Performance evaluation of industrial boiler by heat loss method.

Divyesh T. Patel[1], Dr. K.V.Modi[2]

[1] ME Scholar in Mechanical (Energy Engg.), Government Engineering College, Valsad, India

[2] Associate Professor, Mechanical Engineering Department, Government Engineering College, Valsad, India

ABSTRACT

Boiler performance evaluation is necessary to find out variation of boiler efficiency related to its various operating parameters. Hence, it is necessary to find out the current level of efficiency for performance evaluation of boiler, which is mandatory for energy conservation action in industry. In Sugar industry, out of so many components, Boiler is important from energy conservation. In any sugar industry, heart component is Boiler and to maximize beneficiary output from sugar mill, it is necessary to maintain efficiency of Boiler with the design efficiency. So, in present work, an Energy analysis using direct heat loss is carried out for a Bagasse Boiler of shree Mahuva Sahkari Khand Udyog Mandali. The analysis of this power and steam generating plant is important for the proper functioning of the plant. In present work, heat loss method is utilised to find efficiency and losses in boiler house. All the necessary data for the calculation is taken from boiler house observation reading and plant data of shree Mahuva Sahkari Khand Udyog Mandali.

Keyword : *performance analysis of boiler, direct heat loss method, bagasse fuel, sugar factory ….*

1. Introduction :

Sugar industry is known as one of the major non conventional energy source industry in India. Because it uses renewable sugar cane crop as the raw material, which gives output as a bagasse with sufficient calorific value. Sugar industry mills attached with co-generation plant, both are in co-operative and private sector having great importance in Indian economy. It gives revenues to government, is in the form of generation of power around 9 major states with 3600 MW by using bagasse as the renewable energy source. The sugar cane bagasse boiler efficiency is the most important parameter in sugar mill cogeneration systems; therefore, its calculation helps in cogeneration system optimization. The bagasse boiler development has followed the coal boiler technology. Also, the method to determine the bagasse boiler efficiency has been adopted from those used for coal boilers (ASME PTC 4.1, 1975; ASME PTC 4, 1998) [1]. However, the coal and bagasse fuels are very different, for instance the moisture content of bituminous coal is around 29%, while that for bagasse is around 50%. Consequently, some special considerations become necessary along the analysis of boiler efficiency of a wet fuel (i.e. bagasse). With the direct heat loss method we can easily predict the major areas of loss and we can take some preventive measurement to optimize the performance of boiler.

2. BAGASSE AS A FUEL IN BOILER HOUSE.

Sugarcane is having one of the best potential as agricultural sources of biomass energy in the world. Sugarcane generates two types of biomass:

1. Cane trash
2. Bagasse.

Bagasse is a fuel of varying composition, consistency, and heating value. These characteristics depend on the climate, type of soil upon which the cane is grown, variety of cane, harvesting method, amount of cane washing, and the efficiency of the milling plant[6]. In general, bagasse has a heating value between 1,600 and 2,400 kcal/kg (3,000 and 4,000 Btu/lb) on a wet, as-fired basis. Most bagasse has moisture content between 45 and 55 percent by weight. The sulphur and nitrogen contents of bagasse are generally near or below 0.1 weight percent with ash contents generally less than 4 weight percent, as fired. Table 2.1 and table2.2 represent the comparison of bagasse and coal fuel which will give idea about boiler combustion performance.

Table 1 Proximate analysis of bagasse and coal

Table 1.1 Proximate analysis of bagasse and coal Content	Bagasse (in %)	Coal (in %)
Volatile	35	24
Fixed carbon	11	56
Ash	4	12
Moisture	50	8

(source: sugar mill research institute ,Durban 4041,SA, Prc S afr, technol,ass(2001)75,p-277)

Table 2Ultimate analysis of bagasse and coal

Content	Bagasse %	Coal %
Carbon	22.16	67.20
Hydrogen	2.84	4.0
Oxygen	21.0	6.0
Nitrogen	0.0	1.80
Sulphur	0.0	1.0
Ash	4.0	12.0
Moisture	50.0	8.0

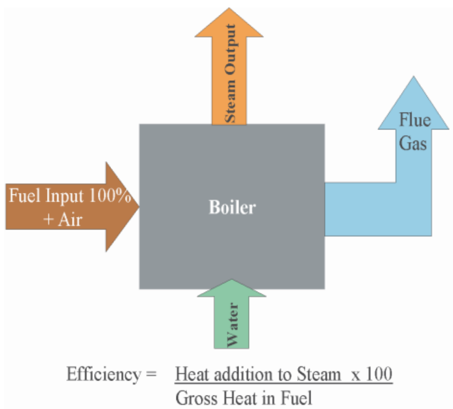
(source: sugar mill research institute ,Durban 4041,SA, Prc S afr, technol,ass(2001)75,p-277)

3. PERFORMANCE ASSESSMENT OF BOILERS:

Performance of the boiler, like efficiency and evaporation ratio reduces with time, due to poor combustion, heat transfer fouling and poor operation and maintenance. Weakening of fuel quality and water quality also leads to poor performance of boiler. Efficiency testing enables us to detect how far the boiler efficiency drifts away from the best efficiency[7]. In the present work, the Energy Balance and the boiler first law efficiency was obtained through two proposals: Direct heat loss method (input/output method) and indirect heat loss method reference taken from code ASME PTC 4.1 (1998): This last one was adapted to bagasse boilers, since it has been formulated for coal boilers. In this research work the performance analysis of boiler is carried out using energy analysis method.

This analysis can be performed through two methods

1. Part One Direct method (Input-output method or energy balance method)
2. Part Two Indirect method (also called as Heat loss method).



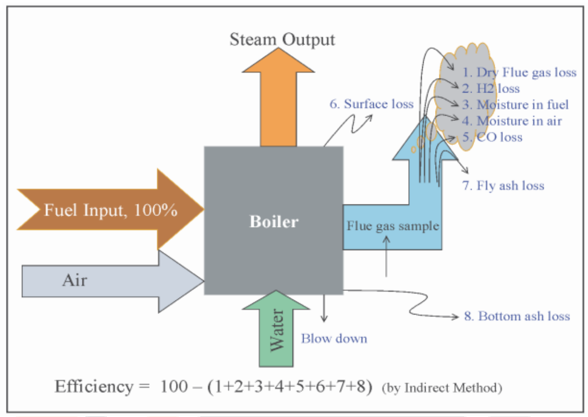


Figure : 1 Energy balance method Figure 2:Heat loss method

Source: Bureau of energy efficiency ,India

3.1 Merits and Demerits of Direct Method

Merits

- Plant people can evaluate quickly the efficiency of boilers
- Requires few parameters for computation
- Needs few instruments for monitoring

Demerits

- Does not give clues to the operator as to why efficiency of system is lower
- Does not calculate various losses accountable for various efficiency levels
- Evaporation ratio and efficiency may mislead, if the steam is highly wet due to water carry over.

4. METHODOLOGY PROCEDURE AND SAMPLE CALCULATIONS

Table 3. Data collected from flue gas analyser used during filed work.

Contents in flue gas	Day	1	2	3	4	5	Avg. value
O_2	%age	12.25	11.6	11.3	11.4	11.8	11.8083
CO	ppm	3905.5	3827	3733	3332.25	3480.75	3641.54
CO_2	%age	8.55	9.3	9.6	9.5	9.1	9.075

Excess air	%age	142.5	124	117	119.25	129	130
Temp. of flue gas	in °C	139.75	139.25	140.75	137.5	138.5	139.125

Table 4 Fuel analysis reading collected from laboratory.

Fuel contents	In %age
C	46.27
$\%H_2$	6.40
$\%O_2$	43.33
%N	0.00
%S	0.00
%Ash content	4
GCV of fuel	2200 kcal/kg

4.1 Heat Loss Method (Indirect Method)[8].

I. Theoretical air required (TA) in (kg /kg of fuel burned)

$$TA = \frac{11.6*46.27+34.8(6.4-0.125*43.33)+4.35*0}{100}$$

= 5.71 kg/kg of bagasse

II. % of excess air supplied(EA)

$$\%EA = \frac{12.25}{(21-12.25)} \times 100$$

= 140 (data from flue gas analyser =142.5)

III. Actual air supplied (AAS)per kg of fuel

$$AAS = \left(1 + \frac{142.5}{100}\right) \times 5.71$$

=13.84 Kg/kg of bagasse

IV. Mass of dry flue gas exhausted from stack(M)

$$M = 0.1357 * 44 + 0 + (8.99 - 7.23) * \frac{23}{100} + \frac{8.99*77}{100}$$

=11.34 kg/kg of bagasse

V. Calculation All kind of losses developed

1. Loss due to dry flue gas (sensible heat)

$$L1 = \frac{mCp(tf-ta)}{cv\ of\ fuel} = \frac{7.536*0.23(139-28)}{2200} = 13.25\ \%$$

2. Loss due to hydrogen in fuel (H2) (L2)

$$\frac{9*0.06\{584+0.45(139-28)\}}{2200} = 0.17\ \%$$

3. Loss due to moisture in fuel (H2O) (L3)

$$\frac{M\{584+Cp(tf-ta)\}}{cv\ of\ fuel} = \frac{0.5\{584+0.45(139-28)\}}{2200} = 14.42\ \%$$

4. Loss due to moisture in air (H2O) (L4)

$$\frac{8.71\times0.025\times\{0.45(170-25)\}}{2200} = 0.79\%$$

5. Loss due to carbon monoxide (CO) (L5)

$$\frac{5744\{0.0722\}\times0.46}{\{0.0722+13.57\}2200}\times100 = 2.50\%$$

6. Loss due to surface radiation, convection and other unaccounted.(L6)

$$= 0.584\times\left[\left(\frac{346}{55.55}\right)^4-\left(\frac{298}{55.55}\right)^4\right]+[1.957(346-25)^{1.25}\sqrt{\frac{196.85*4+68.9}{68.9}}$$

=1266.97

% of radiation and convection loss

$$\frac{L6*}{cv\ of\ fuel\times fuel\ firirng\ rate}\times100$$

$$\frac{L6*}{2200\times50}\times100 = 1.7$$

7. Unburnt losses in fly ash (Carbon)(L7)

$$\frac{Total\ ash\ collected\ per\ kg\ of\ fuel\ burnt\times CV\ of\ fly\ ash}{cv\ of\ fuel}\times100 = 4\%$$

8. Unburnt losses in bottom ash (Carbon) (L8)

$$\frac{Total\ ash\ collected\ per\ kg\ of\ fuel\ burnt\times CV\ of\ bottom\ ash}{cv\ of\ fuel}\times100 = 4\%$$

So finally Boiler Efficiency by indirect method is

$$\eta_B = 100 - (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)$$

$$=100-(13.251+ 0.16+ 14.4166+ 0.79+ 2.497 + 1.77 + 4+4)$$

$$=59.107\%$$

5. RESULT AND DISCUSSION

Table 5; Result- Average value of losses calculated

Date of data taken	L1 in %age	L2 in %age	L3 in %age	L4 in %age	L5 in %age	L6 in %age	L7 in %age	L8 in %age	η_{boiler} in % age
Avg. value	12.82	0.166	14.398	0.761	2.230	1.717	4.000	4.000	59.908

Result table indicates that major losses in the system due to moisture content in fuel which is 14.39% while second largest loss is due to loss heat loss in dry flue exhaust gases 12.82% which is followed by loss due to unburnt combustion losses. All this result indicates poor fuel combustion in combustion chamber due to fuel quality.

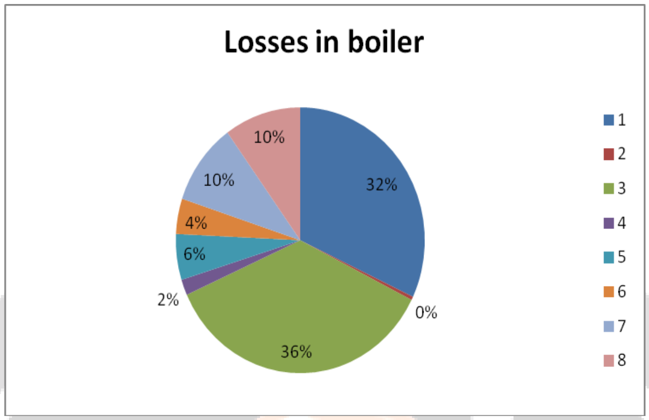


Chart 1 : Losses in boiler stack

Chart 1 indicates individual %age loss shown in table 5 of total loss occur in boiler. From the graphical analysis, major loss occurs in boiler is due to heat losses in dry flue gases and moisture content in fuel.

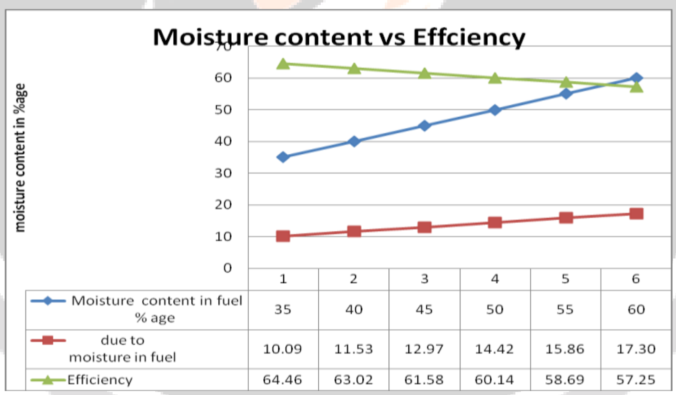


Chart 2 : Moisture vs efficiency of boiler

Chart 2 shows the effect of moisture content in fuel on the efficiency of the boiler. From chart-2, as moisture content increases the efficiency gradually decreases and losses in flue gas increases. Graphical analysis also point out that if by using some arrangement to reduce moisture content, the combustion efficiency as well plant efficiency can be increased.

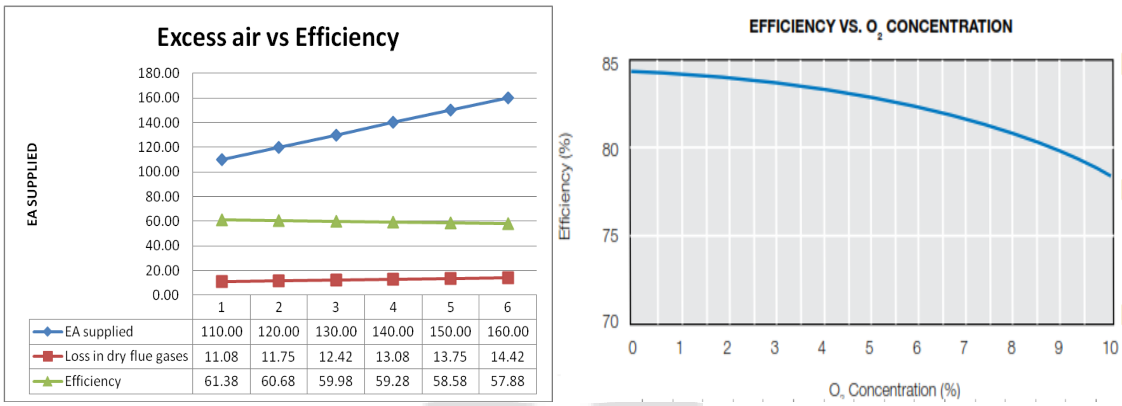


Chart.3 Excess air vs efficiency of boiler

Chart 3 shows the effect of excess air supplied to the combustion chamber. As the excess supplied to the boiler, efficiency decrease and losses in dry flue gases also increases. The efficiency of boiler can be easily increased up to 1-2 % if we can control the excess air supply from the graph. The excess air supply is directly proportional to the stack losses due to dry flue gases.

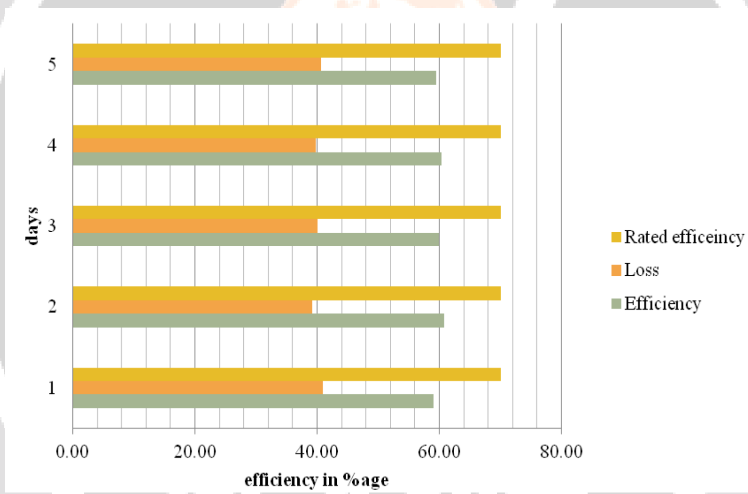


Chart.4 efficiency of boiler

Chart 4 shows the efficiency variation in boiler house, the boiler rated efficiency for specifically bagasse fired efficiency is 68±2 % while the average efficiency of this boiler remains around 59 ±2%.

6. CONCLUSIONS

In the present research work, performance analysis of boiler house located at Mahuva sugar factory near south Gujarat place is performed using the heat loss analysis for the performance evaluation of boiler house. Direct heat loss method is carried out in the boiler house which will give idea about the losses at different stages and the area of losses where one can focus for performance analysis. By using direct heat loss method, as by result the major losses occurs in boiler is due to heat losses in dry flue gases (12.82%) and moisture content in fuel (14.398%) which is followed by loss due to ash content in fuel, loss due to unborn gases .the boiler efficiency is found 59 % by the heat loss method.

On the basis we can suggest that there must be some provision to reduce the moisture content in fuel, by which the combustion efficiency can be improved. Bagasse drying by the use of hot flue gases offer few advantages as discussed below[9].

- It improves the boiler efficiency by recovering part of the heat which otherwise would have been let out of the stack in this case flue gases temperature is ranging between 120 to 130^0 c which is high enough which can be use for such purpose.
- Promotes stable combustion.
- Decreases excess air requirement.
- Increase steam generation

On this basis there must be some provision for bagasse drying by dryer or heating of bagasse should be carried out before supplying to the combustion chamber. There may be easily reduction of moisture content up to 42 – 45 % moisture from 50 % wet bagasse. Use of solid catalyst by direct feeding with fuel i.e. THERMCAT -B can also improve the combustion reactivity in the combustion chamber (i.e 1 kg of THERMCAT –B is dosed for 20 tons of bagasse). It is a solid mixture of primarily carbon which helps to increase the reactivity between carbon and the moisture in bagasse.

REFERENCES

1. Raut Sachin M., Kumbhare Sanjay B.,Thakur Krishna C : Energy Performance Assessment of Boiler at P.S.S.K. Ltd , Basmathnagar, Maharashtra State: Certified Journal, Volume 4, Issue 12, Dec-2014- ISSN 2250-2459, ISO 9001:2008.
2. Reddy B.V.,Mohamed K.: Exergy analysis of natural gas fired combined cycle power generation unit:International Journal of Exergy-2007;4:180–96
3. Sachdeva Kiran Bala and Karun:Performance Optimization of Steam Power Plant through Energy and Exergy Analysis :Current Engineering and Technology,Vol.2, 2012, ISSN 2277– 4106- No.
4. Murehwa Genesis, Davison Zimwara, Wellington Tumbudzuku, Samson Mhlanga: Energy Efficiency Improvement in Thermal Power Plants: IJITEE-2012
5. Raviprakash kurkiya, Sharad chaudhary ; Energy Analysis of Thermal Power Plant; International Journal of Scientific & Engineering Research Volume 3, Issue 7, July-201;ISSN 2229-5518

BOOKS :-

6. System of technical control for cane Sugar factories in India' manual for engineers :by N C varma
7. Bureau of Energy Efficiency
8. Energy conservation in Thermal system:IECC press: V K Gaudani.
9 Hand book of energy conservation; Robert And Collins.