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Energy Audit of Boiler at Chandigarh Distillers and Bottlers Limited

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Abstract—*Boiler is one of the essential component of thermal power plant. The overall performance of the plant is highly dependent on the performance of the boiler. This study presents the energy audit of the boiler. The boiler taken up for analysis has a steam generating capacity of 55 tonnes per hour with 500°C of steam temperature and 67.5 kg/cm^2 of steam pressure. The specifications of the boiler have been described. The properties of the fuel used have been considered. The ultimate analysis and proximate analysis of the fuel was performed. Flue gas analyser was taken to the boiler plant and the results has been shown. By minimising the various losses at the plant the overall profit and efficiency of the boiler have increased. Various components such as storage tank, variable feed drive motor and rice husk feeder are taken into account for analysis and studied. Excess air used in the furnace is the cause of major exergy destruction in the boiler.*

1. INTRODUCTION

An energy audit is a feasibility study to establish and quantify the cost of various energy inputs to, and flows within, a facility or organization over a given period. The overall aim of an energy audit is to identify viable and cost effective energy measures which will reduce operating costs. Energy audit can take a variety of forms but the process usually involves collecting data from energy invoices and meters, and undertaking surveys of plants, equipment and buildings, as well as collecting information from managers and other staff. An energy audit should be viewed as the foundation on which any energy management program is built. Biomass offers important advantages as a combustion feedstock due to the high volatility of the fuel and the high reactivity of both the fuel and the resulting char. For the present work, study has been conducted at Chandigarh distillers and bottlers limited, banur. Chandigarh distillers and bottlers limited has two boilers (55 tph and 30 tph) with which steam is generated which in turn is used to produce electricity. The steam generated is also used to prepare alcohol. Raw material for alcohol production is molasses and grain. Fuel used for combustion in the boiler is rice husk. Energy consumption at 55 tons per hour boiler is studied and sources of wastage are identified.

2. PLANT LAYOUT

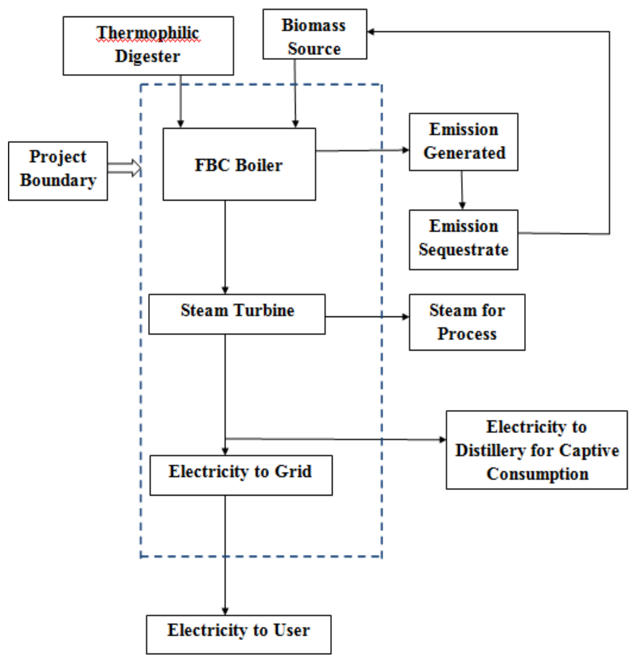

Fig. 1: Plant Layout

2.1 Exergy analysis of boiler using second law of thermodynamics

To have a more accurate idea of the exergy analysis of the boiler components, exergy analysis has been performed on three boiler components i.e. air preheater, economizer and turbine. The indirect method has been discussed above by which the efficiency of the boiler came out to be 63.95%. The reason for using indirect method here is that it is more accurate and precise method of calculating the boiler efficiency than the direct method. The formulas taken for calculating the exergy analysis has been taken from the book "engineering thermodynamics" [7].

1) Air Preheater

An air preheater (APH) is a general term used to describe any device designed to heat air before another process (e.g. combustion in a boiler) with the primary objective of increasing the thermal efficiency of the process. They may be used alone or to replace a recuperative heat system or to replace a steam coil. In particular, this article describes the combustion air preheaters used in largeboilers found in thermal power stations producing electric power from e.g. fossil fuels, biomass or waste. The purpose of the air preheater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas. As a consequence, the flue gases are also conveyed to the flue gas stack (or chimney) at a lower temperature, allowing simplified design of the conveyance system and the flue gas stack. It also allows control over the temperature of gases leaving the stack (to meet emissions regulations).

Ψ_1 = initial exergy of the products

$= (h_1 – h_o) – T_o\times(s_1 - s_o)$

$= C_{pg}\times(T_{g1} – T_o) – T_o\times C_{pg}\times \ln T_{g1}/T_o$

where; T_{g1} = 290℃, T_o = 18 ℃, C_{pg} = 1.073 (from steam table)

$= 1.073\times(563 – 291) - 291\times1.073\times\ln 563/291$

= 85.79 kJ/kg

Ψ_2 = initial exergy of the products

$= (h_2 – h_o) – T_o\times(s_2 - s_o)$

$= C_{pg}\times(T_{g2} – T_o) – T_o\times C_{pg}\times \ln T_{g2}/T_o$

where; T_{g2} = 190℃, T_o = 18 ℃, C_{pg} = 1.073 (from steam table)

$= 1.073\times(463 – 291) - 291\times1.073\times\ln 463/291$

= 49.416 kJ/kg

Decrease in exergy of the products

$= \Psi_1 – \Psi_2$

= 35.3 kJ/kg

Increase in exergy of air

$= m_a\times[(h_2 – h_1) - T_o\times(s_2 - s_1 - R\times\ln\times P_2/P_1)]$

$= m_a\times [C_{pa}\times(T_{a2} – T_{a1}) – T_o\times(C_{pa} \times \ln T_{a2}/T_{a1}$

$- R\times\ln\times P_2/P_1)]$

where; T_{a2} = 142℃, T_{a1} = 18℃, T_o = 18 ℃, C_{pa} = 1.005, P_1 = 811mm of WC, P_2 = 713 mm of WC, R = .274, m_a = 11.66 kg/sec (from steam table)

= 364 kW

The available energy of the air preheater can be increased by blowing of the suit get gets accumulated over the air preheater tubes. Timely maintenance of the air preheater plays a very important role in reducing the overall losses of the boiler. Moreover mass flow rate of the air should also be kept optimum.

2) Economiser

Economizer is a large duct of the rectangular form in which circular hollow tubes are present. Inside the tubes water is flowing and outside it flue gas is present. The flue gas which is formed due to the combustion of fuel goes out of the boiler furnance into the economizer section. The economizer has 25 number of tubes. Inside the tubes water at 120℃ is flowing. The temperature of the water inside the tubes rises from 120℃ to 230℃ before it enters the steam drum. The water gains heat from the flue gases which are at a temperature of around 390℃. The diameter of the tubes which are present inside the economizer is 25 mm and the thickness of the tubes is 3.5mm. The economizer is properly insulated which prevents the heat loss from the economizer walls.

Ψ_1 = initial exergy of the products

$= (h_1 – h_o) – T_o\times(s_1 - s_o)$

$= C_{pg}\times(T_{g1} – T_o) – T_o\times C_{pg}\times \ln T_{g1}/T_o$

(Assuming velocity of water at inlet and outlet of economizer tubes to be constant.)

where; T_{g1} = 390℃, T_o = 18 ℃, C_{pg} = 1.073 (from steam table)

$= 1.073\times(663 – 291) - 291\times1.073\times\ln 663/291$

= 142.046 kJ/kg

Ψ_2 = initial exergy of the products

$= (h_2 – h_o) – T_o\times(s_2 - s_o)$

$= C_{pg}\times(T_{g2} – T_o) – T_o\times C_{pg}\times \ln T_{g2}/T_o$

(Assuming velocity of water at inlet and outlet of economizer tubes to be constant.)

where; T_{g2} = 290℃, T_o = 18 ℃, C_{pg} = 1.073 (from steam table)

$= 1.073\times(563 – 291) - 291\times1.073\times\ln 563/291$

= 85.79 kJ/kg

Decrease in exergy of the products

$= \Psi_1 – \Psi_2$

= 56.256 kJ/kg

Increase in exergy of water

$= m_w\times[(h_2 – h_1) – T_o\times(s_2 – s_1)]$

where; m_w = 15kg/sec, h_2 = 990.3 kJ/kg, h_1 = 503.7 kJ/kg, T_o = 18℃, s_2 = 2.610 kJ/kg K, s_1 = 1.528 kJ/kg K (from steam table)

= 2576.07 kJ/kg

The available energy of the economiser can be increased by keeping a check on fouling and scaling which happens on the economiser tubes. Total Dissolved solids and PH of water should be checked on hourly basis so that the tubes of the economiser do not get corroded which leads to decrease in the heat transfer from flue gas to water.

3) Turbine

A steam turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft. The turbine provided at the plant has a capacity of 8.25 MW. Non-condensing or back pressure turbines are most widely used for process steam applications. The exhaust pressure is controlled by a regulating valve to suit the needs of the process steam pressure. These are commonly found at refineries, district heating units, pulp and paper plants, and desalination facilities where large amounts of low pressure process steam are needed. An ideal steam turbine is considered to be an isentropic process, or constant entropy process, in which the entropy of the steam entering the turbine is equal to the entropy of the steam leaving the turbine

Exergy of steam entering the turbine

$$\Psi_1 = (h_1 - h_o) - T_o \times (s_1 - s_o)$$

$h_1 = 3416.18$ kJ/kg, $h_o = 75$ kJ/kg, $T_o = 18$℃, $s_1 = 6.83$ kJ/kg K, $s_o = 2.67$ (from steam table)

= 2130.62 kJ/kg

Exergy of steam leaving the turbine

$$\Psi_2 = (h_2 - h_o) - T_o \times (s_2 - s_o)$$

$h_2 = 2905.08$ kJ/kg, $s_2 = 7.33$ kJ/kg K (from steam table)

= 1474.02 kJ/kg

Maximum work per kg of steam entering the turbine

$$W_{rev} = \Psi_1 - m_2/m_1 \times \Psi_2$$

$m_2 = 13.8$ kg/sec, $m_1 = 15$ kg/sec

= 774.52 kJ/kg

Irreversibility

$$I = T_o \times (w_2 s_2 - w_1 s_1) - Q$$

$w_1 = 15$ kg/sec, $w_2 = 13.8$ kg/sec, Q = 25 kJ/min (from boiler log sheet)

I = 222.86 kW

2.2 Specifications of the boiler used at Chandigarh distillers and bottlers limited

The boiler used at the plant is fluidized bed combustion boiler. It has got 8.25 MW turbine and 9 MW alternator. The specifications of induced draught fan are 220 hp and 740 rpm, forced draught fan are 220 hp and 1400 rpm and feed pump are 430 hp and 3000 rpm. Above header is air box in which forced air is sent. Nozzles are mounted DB plate which is placed above air box. 3600 number of nozzles are mounted on DB plate. The riser tubes are 17 in number and the 4 inches in dia. The diameter of the water wall tubes is 2 inches. In the steam drum 50% is steam and 50% is water. The link tubes are 16 in number. The air preheater duct has got 1200 number of tubes and their diameter is 2 inches. Inside the tubes flue gases are flowing and outside is forced draught air. Three pumps are there to pump water from feed tank to deaereator tank or dome tank but to pump only one is more than sufficient. Rice husk is thrown inside the boiler with the help of screw feeders. Secondary air is used along with it to spread the husk properly in the boiler so that combustion takes place properly inside the furnance. Nozzles are used to cause bubbling in the boiler. The bed of the boiler is filled with sand up to 5 cm. Forced draught air is passed through the holes in the nozzles. The feed pressure with which water is pumped inside the furnace by the feed pump is 100 kg/cm^2. The temperature of steam in primary superheater is raised from 350℃ to 450℃ and in secondary superheater is raised from 450℃ to 500℃. The preheater and economizer have a temperature raise of 100℃. All these equipments and auxillaries were selected so that detailed study can be done on them. It was observed that ash coming out of the boiler is black and it has retained even its grain structure. This was a clear indication of incomplete combustion in the boiler.

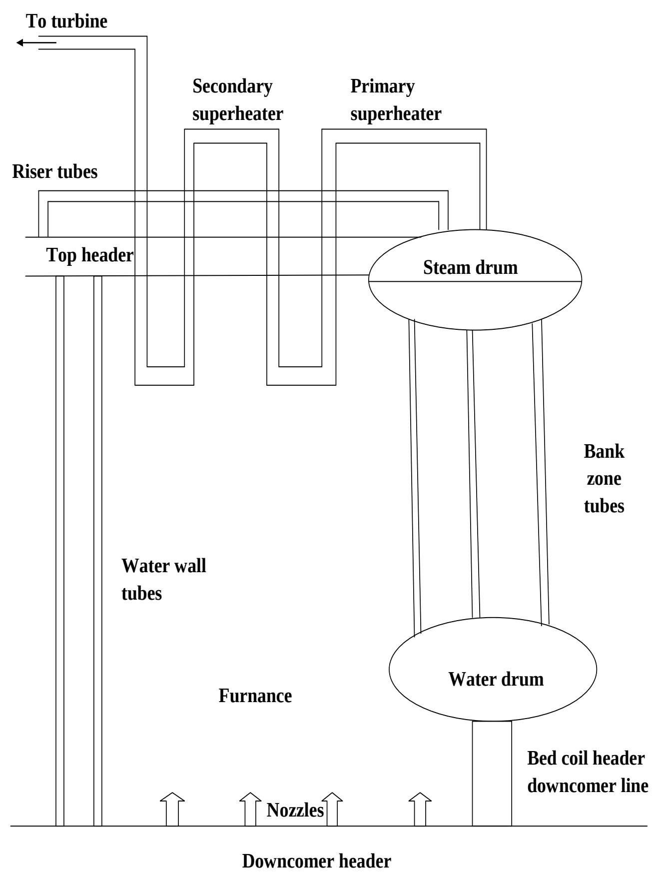

Fig. 2: Energy Flow Diagram

3. ENERGY AUDIT

An energy audit is a feasibility study to establish and quantify the cost of various energy inputs to, and flows within, a facility or organization over a given period. The overall aim of an energy audit is to identify viable and cost effective energy measures which will reduce operating costs. Energy audit can take a variety of forms but the process usually involves collecting data from energy invoices and meters, and undertaking surveys of plants, equipment and buildings, as well as collecting information from managers and other staff. An energy audit should be viewed as the foundation on which any energy management program is built.

3.1 Preliminary audit at Chandigarh distillers and bottlers limited

For the preliminary audit a walk through survey was conducted. On the basis of the information gathered, a detailed questionnaire was prepared and it was circulated to get data. This data helped in finding out energy costs, wastages and highlighted major equipments which need detailed study. On analyzing the information collected through the questionnaire it was observed that at Chandigarh distillers and bottlers limited use rice husk as a fuel in their boiler which is a biomass fuel. The raw material which is used at the plant for the production of alcohol is molasses. But nowadays due to the coming of modern technologies the sugar present in the molasses is very less for the preparation of alcohol. So the factory has shifted to using grain to prepare alcohol instead of molasses. 340 kilolitres of extra neutral alcohol is prepared every day. 30 trucks full of rice husk arrive at the plant daily. The packing of alcohol in the bottles is done at the plant itself. 50 percent of the bottles are new and 50 percent of the bottles are recycled. Recycled bottles are the ones which are collected from all over the city as waste. These bottles are properly washed and cleaned and then alcohol is filled into them. The plant produces steam with the help of which it generates electricity. The surplus electricity is exported to the Punjab electricity board at a settled price. It was observed that ash coming out of the boiler is black and it has retained even its grain structure. This was a clear indication of incomplete combustion in the boiler.

3.2 Energy Audit at Chandigarh distillers and bottlers limited

1. If air flow is controlled with the help of damper it will help only in improving the efficiency of the boilers. But if we go for variable aped motors it will result in savings in electric power as well. Saving which will result by controlling excess air to about 50% of stiochiometer air can be as high as Rs. 1,18,933.92/- per month.
2. At Chandigarh distillers and bottlers limited fluidized bed combustion is used. In this plant a simplest furnance is used for burning the rice husk. The flue gases are taken around the boiler before disposing off into the chimney. With fluidized bed combustion it is possible to achieve about 4% unburnt carbon in the ash. This will result in improvement of efficiency from 63.95% to 75.32.
3. Efficiency of the boiler can also be increased by minimizing clinker deposition and maintaining proper bed temperature. In fluidized bed boilers bubbling bed is present. There are some places on the bed where proper bubbling does not take place. This leads to clinker deposition. To avoid clinker deposition fuel should be sprayed properly so that it does not accumulate at one place. Moreover sand should be changed after every 12 hours i.e. new sand should be thrown inside the furnance. Normally the size of sand particles is 1 mm. Generally what happens due to continuous combustion the size of the sand reduces and the sand particles are carried away by flue gases. So the amount of sand on the furnance bed reduces. So new sand has to be thrown inside the furnance accordingly. If bulk density of the sand is more then also bubbling drops. The alertness of the workers play a very important role for the bubbling phenomena to take place properly.
4. Efficiency of the boiler can also be increased by maintaining proper bed temperature. This can be achieved by increasing the supply of secondary air so that proper combustion takes place inside the furnance. Sometimes if more unburnt fuel is going out i.e. ash contains more unburnt particles then the feeding rate is decreased, and so is draught rate, by closing the dampers. Moreover terminal velocity plays a very important role for proper combustion. It should be kept 6 m/sec for underbed and 4.2 m/sec for overbed. If this velocity is kept then 4% carbon in the residue can be achieved and the efficiency of the boiler goes up to 75.32%.

4. CONCLUSION

1. Heat loss through the furnance walls should be reduced by proper insulation.
2. Timely maintenance of the air preheater so that air leakage can be prevented and efficiency of the boiler can be increased.
3. Standard controls should be installed on the boilers which give correct reading on even very small variations so that the boiler operation can be improved losses can be minimized.
4. Major exergy destruction areas such as combustion chamber and heat exchanger should be focused more upon because 8% and 3% respectively.

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