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PERFORMANCE IMPROVEMENT AND WASTAGE ELIMINATION IN THERMAL POWER PLANT

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***Abstract*— Coal power plants are the major source of the power generation in many industries etc. To study and complete understand of thermal power plant in the industry, various systems in the thermal power plant - boiler system and thermal losses. Surface heat loss in the boiler and boiler blow down are analyzed by practical observations. After analysis the values of the systems are compared with OEM (Original equipment manufacturer) values and try to optimize further by performance improvement, wastage elimination and proper thermal insulations in thermal power plant. There is a chance to improve performance and wastage elimination in following systems.**

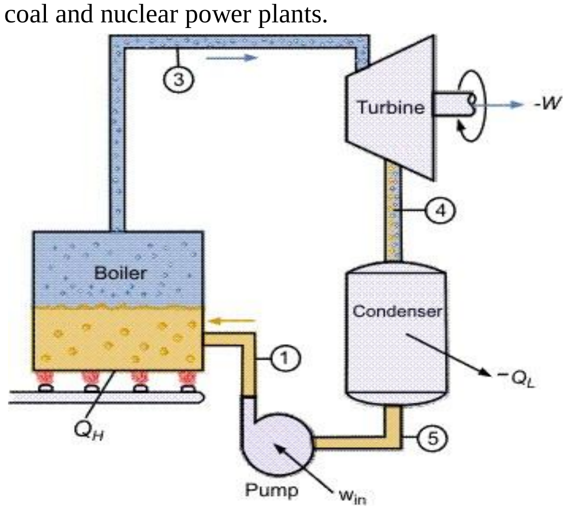
***Index Terms*—Thermal power plant layout, Coal handling system, Boilers, ash handling system, surface heat losses , boiler blow down & other leakages.**

I. INTRODUCTION

Thermal power plants are one of the main sources of electricity in both industrialized and developing countries. The variation in the thermal power stations is due to the different fuel sources (coal, oil or natural gas etc). In a thermal power plant, one of coal, oil or natural gas is used to heat the boiler to convert the water into steam. In fact, more than half of the electricity generated in the world is by using coal as the primary fuel.

A simple power plant consists of a boiler, turbine, condenser and a pump. Firstly, Water is taken into the boiler from a water source. The boiler is heated with the help of coal. The increase in temperature helps in the transformation of water into steam. The steam generated in the boiler is sent through a steam turbine. The turbine has blades that rotate when high velocity steam flows across them. This rotation of turbine blades is used to generate electricity. A generator is connected to the steam turbine. When the turbine turns, electricity is generated and given as output by the generator, which is then supplied to the consumers through high-voltage power lines. And after that the steam leaves the turbine it is cooled to its liquid state in the condenser. The liquid is pressurized by the pump prior to go back to the boiler. A simple power plant is described by a Rankine Cycle.

The Rankine cycle is a cycle that converts heat into work. The heat is supplied externally to a closed loop, which usually uses water. This cycle generates about 90% of all electric power used throughout the world including virtually all solar thermal, biomass, coal and nuclear power plants.



This paper discusses about analysis, performance improvement and wastage elimination in thermal power plant.

II. BOILERS

Boiler is a closed vessel in which water is heated and converted into steam. We have many types' boilers. We mainly consider Circulating Fluidized bed combustion boiler Mechanism of Fluidized Bed Combustion when an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles are undisturbed at low velocity. As air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream – the bed is called “fluidized”._With further increase in air velocity, there is bubble formation, vigorous turbulence, rapid mixing and formation of dense defined bed surface. The bed of solid particles exhibits the properties of a boiling liquid and assumes the appearance of a fluid – “bubbling fluidized bed”. At higher velocities, bubbles disappear, and particles are blown out of the bed. Therefore, some amounts of particles have to be re-circulated to maintain a stable system – “circulating fluidized bed”.

Fluidization depends largely on the particle size and the air velocity. The

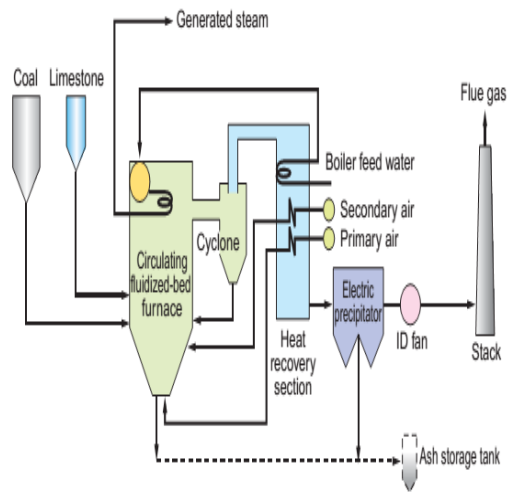
mean solids velocity increases at a slower rate than does the gas velocity. The difference between the mean solid velocity and mean gas velocity is called as slip velocity. Maximum slip velocity between the solids and the gas is desirable for good heat transfer and intimate contact. If sand particles in a fluidized state is heated to the ignition temperatures of coal and coal is injected continuously into the bed, the coal will burn rapidly and bed attains a uniform temperature. The fluidized bed combustion (FBC) takes place at about 840º C to 950 º C. Since this temperature is much below the ash fusion temperature, melting of ash and associated problems are avoided. The lower combustion temperature is achieved because of high coefficient of heat transfer due to rapid mixing in the fluidized bed and effective extraction of heat from the bed through in-bed heat transfer tubes and walls of the bed. The gas velocity is maintained between minimum fluidization velocity and particle entrainment velocity. This ensures stable operation of the bed and avoids particle entrainment in the gas stream.

Circulating Fluidized Bed combustion has given boiler and power plant operators a greater flexibility in burning a wide range of coal and other fuels. All this without compromising efficiency and with reduced pollution.

In the olden days blacksmiths used to heat the iron by placing it on a bed of coal. Bellows provide air to the coal from the bottom of the bed. Fluidized Bed combustion is similar to this.

At the bottom of the boiler furnace there is a bed of inert material. Bed is where the coal or fuel spreads. Air supply is from under the bed at high pressure. This lifts the bed material and the coal particles and keeps it in suspension. The coal combustion takes place in this suspended condition.

Special design of the air nozzles at the bottom of the bed allows air flow without clogging. Primary air fans provide the preheated Fluidizing air. Secondary air fans provide pre-heated Combustion air. Nozzles in the furnace walls at various levels distribute the Combustion air in the furnace.



Bed Material

To start with the bed material is sand. Some portion is lost in the ash during the operation and this has to be made-up. In coal fired boilers the ash from the coal itself will be the makeup material. For high Sulphur coals Limestone addition to the bed material reduces SO_2 emissions.

CFBC uses crushed coal of 3 to 8 mm size. This requires only a crusher not a pulveriser. From storage hoppers Conveyer and feeders transport the coal to feed chutes in the furnace. Start up is by oil burners in the furnace. Ash spouts in the furnace remove the ash from the bottom of the furnace.

The features of circulating fluidized-bed boilers are described below.

1) Compatibility with wide range of fuels Conventional boilers for power generation can use only fossil fuels, such as high-grade coal, oil, and gas. The CFBC is also capable of using low-grade coal, biomass, sludge, waste plastics, and waste tires as fuel.

2) Low polluting NOx and SOx emissions are significantly decreased without special environmental modifications. In the case of fluidized-bed boilers,

desulfurization is carried out , using mainly limestone as the fluidizing material. For denitration, PC boilers operate at combustion temperatures from 1,400oC to 1,500oC, whereas circulating fluidized-bed boilers operate at lower temperatures, ranging from 850oC to 900oC, thereby suppressing
thermal NOx emissions as the generation of NOx is dependent upon the combustion temperature. In addition, the operation of circulating fluidized-bed boilers involves a two-stage combustion process: the reducing combustion at the fluidized-bed section, and the oxidizing combustion at the freeboard section. Next, the unburned carbon is collected by a high-temperature cyclone located at the boiler exit to recycle to the boiler, thus increasing the denitration efficiency.

3) High combustion efficiency Improved combustion efficiency is attained through the use of a circulating fluidization-mode combustion mechanism.

4) Space-saving, ease of maintenance Space saving is attained because there is no need for separate desulfurization, denitration, and fine-fuel crushing units. Accordingly, trouble-spots are minimized, and maintenance is simplified.

III. SURFACE HEAT LOSSES IN BOILER

The external surface of an operating system boiler is hotter than its surroundings therefore losses heat by both radiation and convection. So insulation is required to minimize the surface heat loss

Insulation Boiler has following purpose

(1) Reduce the heat loss and increase the efficiency of the boiler.
(2) It aids protection contact by minimising the surface temperature.
(3) Prevents the compartment air in the boiler house which guarantees and acceptable working.

Insulation materials

Fiber glass

Fibre glass is a type of fibre reinforced plastic fibre glass blanket insulation is suited for application on rounded shapes such as pipes, tanks, ducts, vessels and irregular shapes. Fibre glass insulation of boiler is for application 538℃ and the valve of R-3.1

Mineral wool blanket insulation

Mineral wool blanket insulation is suitable for boiler furnace. The melting point of mineral is 1177℃

Cellulose

Cellulose insulation is perhaps is one of the most eco- friendly forms of insulation. Cellulose is made from recycled card board; paper the R-value between R-3.1 to 3.7

Plastic fiber

Plastic fibre insulation material primarily made from recycled plastic milk bottles. The fibres are formed into batt insulation similar to high density fibre glass.

Natural Fibre

Natural fibres are used for insulation. The natural fibres are cotton sheep's wool.

Fibre bricks

Fire bricks are soft and light in weight. The fire bricks are used for insulation. Fire bricks are best insulation product it contains alumina 37%, silica 61% and ferric oxide 1.6% the thermal conductivity of fibre bricks is 750℃ insulating fibre bricks are generally used in boiler furnace.

Ceramic insulation

The type of ceramic insulation is the latest in spray on technology. The application is for high temperature steam lines and vessels. Ceramic is more expensive than fibre glass insulation. Therefore, where fibre glass or other conventional insulation can be effectively used ceramic is also great corrosion inhibitor and more resistant to impact damage and moisture. There are types of ceramics that can be applied to hot surface

IV. PRACTICAL OBSERVATION

Practically observed where the uninsulated areas in the boiler.
These areas are found uninsulated about 50sqm.

The total uninsulated area is 50sqm and the surface temperature is 400℃. The uninsulated areas cause surface heat loss. It requires insulation where uninsulated areas to reduce the surface heat loss in the boiler.

Surface heat loss calculations

(1) Surface temperature 400 ℃

(2) Required temperature after insulation 60 ℃

(3) Total area of uninsulated surface 50 m^2

FORMULAS

Heat loss due to uninsulated surfaces

= [(10+ (surface temperature℃–required temperature after insulation ℃) ×

20

(Surface temperature ℃ – required temperature after insulation ℃)] × Total area of insulated surface m^2

Average GVC of the coal burned 6500Kcal/hr

Equivalent Coal loss

=Heat loss due to uninsulated surface × 24

Average GCV of the Coal burned 1000

Landing Cost of Coal per ton 5000

Daily Financial loss at 85% Boiler efficiency

= (equivalent coal loss × loading cost of coal per ton)

0.85

Yearly financial loss at 92% availability

= Daily financial loss at 85% boiler efficiency × 365 × 0.9

Tabular Form

1	Surface temparature	^{0}C	400
2	Required temp after insulation (Max)	^{0}C	60
3	Total area of un insulated surface	m^2	50
	Heat loss due to un insulated surface	**Kcal/hr**	**459000**
4	Average GCV of the coal burned	Kcal/Kg	6500
5	Equivalent coal loss	TPD	1.695
6	Landing cost of Coal per ton	Rs.	5000
7	Daily financial loss at 85% boiler efficiency	Rs.	9969
		Rs.	
	Yearly financial loss at 92% availability	**Rs.**	**3347668**

FINDING:

Heat loss due to uninsulated surface is 459000KCAL/hr. So the uninsulated area should be insulated for energy wastage elimination and to increase performance of the boiler

V. BOILER BLOWDOWN AND LEAKAGES

Boiler blow down is the removal of water from a boiler. Its purpose is to control boiler water parameters within prescribed limits to minimize scale, corrosion, carryover, and other specific problems. Blow down is also used to remove suspended solids present in the system. These solids are caused by feed water contamination, by internal chemical treatment precipitates, or by exceeding the solubility limits of otherwise soluble salts.

In effect, some of the boiler water is removed (blown down) and replaced with feed water.

The percentage of boiler blow down is as follows:

$$\frac{\text{Quantity blow down water}}{\text{Quantity feed water}} \times 100 = \%\text{blow down}$$

The blow down can range from less than 1% when extremely high-quality feed water is available to greater than 20% in a critical system with poor-quality feed water. Blow down should not be more than 1%. In plants with sodium zeolite softened makeup water, the percentage is commonly determined by means of a chloride test. In higher-pressure boilers, a soluble, inert material may be added to the boiler water as a tracer to determine the percentage of blow down.

LIMITING FACTORS AFFECTING BLOWDOWN

The primary purpose of blow down is to maintain the solids content of boiler water within certain limits. This may be required for specific reasons, such as contamination of the boiler water. In this case, a high blow down rate is required to eliminate the contaminants as rapidly as possible.

The blow down rate required for a particular boiler depends on the boiler design, the operating conditions, and the feed water contaminant levels. In many systems, the blow down rate is determined according to total dissolved solids. In other systems, alkalinity, silica or suspended solids levels determine the required blow down rate.

MANUAL BLOWDOWN

Intermittent manual blow down is designed to remove suspended solids, including any sludge formed in the boiler water. The manual blow down take-off is usually located in the bottom of the lowest boiler drum, where any sludge formed would tend to settle.

Properly controlled intermittent manual blow down removes suspended solids, allowing satisfactory boiler operation. In practice, the manual blow down valves opened periodically in accordance with an operating schedule.

CONTINUOUS BLOWDOWN

Continuous blow down, as the term implies, is the continuous removal of water from the boiler. It offers many advantages not provided by the use of bottom blow down alone. For instance, water may be removed from the location of the highest dissolved solids in the boiler water. As a result, proper boiler water quality can be maintained at all times. Also, a maximum of dissolved solids may be removed with minimal loss of water and heat from the boiler.

Another major benefit of continuous blow down is the recovery of a large amount of its heat content through the use of blow down flash tanks and heat exchangers. Control valve settings must be adjusted regularly to increase or decrease the blow down according to control test results and to maintain close control of boiler water concentrations at all times.

EQUIPMENT EMPLOYED

Manual Blow down

Equipment for manual blow down, considered a part of the boiler and installed with the unit, usually consists of a take-off line, a quick-opening valve, and a shut-off valve. The take-off line is always located in the lowest part of the lowest boiler drum, where the greatest concentration of suspended solids should form.

Several types of water-tube boilers have more than one blow down connection. They permit blow down from both ends of the mud drum. Blow down connections are installed on headers for draining and for removal of suspended solids which may accumulate and restrict circulation. The boiler manufacturer usually specifies certain restrictions on the blow down of water wall headers. These restrictions should be followed closely.

Continuous Blow down

Usually, continuous blow down equipment is installed by the boiler manufacturer. The exact location of the continuous blow down take-off line depends primarily on the water circulation pattern. Its position must ensure the removal of the most concentrated water. The line must also be located so that boiler feed water or chemical feed solution does not flow directly into it. The size of the lines and control valves depends on the quantity of blow down required. In most units the take-off line is several inches below the low water level. In other designs, the take-off is close to the bottom of the steam drum.

Automatic Blow down

An automatic blow down control system continuously monitors the boiler water, adjusts the rate of blow down, and maintains the specific conductance of the boiler water at the desired level. The basic components of an automatic blow down control system include a measurement assembly, a control centre, and a modulating blow down control valve.

Practical observation

Practically observed the boiler blow down of a boiler on 9th march 2016

The total steam generation in the boiler is 10550 cubic meters and the DM water consumption is 416.67 cubic meters.

The boiler blow down is 3.95% and drum operating temperature is 320 c and operating pressure 112

Suggested DM consumption as per original equipment manufacturer the blow down should less 1%.

The blow down is 105.50 cubic meter.

Heat loss calculations for boiler blow down and other leakages

Boiler drum operating temperature =320℃

Operating Pressure =112 kg/sq.cm

Total steam generation = 10550 cubic meters

DM WATER consumption = 416.67 cubic meters

Boiler blow down percent = 3.95%

Suggested DM consumption as per original equipment manufacturer the blow down should less 1%.

The blow down is 105.50 cubic meter.

Excess quantity used = DM water consumption – boiler blow down water (105.50cubic meters value suggested by OEM)

= 416.67 – 105.50

=311.17 cubic meters

Considering ambient temperature is 40℃

Heat loss = 320 – 40 = 280 ℃

Considering equivalent enthalpy 295.93 kcal/kg

Total heat loss due to excess utilization of Dm water = 311.17 × 295.93 = 92084.5381 Kcal/day

Heat value of the consumed fuel = 6500 kcal / kg

$$\text{Equivalent coal loss} = \frac{\text{(Heat loss due to Excess utilization of dm water)}}{\text{(Average GCV of coal burned)}}$$

$$= \frac{92084.5381}{6500}$$

= 14.166 TPD

FINDING

Due to excess utilization and other leakages cause heat loss of 92084.5381 kcal / day. So we have to reduce the heat loss due to excess utilization of water for saving the energy.

The probable causes for excess utilization of DM water consumption

(1) Excess blow down
(2) Leakage losses
(3) Venting losses

VI. CONCLUSION

In-depth study and analysis by practical observations of surface heat loss in the boiler and boiler blow down & other leakages reveals the following conclusion and suggestions for performance improvement and wastage elimination in thermal power plant i.e. Heat loss due to uninsulated surface is 459000KCAL/hr. So the uninsulated area should be insulated for energy wastage elimination and to increase performance of the boiler. Due to excess utilization and other leakages cause heat loss of 92084.5381 kcal / day. So we have to reduce the heat loss due to excess utilization of water for saving the energy.

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