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ENERGY AUDIT OF BOILER WHILE USING ALTERNATE FUEL SUCH AS RICE HUSK

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Abstract
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. In this paper energy audit in maintenance having aim to improve the performance and minimization of energy loss is conducted. Also the alternate fuel rice husk is used for increasing efficiency with minimization of fuel cost. Feasibility of rice husk is also checked as efficient fuel. An energy audit should be viewed as the foundation on which any energy management program is built to enhance the performance of Boiler.

Keywords - *Energy Audit, Boiler, Rice Husk, Energy, Calorific Value*

ENERGY WASTAGE IN PLANTS

Energy is wasted in plants because of these main factors:
(i) Poorly design buildings and installations (buildings may be poorly insulated and ventilation ducts may be undersized resulting in high fan power consumption).
(ii) Inadequate control systems (heating systems may be installed without any optimum start control).
(iii) Poor control settings (time clock controllers may be incorrectly set so that buildings are heated when not in use).
(iv) Poor operating and working practices (lights are often left on in buildings when they should be switched off).
Energy audit is usually a two step process. In the first step, detailed questionnaires are circulated to collect data. On the basis of this information, energy costs and wastages are highlighted in major equipments and processes. In the second step, a detailed audit may be conducted lasting upto ten weeks and using a detailed audit instrument kit. Here all the departmental heads have to be informed in advance and their involvement is essential even during the course of work. The involvement and commitment of top management is essential for achieving the final objectives. Energy audit attempts to balance the total energy inputs with its use and serves to identify all the energy streams in the systems and quantifies energy usages according to its discrete function. Energy audit helps in energy cost optimization, pollution control, safety aspects and suggests the methods to improve the operating and maintenance practices of the system.

LITERATURE SURVEY

Kaya et al. [1] has performed the energy efficiency study on an industrial boiler which is mixed-fueled (solid + gas) type. In this study the boiler is operated with different fuels as coal, coke gas, blast furnace gas at a pressure of 70 bars and temperature of 505º C and with a nominal capacity of 100,000 kg/hr. The boiler efficiency is obtained by measuring the working temperature, pressure, velocity and combustion gas measurements at boiler operation conditions. Sahin et al. (2011) [2] investigated the energy and exergy analysis as reported by Kaya et al. (2014) which applied to the power plant in an Iron and Steel Works Co. and found out that the major energy efficiency losses have been determined as: air leakage at rotary air heaters, operating boilers at high excess air coefficients, heat losses of the surface, and insulation losses. To completely avoid air leakage is impossible and there is no model available to calculate wall heat. In another study done by Zheng G. et al. [3] centrifugal heat pump has to be coupled with gas boiler to supply high temperature water in radiator heating system. Regarding to hybrid heating system (HHS), operation strategy has significant impact on its annual energy consumption and cost. Dexter et al. [4] investigates the potential for energy saving in heating systems that can be achieved through improving boiler controls. The result shows that improving boiler controls can lead to up to 20% of energy saving and a significant improvement in thermal comfort. Kumar T.A., Chandramouli R. et al. [5] studied the energy and exergy flow of each component of the system in order to identify the areas of major exergy loss. Bakhshesh M.,Vosough A. et al. [6] studied the useful concept of energy and exergy utilization is analyzed, and applied to the boiler system. Energy and exergy flows in a boiler have been shown in this paper. Sulaiman M.A.,Fadare D.A. et al.[7] conducted energy and exergy analysis for a vegetable oil refinery in the Southwest of Nigeria. The suggestion may help the company to reduce its high expenditure on energy and thus improve the profit margin. Rashidi M.M., Aghagoli A. et al. [8] investigated a steam cycle with double reheat and turbine extraction is presented. Six heaters are used, three of them at high pressure and the other three at low pressure with deaerator. According to Vuckovic G. D. et al. [9] exergy analysis is a universal method for evaluating the rational use of energy. It can be applied to any kind of energy conversion system or chemical process. Based on the all-reaching analysis, by improving the boiler operation (elimination of approximately 1 MW of avoidable exergy destruction in the steam boiler) the greatest improvement in the efficiency of the overall system can be achieved.

Naik R.J. et al. [10] studied the concept of exergy analysis and said that it provides a mean to evaluate the degradation of energy during a process, the entropy generation, the lost of opportunities to do work and offers an another approach for improvement of power plant performance. Faaij A. et al. [11] gave an overview of the state of the art of key biomass conversion technologies currently deployed and technologies that may play a key role in the future, including possible linkage to CO_2 capture and sequestration technology (CCS). In doing so, special attention is paid to production of bio fuels for the transport sector, because this is likely to become the key emerging market for large scale sustainable biomass use.

FORMULAE FOR ENERGY CALCULATIONS:

The formulae which are being used for the calculation of losses are taken from the book "optimizing energy efficiencies in industry". These are the standard formulae for calculating the various energy losses in the boiler. By minimizing them the efficiency of the boiler can be increased. The formulations given below are although well known but are still being compiled for the sake of convenience.

(1) Heat given by fuel

This is the heat which is supplied by the fuel on combustion. The better the quality of fuel the more heat it will liberate after burning and the percentage of carbon in ash will be very less. There are other factors by which we can increase the heat given by fuel. One factor is by spraying the fuel properly inside the furnace so that complete combustion takes place. Other is by supplying nearly exact amount of air which is required for proper burning of fuel.

Heat given by fuel = M X C.V. of fuel = $\frac{30 X 100 X 100 X 13020}{24 X 3600}$

Heat given by fuel = 45208.33 kW

Where,

Gross calorific value of fuel in kilo joule per kg = 13020

Number of trucks coming into the plant per day (1 truck = 10 Tons) = 30

Quintals of rice husk loaded per truck = 100

(2) Loss estimation in flue gas

This loss occurs when the temperature of the flue gases going out of the chimney is very high. This temperature should be controlled and brought within a specified range so that the efficiency of the boiler can be increased. Moreover some arrangement should be made in such a way that this excess heat which is going out of the chimney can be utilized.

$hl_{fg} = w_{fg}$ X c ($t_{fg} – t_r$)

hl_{fg} = 2.11.073(125 – 18) = 837.163 kW

Where,

hl_{fg} = Heat loss in dry flue gas, kW

W_{fg} = Weight of dry flue gas per kg of fuel fired

C = Average specific heat of flue gas in kilo joule per kg per

t_{fg} = Flue gas temperature entering the chimney in

t_r = Reference temperature in

(3) Losses due To moisture

Water is formed due to the oxidation of hydrogen present in the fuel into water which is estimated by the following equation. The fuel is kept in open inside the plant as a result it absorbs a small quantity of moisture from the atmosphere. So, more heat has to be given to the fuel which leads to the decrease in efficiency.

$h_{wc} = W_c$ X L

h_{wc} = 0.542100 = 3439.98 kW

Where,

Wc = Weight of moisture formed in kg per kg of dry fuel

L = Latent heat of vaporization at the dew point of flue gas, kJ/kg

h_{wc} = Heat loss due To water of combustion, kW

(4) Losses due to fuel moisture

Moisture present in the fuel is also lost to the atmosphere from the chimney. This is given by the following equation. This loss indicates the amount of excess heat given to the fuel due To the moisture present in the fuel. The more good quality the fuel is the less moisture will be present per kg of fuel.

h_w = W X L

h_w = 0.1662100 3.47 = 1209.642 kW

Where,

W = Weight of moisture present in kg per kg of dry fuel

L = Latent heat of vaporization at the dew point of flue gas, kJ/kg
h_w =Heat loss due To water present in fuel, kW

(5) Loss due To incomplete combustion of carbon To carbon monoxide

This loss occurs when sufficient amount of air is not provided to the fuel for combustion. This results in incomplete combustion of the fuel which leads to decrease in the boiler efficiency as well as higher carbon content in ash. Also if the ash is black in color it is a clear indication that incomplete combustion is taking place.

h_{co} = [CO / (CO + CO_2)] X C X 5636.7 X 3.47 X 4.2kW
$h_{co} = [\frac{0.004}{0.004+0.122}]$ X 0.375 X 5636.7 X 3.47 X 4.2 = 977.96 kW
Where,
CO = Volume % of carbon monoxide in flue gas
CO_2 = Volume % of carbon dioxide in flue gas
C = Carbon content in fuel in kg per kg fuel
h_{co} = Heat loss due To incomplete combustion, kW

(6) Loss due To presence of combustibles in refuse

Some quantity of energy is also lost due To the presence of combustibles in the refuse in case of solid fuels and soot in case of other fuels. This can be calculated by the following equation. Due To the accumulation of soot on the boiler tubes the heat transfer rate is reduced due To which boiler efficiency decreases.
$h_{rf} = W_c$ X 7837 X 4.2 X 3.47
h_{rf} = 0.085 X 7837 X 4.2 X 3.47 = 9708.39 kW
Where
W_c = Weight of carbon in the refuse in kg per kg of fuel
h_{rf} = Heat loss due To presence of carbon in refuse, kW

(7) Blow-down losses

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. In normal boiler operation the steam generated is less than the boiler feed water quantity, the difference being due To blow-down. Hence blow-down losses can be estimated by the following relationship. To maintain the hardness of water blow-down is necessary. If the temperature of the blow-down water is more it carries away large amount of useful heat with it.
$h_{bd} = W_{bd}$ X [h_{bw} X h_{fw}]
h_{bd} = 0.066 X (2836.17 – 990.877) = 123.01 kW
Where,
h_{bd} = Loss in kilo watt due To blow-down
W_{bd} = Blow-down rate in kg per sec
h_{bw} = Enthalpy of boiler water in kilo joule per kg at drum pressure and temperature
h_{fw} = Enthalpy of boiler feed water in kilo joule per kg
w_f = Ws + W_{bd} (w_f = feed water, Ws = steam generated, W_{bd} = blow-down)

(8) Radiation losses

Radiation, convention and miscellaneous losses are those losses which are taking place from boiler furnace walls, economizer walls, air preheated walls, electrostatic precipitator walls, chimney wall etc. These losses can be minimized by proper insulation and proper maintenance of temperature at various places. The radiation losses account for about 2%.

(9) Boiler efficiency (by indirect method)

$$Efficiency = \frac{Heat\ Given\ by\ Fuel - Losses}{Heat\ Given\ by\ Fuel}\ X\ 100$$

So, efficiency = 63.95%

ESTIMATION OF ENERGY SAVINGS

The energy audit discussed in this report is known as "Detailed Energy Audit". This type of audit is the most comprehensive and time-consuming type of energy audit. This includes the use of instruments to measure the energy use of energy systems within the plant. This energy audit process is an organized approach to identify energy waste in the plant and determining how this waste can be eliminated at a reasonable cost with a suitable time frame.

BOILER AUDIT

The boiler used at the plant is fluidized bed combustion boiler. It has got 8.25 MW turbines and 9 MW alternators. 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 3000rpm. 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 is 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 pre-heater 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 furnace. Nozzles are used to cause bubbling in the boiler. The bed of the boiler is filled with sand up to 5cm. 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 super heater is raised from 350ºC to 450ºC and in secondary super heater is raised from 450ºC to 500ºC. The pre-heater and economizer have a temperature raise of 100ºC. All these equipments and auxiliaries 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.

CONCLUSION

The salient conclusions are withdrawn which is as follows;
(i) No insulation is provided on storage tank. With the passage of time the insulation of the storage tank has come down and rusting has also taken place. If insulation is provided on storage tank steam used in the deaerator can be saved. (ii) Feeding of rice husk in the vibrating screens at the plant is done manually. If a tractor is used instead of laborers time as well as money can be saved which will overall increase the profit of the company. (iii) Variable speed drive motor is not working at the factory for the past 5 years which leads to increase in the current load of the plant. Moreover excess air is going in the furnace due to which lot of rice husk is going out of the chimney unburnt. (iv) Moreover if the fuel which is currently used in the plant i.e. rice husk is replaced by pet coke the overall profit of the factory will go up as the gross calorific value of pet coke is much higher than rice husk. (v) There are many other parameters which play a very important role in increasing the efficiency of the boiler. One such parameter is the quality of fuel which is being fed inside the furnace. The fuel should have minimal moisture and impurities in it. Timely blow-down should be performed so that the hardness of the water is properly maintained.

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