"CASE STUDY ON EFFICIENCY OF BOILER AND FACTORS AFFECTING IT"

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Abtract :

Thermal power plant converts the chemical energy of the coal into electricity. The heat rate of a conventional coal fired power plant is a measure of how efficiently it converts the chemical energy contained in the fuel into electrical energy. Coal fired Boiler is one of the most important components for any Thermal Power Plant. The aim of monitoring boiler performance is to control the heat rate of plant. The world over energy resources are getting scarcer and increasingly exorbitant with time. In India bridging the ever widening gap between energy demand and supply by increasing supply is an expensive option. The share of energy costs in total production costs can, therefore improve profit levels in all the industries. This reduction can be achieved by improving the efficiency of industrial operations and equipments. The power sector is one of the sectors of the India's economy. The development of the country to a large extent is dependent on the growth of this sector. Through the progress of the power sector during the past four decades has been sustainable, the power industry has been unable to fulfill primary obligation of production quality power supply in required quantity. We did our project in Khaper kheda Thermal Power Station, Nagpur (India) and analyzed the performance of the boiler of the unit of capacity 210 MW and find out the remidies. Our project was mainly concerned with the Boiler Operations & Maintenance Department (O&M). This study will help to increase overall boiler efficiency and as a result, annual monetary savings of the thermal power plant. The aim of monitoring boiler performance is to control the heat rate of plant and suggest our solution on the problems observed in power plant.

Keywords:
Boiler performance, Heat rate, Remedies, Overall boiler efficiency.

Introduction:

The energy demand in India, not unexpectedly, is amongst the lowest in the world on per capita basis. All efforts must be made to conserve energy is an understatement and even the most modest attempt in this direction is worthy. The energy released from the combustion processes is used to generate process steam in a boiler system. About 70% of energy generation capacity is from fossil fuels in India. Coal consumption is 40% of India's total energy consumption which followed by crude oil and natural gas at 24% and 6% respectively. India is dependent on fossil fuel import to fulfill its energy demands. The energy imports are expected to exceed 53% of the India's total energy consumption. In 2009-10, 159.26 million tones of the crude oil is imported which amounts to 80% of its domestic crude oil consumption Cause of this, India's coal imports is increased by 18% for electricity generation in 2010.When investigating steam systems the boiler is one of the primary targets for energy efficiency improvement. Boiler efficiency describes the fraction transferring heat to a process. When water is boiled into steam its volume increases about 1,600times, producing a force that is almost as explosive as gunpowder that will run the turbine in later processes to generate electricity. This causes the boiler to be of fuel energy that is converted into useful steam energy. Of course, the fuel input energy that is not converted into useful steam energy represents the losses of the boiler operation. Boiler research generally evaluates the losses by identifying the paths of loss, measuring the individual loss, and developing a strategy for loss reduction. The project is based on Khaperkheda powerplant which is operated by MAHAGENCO. The coal for the powerplant is sourced from Saoner and DumriKhurd mines of WesternCoalfields Limited (WCL). Source of water for the powerplant is from Pench reservoir through a pond of koradi thermal power station.

1. Boiler and it's types :

A coal fired boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes steam. The steam under pressure is then usable for transferring the heat to a process. Water is a useful and cheap medium for extremely dangerous equipment that must be treated with utmost care. The process of heating a liquid until it reaches its gaseous state is called evaporation. Heat is transmitted from one body to another mainly by three modes of heat transfer viz. radiation, convection and conduction. Thermal power plant boilers are different from other boilers because of the complexity of the process and different types of system involve in the entire combustion process. The complexity of the system is basically addressed in terms of efficiency of the boiler. The primary aim of any thermal combustion system is to maximize the efficiency. i.e., net output energy we get, by input energy. The boiler designed in Thermal Power Plant serves the above end. In Boilers, differential heating takes place, and each area of the boiler has got different temperature. To maximize efficiency it is important to construct/assemble water tube in the way to maximize heat absorption by conduction, which gives rise to different process.

1.2. Types of Boilers:

a. Fire tube:

Fire tube or "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. The heat source is inside a furnace or firebox that has to be kept permanently surrounded by the water in order to maintain the temperature of the heating surface below the boiling point. The furnace can be situated at one end of a fire-tube which lengthens the path of the hot gases, thus augmenting the heating surface which can be further increased by making the gases reverse direction through a second parallel tube or a bundle of multiple tubes (two-pass or return flue boiler); alternatively the gases may be taken along the sides and then beneath the boiler through flues (3-pass boiler) . Fire-tube boilers usually have a comparatively low rate of steam production, but high steam storage capacity. Fire-tube boilers mostly burn solid fuels, but are readily adaptable to those of the liquid or gas variety.Firetube boilers, typically have a lower initial cost, are more fuel efficiency**.** Firetube 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.

b. Water tube:

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. In this type, tubes filled with water are arranged inside a furnace in a number of possible configurations. Often the water tubes connect large drums, the lower ones containing water and the upper ones steam and water; in other cases, such as a mono-tube boiler, water is circulated by a pump through a succession of coils. This type generally gives high steam production rates, but less storage capacity than the above. Water tube boilers can be designed to exploit any heat source and are generally preferred in high-pressure applications since the high-pressure water/steam is contained within small diameter pipes which can withstand the pressure with a thinner wall. 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.

c. 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.

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

2. Boiler Performance :

The performance parameters of boiler, like efficiency and evaporation ratio reduces with time due to poor combustion, heat transfer surface fouling and poor operation and maintenance .Even for a new boiler, reasons such as deteriorating fuel quality, water quality etc. can result in poor boiler performance. Boiler efficiency tests help us to find out the deviation of boiler efficiency from the best efficiency and target problem area for corrective action. The boiler efficiency by "Losses Method" or "Indirect Method" can be calculated by considering a varied number of factors such as unit load, feed water flow at economizer inlet, dry bulb temperature, wet bulb temperature, fly ash, bottom ash, gross calorific value, calorific value, total secondary air flow, total primary air flow, total air flow, total main stream flow, carbon, nitrogen, hydrogen, oxygen, moisture, etc

3. Losses in Boiler:

a. Sensible Heat Loss:

Sensible heat losses can be thought of as heat you can sense directly with a thermometer. For example, combustion air enters your power plant at ambient conditions, and flue gas is exhausted from the cold end of the boiler air heater at some elevated temperature. The closer the exhaust gas is to ambient temperature, the less sensible heat is lost to the environment. Other sensible heat losses include the heat contained in bottom and fly ash removed from the boiler and pyrites and rock that are rejected from coal mills. The quantity of excess air used for combustion has a significant effect on this loss, as every pound of excess air that travels through the boiler carries with it potentially usable energy.

b. Latent Heat Loss:

Latent heat losses are not easily detectable by a thermometer and are energy losses associated with a phase change of water. When a fuel is burned in a boiler, not only does all moisture contained within the fuel vaporize into steam, but all hydrogen contained within the fuel combusts to form water, which also is vaporized into steam. Unless the temperature of the exhaust gas leaving the boiler air heater is below the boiling point of the water contained within the gas, all of that latent heat of vaporization will exit the boiler and be lost to the environment. Because latent heat losses are primarily fuel-related, they cannot be easily changed without switching or drying your fuel.

c. Unburned Combustible Loss:

Unburned combustible losses are efficiency losses from incomplete combustion of fuel in the boiler. This is primarily measured in the form of carbon residue in the ash, but it also includes carbon monoxide (CO) production. These losses are generally influenced by both fuel properties (fuel volatility) and operations practices (excess air level, fuel fineness, and the like). It is important to note that unburned combustible loss is not the same as loss-on-ignition (LOI), as unburned combustible loss is an energy loss, whereas LOI is calculated on a mass basis in the ash.

d. Radiation and Convection Loss:

Utility boilers are enormous equipment systems, with numerous penetrations for tubes and instruments, and a very large surface area exposed to the environment. As a result, no matter how well-designed the insulation is and how diligent plant personnel are in fixing air leaks, energy will still be lost via radiation and convection.

e. Margin and Unknown Losses:

Due to the large size and complexity of the boiler, it is often not practical to measure every single possible source of energy loss from the power plant. As a result, a "margin" or "unknown loss" value is typically used to estimate these losses. Typical values range from 0.5% to 2.0%.When all of these efficiency losses are taken into account, a typical utility boiler can utilize fuel energy with an efficiency ranging from 83% to 91%.

4. Boiler Blowdown:

When water is boiled and steam is generated, any dissolved solids contained in the water remain in the boiler. If more solids are put in with the feed water, they will concentrate and may eventually reach a level where their solubility in the water is exceeded and they deposit from the solution. Above a certain level of concentration, these solids encourage foaming and cause carryover of water into the steam. The deposits also lead to scale formation inside the boiler, resulting in localized overheating and finally causing boiler tube failure. It is, therefore, necessary to control the level of concentration of the solids and this is achieved by the process of 'blowing down', where a certain volume of water is blown off and is automatically replaced by feed water – thus maintaining the optimum level of total dissolved solids (TDS) in the boiler water. Blow down is necessary to protect the surfaces of the heat exchanger in the boiler. However, blow down can be a significant source of heat loss, if improperly carried out.

5. MAINTENANCE OF BOILERS:

a. Perform regular servicing:

A full boiler service should be carried out on an annual basis, ideally before the start of the summer season. This service should include a flue gas analysis (to check fuel-to-air ratio), an operational check, controls calibration, burner cleaning and lime scale treatment.

b. Analyse flue gas:

Analysis of the boilers flue gases for levels of carbon dioxide (CO_2), oxygen (O_2) and carbon monoxide (CO) will determine whether this ratio is correct and what adjustments need to be made. Flue gas analysis should be carried out typically for every three months and the combustion efficiency which includes measures for improving it.

c. Soot removal:

If combustion conditions are not correct, particularly if too little air is used, fuel combustion will not be complete. So excessive amounts of CO and particles of carbon (soot) will form. If these particles build up on the fire side of the boilers heat exchanger they will form an insulating layer, inhibiting heat transfer to the water. More heat input is required to meet the heat demand and more heat energy will be lost to the flue. Fossil fuel like coal is more likely to form soot and should be carefully monitored. A 1 mm layer of soot will cause a 10% increase in energy input to the boiler to meet the same heat demand. Integrated soot-blowers are often installed in boilers to provide continual cleaning; however, these will need to be checked regularly to ensure good working.

D. Minimise limescale build-up:

In hard water areas, limescale can build up on the water side of the boilers heat exchanger. This creates an insulating layer, preventing heat transfer to the water in the same way as the soot deposits. The most effective method of limescale removal is through chemical treatment of the water. This should be done annually to minimise lime scale build-up and keep your boiler running at its most efficient.

6. BoilerWater Treatment:

Producing quality steam on demand depends on properly managed water treatment to control steam purity, deposits and corrosion. A boiler is the sump of the boiler system. It ultimately receives all of the pre-boiler contaminants. Boiler performance, efficiency, and service life are direct products of selecting and controlling feed water used in the boiler. When feed water enters the boiler, the elevated temperatures and pressures cause the components of water to behave differently. Most of the components in the feed water are soluble. However, under heat and pressure most of the soluble components come out of solution as particulate solids, sometimes in crystallized forms and other times as amorphous particles. When solubility of a specific component in water is exceeded, scale or deposits develop. The boiler water must be sufficiently free of deposit forming solids to allow rapid and efficient heat transfer and it must not be corrosive to the boiler metal.

7. Energy Conservation opportunities:

The various energy efficiency opportunities in boiler system can be related to combustion, heat transfer, avoidable losses, high auxiliary power consumption, water quality and blowdown. Examining the following factors can indicate if a boiler is being run to maximize its efficiency:

a. Stack Temperature:

The stack temperature should be as low as possible. However, it should not be so low that watervapor in the exhaust condenses on the stack walls. This is important in fuels containing significant sulphur as low temperature can lead to sulphur dew point corrosion. Stack temperatures greater than 200°C indicates potential for recovery of waste heat. It also indicate the scaling ofheat transfer/recovery equipment and hence the urgency of taking an early shut down for water/ flue side cleaning. Heat can be recovered from exhaust gases through the use of a device like air preheater, economizer. The heat can be used to pre-heat the return water or the combustion air. Increasing the temperature of the combustion air by 20 ºC can improve the overall efficiency of the boiler by 1%.

b. Combustion Air Preheat:

Combustion air preheating is an alternative to feedwater heating. In order to improve thermal efficiency by 1%, the combustion air temperature must be raised by 20 °C. Most gas and oil burners used in a boiler plant are not designed for high air preheat temperatures. Modern burners can withstand much higher combustion air preheat, so it is possible to consider such units as heat exchangers in the exit flue as an alternative to an economizer.

c. Incomplete Combustion:

Incomplete combustion can arise from a shortage of air or surplus of fuel or poor distribution of fuel. It is usually obvious from the colour or smoke, and must be corrected immediately. In the case of oil and gas fired systems, CO or smoke (for oil fired systems only) with normal or high excess air indicates burner system problems. A more frequent cause of incomplete combustion is the poor mixing of fuel and air at the burner. Poor oil fires can result from improper viscosity, worn tips, carbonization on tips and deterioration of diffusers or spinnerplates. With coal firing, unburned carbon can comprise a big loss. It occurs as grit carry-over or carbon-in-ash and may amount to more than 2% of the heat supplied to the boiler. Non uniform fuel size could be one of the reasons for incomplete combustion. In chain grate stokers, large lumps will not burn out completely, while small pieces and fines may block the air passage, thus causing poor air distribution. In sprinkler stokers, stoker grate condition, fuel distributors, wind box air regulation and over-fire systems can affect carbon loss. Increase in the fines inpulverized coal also increases carbon loss.

d. Excess Air Control:

Excess air is required in all practical cases to ensure complete combustion, to allow for the normal variations in combustion and to ensure satisfactory stack conditions for some fuels. The optimum excess air level for maximum boiler efficiency occurs when the sum of the losses due to incomplete combustion and loss due to heat in flue gases is minimum. This level varies with furnace design, type of burner, fuel and process variables. It can be determined by conducting tests with different air fuel ratios. Controlling excess air to an optimum level always results in reduction in flue gas losses; for operates at only 25 percent output. Repairing or augmenting insulation can reduce heat loss through boiler walls and piping.

every 1% reduction in excess air there is approximately 0.6% rise in efficiency. Various methods are available to control the excess air:

- Portable oxygen analysers and draft gauges can be used to make periodic readings to guide the operator to manually adjust the flow of air for optimum operation. Excess air reduction up to 20% is feasible.

e. Radiation and Convection Heat Loss:

The external surfaces of a shell boiler are hotter than the surroundings. The surfaces thus lose heat to the surroundings depending on the surface area and the difference in temperature between the surface and the surroundings. The heat loss from the boiler shell is normally a fixed energy loss, irrespective of the boiler output. With modern boiler designs, this may represent only 1.5% on the gross calorific value at full rating, but will increase to around 6%, if the boiler

f. Automatic Blowdown Control:

Uncontrolled continuous blowdown is very wasteful. Automatic blowdown controls can be installed that sense and respond to boiler water conductivity and pH. A 10% blow down in a 15kg/cm2 boiler results in 3% efficiency loss.

g. Install variable speed drives and pumps:

On forced/induced-draught boilers, a variable speed drive can be installed on the fan to operate at lower speeds when less air flow is required. A reduction in in fan speed of just 10% can result in fan energy consumption savings of around 20%, and a reduction in fan speed of 20% will save up to 40%. This is particularly relevant for big boiler systems. Variable speed control is an important means of achieving energy savings. Generally, combustion air control is effected by throttling dampers fitted at forced and induced draft fans. Though dampers are simple means of control, they lack accuracy, giving poor control characteristics at the top and bottom of the operating range. In general, if the load characteristic of the boiler is variable, the possibility of replacing the dampers by a VSD should be evaluated.

8. Coals and type of coal used:

Coal is an organic sedimentary rock that forms from the accumulation and preservation of plant materials, usually in a swamp environment. Coal is a combustible rock and, along with oil and natural gas, it is one of the three most important fossil fuels. Coal has a wide range of uses; the most important use is for the generation of electricity.

8.1. Types of coal (from lowest to highest grade):

Rank (From Lowest to Highest)	**Properties**	
Peat	A mass of recently accumulated to partially carbonized plant debris. Peat is an organic sediment. Burial, compaction, and coalification will transform it into coal, a rock. It has a carbon content of less than 60% on a dry ash-free basis.	

Lignite	Lignite is the lowest rank of coal. It is a peat that has been transformed into a rock, and that rock is a brown-black coal. Lignite sometimes contains recognizable plant structures. By definition it has a heating value of less than 8300 British Thermal Units per pound on a mineral-matter-free basis. It has a carbon content of between 60 and 70% on a dry ash-free basis. In Europe, Australia, and the UK, some low-level lignites are called "brown coal."	
Sub Bituminous	Sub bituminous coal is a lignite that has been subjected to an increased level of organic metamorphism. This metamorphism has driven off some of the oxygen and hydrogen in the coal. That loss produces coal with a higher carbon content (71 to 77% on a dry ash-free basis). Sub bituminous coal has a heating value between 8300 and 13000 British Thermal Units per pound on a mineral-matter-free basis. On the basis of heating value, it is subdivided into sub bituminous A, sub bituminous B, and sub bituminous C ranks.	
Bituminous	Bituminous is the most abundant rank of coal. It accounts for about 50% of the coal produced in the United States. Bituminous coal is formed when a sub bituminous coal is subjected to increased levels of organic metamorphism. It has a carbon content of between 77 and 87% on a dry ash-free basis and a heating value that is much higher than lignite or sub bituminous coal. On the basis of volatile content, bituminous coals are subdivided into low-volatile bituminous, medium-volatile bituminous, and high-volatile bituminous. Bituminous coal is often referred to as "soft coal"; however, this designation is a layman's term and has little to do with the hardness of the rock.	
Anthracite	Anthracite is the highest rank of coal. It has a carbon content of over 87% on a dry ash-free basis. Anthracite coal generally has the highest heating value per ton on a mineral-matter-free basis. It is often subdivided into semi-anthracite, anthracite, and meta-anthracite on the basis of carbon content. Anthracite is often referred to as "hard coal"; however, this is a layman's	

	term and has little to do with the hardness of the rock.	

9. Problems observed and their Solutions:

Sr no.	Problems observed	Remedies
1.	Chocking of wet coal in chain feeder	Providing the piston cylinder arrangement at the outlet of the chain mechanism so that the coal will be feeded continuously to the boiler
2.	High unburnt fuel in stack	Use of flue gas analyser and provide excess oxygen by using variable frequency drive in F.D. fan
3.	Corrosion in boiler due to the oxygen entering with feed water.	In internal heat treatment for dissolve oxygen by addition sodium sulphite.

10. CONCLUSIONS:

The objective of the study was to analyze the overall efficiency and the thermodynamic analysis of boiler. There are many factors, which are influencing the performance of the boiler. Heat rate is increases as boiler efficiency decreases so to achieve desired heat rate boiler performance required to be improved. Boiler efficiency is improved by reducing various losses and controlling stack temperature. The fuel used for combustion, type of boiler, varying load, power plant age, heat exchanger fouling are some factors which affects the efficiency. Blow down water carries thermal energy in the form of steam that can be reused may result in improve the boiler efficiency. Blow down heat recovery system may provide you with significant savings to the boiler plant. Hence flue gas analyser and automatic blowdown equipments should be used to reduce the stack losses and blowdown losses. It is necessary to check all the equipments periodically to avoid chocking and wear. Hence, a viable study is carried out to assess the performance of boiler plant in this context.

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