, air dampers and baffles, to ensure clean combustion leaving minimum of unburnt carbon in the ash.

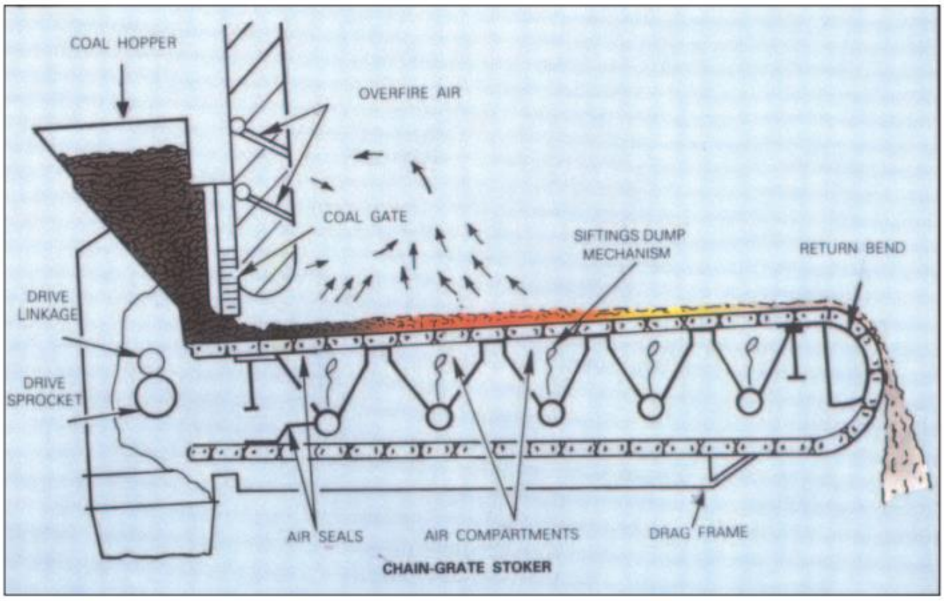


Figure 2.5 Chain Grate Stoker

The coal-feed hopper runs along the entire coal-feed end of the furnace. A coal grate is used to control the rate at which coal is fed into the furnace, and to control the thickness of the coal bed and speed of the grate. Coal must be uniform in size, as large lumps will not burn out completely by the time they reach the end of the grate. As the bed thickness decreases from coalfeed end to rear end, different amounts of air are required- more quantity at coal-feed end and less at rear end (see Figure 2.5).

Combustion

Combustion is the rapid recombination of fuel with heat. It is also thought to be the process of rapid oxygenation of the fuel, resulting in heat.

Accurate combustion (stoichiometric combustion) is obtained by making and burning the right amount of fuel and oxygen so that no products are left after combustion is complete. If too much oxygen (excess air) is supplied, the flame will be cold, short and clear; It is a complete combustion but not a complete combustion. Excess air does not participate in the combustion process unless it absorbs heat from the flame and expels it from the stock.

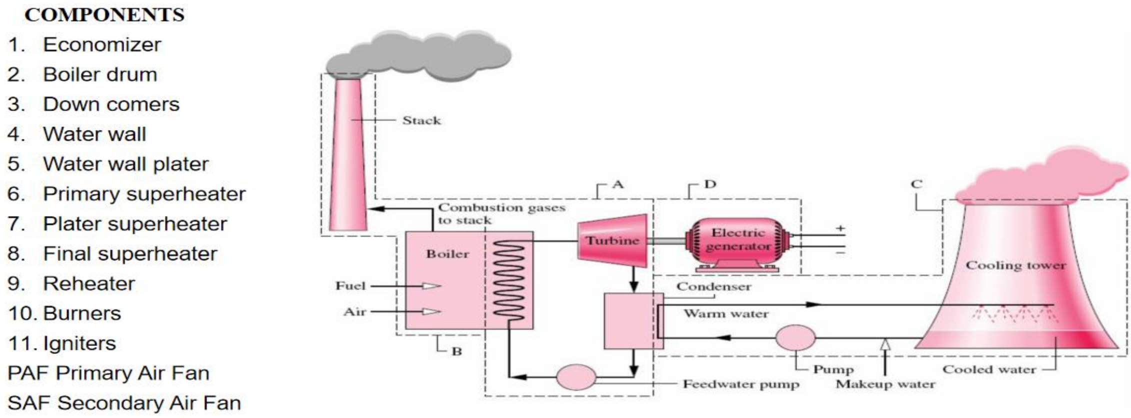
If too much fuel and not enough oxygen is supplied, the flame will last longer and sometimes smoke. It is formed by incomplete combustion and non-burning fuel (carbon monoxide, hydrogen, unburned hydrocarbons and free carbon) from the stock. Hydrocarbons are compounds made up of carbon and hydrogen atoms (eg fuel, natural gas, propane and coal).

It is important to remember the three Ts of combustion: time, temperature and turbulence. Time because all chemical processes take time to complete; Temperature because this process must take place at elevated temperatures; and turbulence must be by combining fuel and air.

Working Principle Of a Boiler

It is easy to understand how the boiler works. To understand it, let us examine it.Boiler is a closed vessel where water is stored. Hot gases are formed by burning fuel in a furnace. These glasses are made to touch the water vessel, the point where heat transfer takes place between steam and water. Therefore, the basic principle of the boiler is to convert water into steam with heat energy. There are different types of boilers available to use for different purposes.

Layout of thermal power plant



Activator Physical & Chemical Properties

Physical Properties

Appearance non-free flowing is white to off white inorganic polymer powder odourless and tasteless

Density: 0.4 to 1.2 (Varies as per fuel input grade)

Chemical Properties

Non-reactive to metals, Coal, ash or atmospheric air

Non-toxic, non-corrosive

pH value -7

Moisture – Less than 2%

Manual Fired Boilers

By Sprinkling Coal activator on ready to fire coal, and then feed into the boiler to fire.

Stoker / Spreader Stoker / FBC / AFBC / BBFC / CFBC Boilers

By Sprinkling Coal activator on Vibro Feeders, fixed over Conveyors leading to boiler bunkers, located after Coal Crusher

Mechanism of fluidized bed combustion

If the sand, in a fluidized state, is heated to the ignition temperature of the fuel and the fuel is injected continuously into the bed, the fuel will burn rapidly and the bed attains a uniform temperature due to effective mixing. This, in short is fluidized bed combustion. While it is essential that temperature of bed should be at least equal to ignition temperature of fuel and it should never be allowed to approach ash fusion temperature (1050°C TO 1150°C) to avoid melting of ash. This is achieved by extracting heat from the bed by conductive and convective heat transfer through tubes immersed in the bed.

If velocity is too low, fluidization will not occur and if the gas velocity becomes too high, the particles will be entrained in the gas stream and lost. Hence to sustain stable operation of the bed, it must be ensured that gas velocity is maintained between minimum fluidization velocity and particle entrainment velocity. Combustion temperature Excess air level and Superficial gas residence time are the principal factors that influence combustion efficiency of a FBC boiler. Combustion efficiency of Fluidized Bed Combustion (FBC) Boiler is 70%, for AFBC Boiler is upto 80%, for CFBC Boiler above 85%, for PFBC Boiler up to 90%.

Coal Activator Performance

Above Input fuel GCV, often exceeds Boiler design thermal capture %. Works hand in hand with boiler design. (Not trackable in 100 - Loss method or heat balance method)

Combustion Chamber

All action is in the Combustion Chamber. Activator raises 15 to 28% KCal / M3 (thermal concentration) across all thermal zones, lowers heat resistance in Flue gas, steel mediums, increases rate of net heat transfer, allows increment in Thermal Capture of the Boiler

System Temperatures

All furnace, flue gas, steam temperatures remain identical for 15 to 20% reduced fuel input

Steam Side

For Identical GCV, Coal Qty input, 15 to 20% more steam is generated

Coal Side

For Identical Steam, Steam net enthalpy, Coal consumption reduces by 15 to 20%

Pollution Side

15 to 20% Lower CO_2 emissions / MT Steam, Lower SO_2 emissions Lower Ash generation (identical Steam, identical coal type)

Performance Evaluation of Boilers

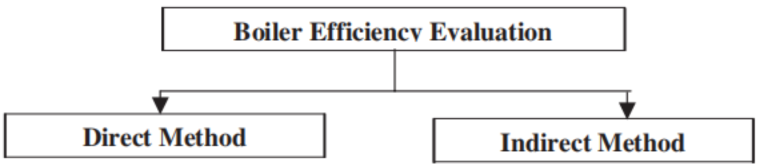
Boiler performance parameters, efficiency and evaporation ratio decrease over time due to poor combustion, heat transfer surface fouling and poor operation and maintenance even for a new boiler, deterioration of fuel quality, water quality, etc. can occur poor boiler performance. Boiler capacity tests help us to find the deviation of the boiler the best capacity for corrective action and efficiency from the target problem area.

Boiler Efficiency

The heat capacity of a boiler is defined as the percentage of heat input that can be used efficiently to produce steam. There are two methods for estimating boiler efficiency.

a) Direct method Where is the energy gain of the working fluid (water and vapor) compared to the energy content of the boiler fuel.

b) Indirect method Here efficiency is the difference between losses power input.



a) Direct method

This is also known as the 'input-output method' as only useful output is required (Steam) and heat input (i.e. fuel) to estimate efficiency. This efficiency can be estimated using the formula

$$\text{Boiler Efficiency } (\eta) = \frac{\text{Heat Output}}{\text{Heat input}} \times 100$$

Parameters to be monitored to calculate boiler capacity by direct method:

1. Quantity of steam generated per hour (Q) in kg/hr.
2. Quantity of fuel used per hour (q) in kg/hr.
3. The working pressure (in kg/cm2 (g)) and superheat temperature (°C), if any
4. The temperature of feed water (°C)
5. Type of fuel and gross calorific value of the fuel (GCV) in kCal/kg of fuel

$$\text{Boiler Efficiency } (\eta) = \frac{Q \times (h_g - h_f)}{q \times GCV} \times 100$$

Where, hg – Enthalpy of saturated steam in kCal/kg of steam

hf – Enthalpy of feed water in kCal/kg of water

Note: It should be noted that boiler may not generate 100% saturated dry steam, and there may be some amount of wetness in the steam.

Analysis of the problem

Example with Coal

Find out the efficiency of the boiler by direct method with the data given below:

Type of boiler:	Coal fired
Quantity of steam (dry) generated:	16 TPH
Steam pressure (gauge) / temp:	10 kg/cm^2 (g)/ 180°C
Quantity of coal consumed:	4.1 TPH
Feed water temperature	85°C
GCV of coal:	3200 kCal/kg
Enthalpy of steam at 10 kg/cm2 pressure:	665 kCal/kg (saturated)
Enthalpy of feed water:	85 kCal/kg

$$\text{Boiler Efficiency } (\eta) = \frac{16 \times (665-85) \times 1000}{4.1 \times 3200 \times 1000} \times 100 = 70\%$$

Example with Coal activator:

Find out the efficiency of the boiler by direct method with the data given below:

Type of boiler:	Coal fired
Quantity of steam (dry) generated:	16 TPH
Steam pressure (gauge) / temp:	10 kg/cm^2 (g)/ 180°C
Quantity of coal consumed:	3.4 TPH
Feed water temperature	85°C
GCV of coal:	3200 kCal/kg
Enthalpy of steam at 10 kg/cm2 pressure:	665 kCal/kg (saturated)
Enthalpy of feed water:	85 kCal/kg

16×(665-85)×1000

$$\text{Boiler Efficiency } (\eta) = \frac{\quad}{3.4\times3200\times1000} \times 100 = 85\%$$

Advantages of direct method

1. Plant people can evaluate quickly the efficiency of boilers
2. Requires few parameters for computation
3. Needs few instruments for monitoring

Disadvantages of direct method

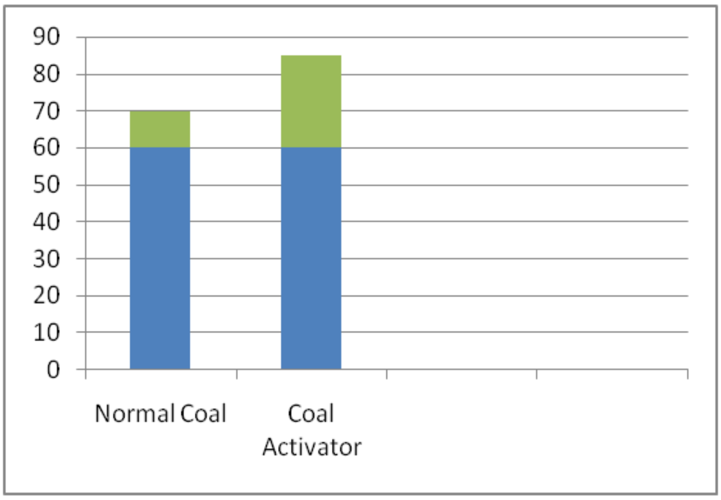
1. Does not give clues to the operator as to why efficiency of system is lower
2. Does not calculate various losses accountable for various efficiency levels

Results and Discussions

By using the coal activator, improved the performance of the boiler upto 15 to 20%.
For Manual fired boiler dosing upon raw input fuel before firing. For all other boilers upon raw input fuel in prescribed dosages after fuel crusher & Dust extraction systems, upon fuel conveyor leading to bunker, proof of performance by Direct Method.

Dosage / MT Fuel: Min. 1 to 1.2 kg; Max. 1.5 kg (High VM Coal) (Depends upon % VM)
Fringe Benefits (Other than Fuel Saving):
Lower CO_2 / MT steam, Carbon credits to user, more environment friendly steam generation process, lower ash disposals, lower cost of fuel transfers, higher life of fuel mines, lower power consumption on fuel crusher, fuel transfer etc.

Conclusions



The following conclusions were drawn from the coal activator performance analysis using a simple fire tube boiler.

1) In simple fire tube boiler by using normal coal it gives efficiency 70% and by using a coal activator it gives efficiency 85%.
2) So, the efficiency of fire tube boiler is improved 70 to 85%, thus shows the result in increase of 15%.
3) Finally it saves, reduces excess amount of coal input, lower ash disposals, lower cost of fuel transfers, higher life of fuel mines, lower power consumption on fuel crusher, fuel transfer etc.

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References

[1]. **Farhan Md. Amanulla, RathnakumarP. 2017**. 'Investigation of Boiler Performance in a Power Plant'. International Journal of Innovative Research in Advanced Engineering (IJIRAE). ISSN: 2349-2163, PP 18-22.

[2]. **Papireddy P., Ananth S., Kumar Vikash. 2018**. 'Performance analysis of boiler in thermal power plant'. International Journal of Research and Analytical Reviews (IJRAR). ISSN 2348 – 1269, Pg.no.196-203.

[3]. **Chirag Acharya, Mehta Nirvesh, Dabhi Jaspal. 2014**. 'Research paper on Analysis of Boiler losses to improve Unit heat rate of coal fired thermal power plant'. International Journal of Advance Engineering and Research Development (IJAERD). E-ISSN: 2348 – 4470, PP 1-6.

[4]. **Mr. Amitkumar, Tiwari G., Jane Shubham S., Katoke Pravin, Talmale Kunal, Dongre Kritesh. 2017**. 'Case Study on Efficiency of Boiler and Factors Affecting It'. International Journal for Scientific Research & Development (IJSRD). ISSN (online): 2321-0613, PP 1790-1793.

[5]. **G.S. Sangeeth., Marathur Praveen. 2015.** 'Efficiency improvement of boilers'. International Research Journal of Engineering and Technology (IRJET). E-ISSN: 2395 -0056, PP 265-268.

[6]. **Babu J. Suresh.Latha, Praveen B R, kumar V.Anil, kumar R Rama, Peerulla S. 2015.** 'A Study Analysis and Performance of High Pressure Boilers with its Accessories'. International Research Journal of Engineering and Technology (IRJET). E-ISSN: 2395 -0056, PP 353-359.

[7]. **Srinivas Gudimella Tirumala, Kumar Doddapineni Rajeev, Mohan Peruri Venkata Vithal Murali, Rao Boggarapu Nageswara. 2017**. 'Efficiency of a Coal Fired Boiler in a Typical Thermal Power Plant'.American Journal of Mechanical and Industrial Engineering. 2(1), PP 32-36.

[8]. **PatelChetan T., patel Bhavesh K., Patel Vijay K. 2013**. 'International Research Journal of Engineering and Technology'. International Journal of Innovative Research in Science, Engineering and Technology. ISSN: 2319-8753, PP 1518-1527.

[9]. **Kumar Ashutosh, Kumar Raj. 2017**. 'Performance analysis of atmospheric fluidized bed combustion boiler'. International journal of engineering sciences & research technology. ISSN: 2277-9655, PP 270-275.

[10]. **Bora Moni Kuntal and Nakkeeran S. 2014**. 'Performance Analysis from the Efficiency Estimation of Coal Fired Boiler'. International Journal of Advanced Research. ISSN 2320-5407, PP 561-574.

[11]. **Manikandan T, Velmurugan P, selvam P.Tamil. 2017**. 'Performance analysis of boilers'. International Journal of Advanced science and Engineering Research. ISSN:2455-9288, PP 302- 315.

[12]. **Celen P., Erdem H.H. 2017**. 'A case study for calculation of boiler efficiency by using indirect method'. 3rd conference on advances in mechanical engineering Istanbul 2017.

[13]. **Lahijani Ahmad Mahmoudi, Supeni Eris.E., Kalantari Fatemeh. 2018**. 'A Review of Indirect Method in Fire Tube Steam Boilers'. Journal of Industrial Pollution Control.

[14]. **Gulhane Sarang j, thakur Amit kumar. 2013.** 'Scope and energy losses minimizes in the afbc boiler in the cogeneration thermal power plant'. Journal of Modern Engineering Research (IJMER). ISSN: 2249, PP 1-10.

[15]. **Nuraini A. A., Salmi S., Aziz H. A. 2018.** 'Efficiency and Boiler Parameters Effects in Subcritical Boiler with Different Types of Subbituminous Coal'. Iranian Journal of Science and Technology. DOI- 10.1007.

[16]. **Gupta Rahul Dev Ghai, Sudhir, Jain Ajai. 2011**. Energy efficiency improvement strategies for industrial boiler: A case study'. Journal of Engineering and technology. DOI-10.4103/0976- 8580.74541.

[17]. **Sahu Rakesh Kumar, Rao G.Ishwar Maurya, Kirti. 2015.** 'Energy Performance Assessment of CFBC Boiler'. ISSN: 2278-0181, PP 1-5.

[18]. **Al-Taha Wadhah H., Osman Hassan A. 2018.** 'Performance Analysis of a Steam Power Plant: A Case Study'. MATEC Web of Conferences 225, 05023.DOI- 10.1051.

[19]. **Vosough Amir, falahat Alireza, vosough Sadegh, esfehani Hasan nasr. 2011.** 'Improvement Power Plant Efficiency with Condenser Pressure'. International journal of multidisciplinary sciences and engineering. PP 38-43.

[20]. **Pachaiyappan R., Prakash J. Dasa. 2015.** 'Improving the boiler efficiency by optimizing the combustion air'. Applied Mechanics and Materials. PP 238-242.

[21]. **Ghorpade Amol, Navadagi Vivekananda, Shastri C Shriram. 2016**. 'Performance Analysis for Heat Recovery Components in Coal or Biomass Fired Boilers'. International Engineering Research Journal (IERJ). ISSN 2395-162, PP 1-9.

[22]. **Sahai Abhinav, Kumar Saurabh. 2017.** 'To calculate and improvement in the efficiency of FBC boiler'. International Research Journal of Engineering and Technology (IRJET). E-ISSN: 2395-0056, PP 244-260.

[23]. **Sati Vinay, Gupta Anirudh. 2013.** 'Efficiency Improvement Opportunity in Boiler without Changing GCV of the Coal'. International Journal of Scienceand Research (IJSR). ISSN (Online): 2319-7064, PP 1057-1060.

[24]. **Kumar A., Nikam K.C., Behura A. K. 2020.** 'An Exergy Analysis of a 250 MW Thermal Power Plant'. Journal of Renewable Energy Research and Application. DOI: 10.22044.

[25]. **Khare Vivek, Bhargava Ashish, Mishra Priyanka. 2018**. 'Performance Assessment of 2X250 MW Coal Based Thermal Power Plant'. International Research Journal of Engineering and Technology (IRJET). E-ISSN: 2395-0056, PP 3552-3561.

[26]. **Satyam Purseth, Jayprakash Dansena 2021.**'Performance Analysis And Efficiency Improvement of Boiler'.International Journal of Engineering Applied Sciences and Technology, 2021 Vol. 5, Issue 12, ISSN No. 2455-2143.

[27]. Ventrapati, T., and B. Rao. "Efficiency and cost-benefit assessments on a typical 600MW coalfired boiler power plant." International Journal of Mechanical and Production Engineering Research and Development 1 (2019): 201-206.

[28]. Kumar, M., B. Veerabhadra Reddy, and P. Venkateshwar Reddy. "Experimental Comparison of Solar Paraboloid Collector with and without Mirror in Aluminum Foil as Reflectors." International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) 8.2 (2018): 1117-1124.

[29]. Emeema, J., MD KHIMRAN UDDIN, and M. A. Pasha. "Design and analysis of air preheater." International Journal of Mechanical and Production Engineering Research and Development 8.3 (2018): 1009-1022.

[30]. Chaurasiya, Ritesh Kumar, and Priyash Agarwal. "Thermodynamic Analysis for Performance Improvement of Power Plant by Flue Gas Heat Recovery System." International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) 8 (2018): 569-578.

[31]. Singh, S. E. W. A., V. I. K. A. S. Chawla, and G. S. Brar. "The performance of TIG welded similar and dissimilar weldments under tensile loading: An experimental investigation." Int. J. Mech. Prod. Eng. Res. Dev. 9.4 (2019): 1015-1026.

[32]. Deepak, D., and Beedu Rajendra. "Investigation of the effect of process parameters on material removal rate in machining of is 5986 fe 410 steel by wire-edm: the Optimization and regression modeling." International Journal of Mechanical and Production Engineering Research and Development 9.6 (2019): 411-420.