Energy Auditing: A Basic Tool For Optimization Of Boiler Parameter

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***Abstract*—**now a day efficiency is a major issue and if it is concern with a generation then it is also burning issue. This document cover optimization of boiler parameter with calculation on basis of energy auditing (BEE)mythology. it cover chemical as well as mechanical process on flue gas data analyzer data sheet.

Keywords*—*G.C.F.(Gas calorific value), ppm(parts per million),GCV(gross calorific value),

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INTRODUCTION

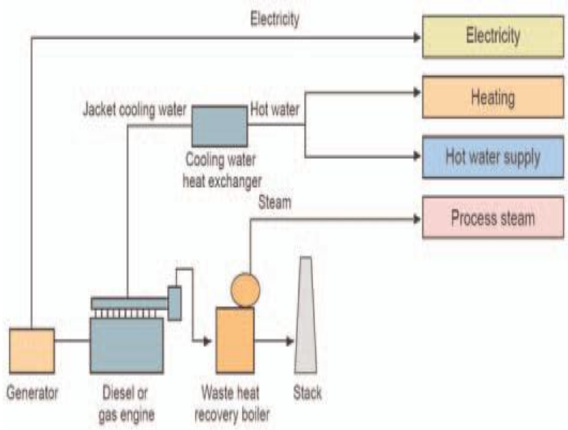
In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction.

Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists.

The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc.

In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a " bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.



(heat recovery from an engine exhaust and/or jacket cooling system flowing to a heat recovery boiler, where it is converted to process steam / hot water for further use.)

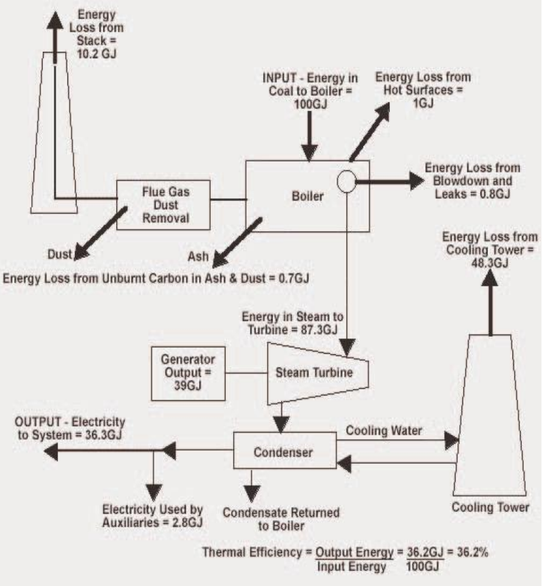
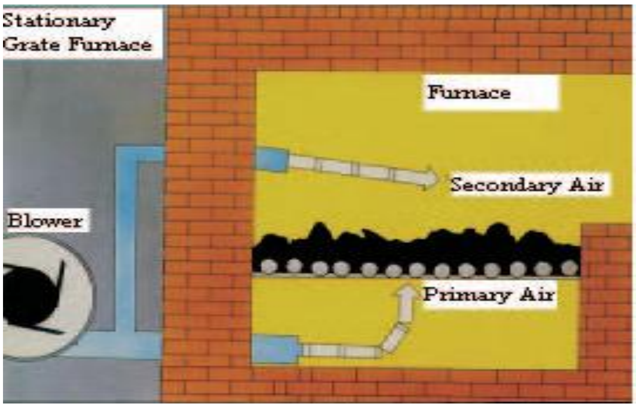


Figure 7.1 BALANCE IN A TYPICAL COAL FIRED POWER STATION
For an Input Energy of 100 Giga Joules (GJ)

BOILER EFFICIENCY

Thermal efficiency of boiler is defined as the percentage of heat input that is effectively utilised to generate steam. There are two methods of assessing boiler efficiency.

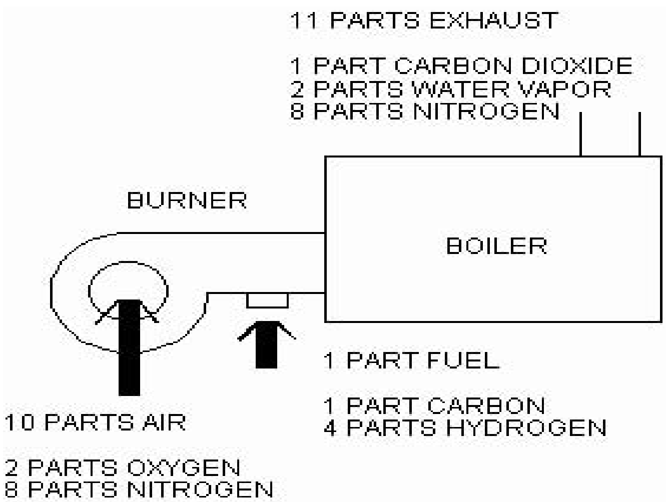


The Direct Method: *Where the energy gain of the working fluid (water and steam) is Compared with the energy content of the boiler fuel.*

This is also known as 'input-output method' due to the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for valuating the efficiency. This efficiency can be evaluated using the formula Parameters to be monitored for the calculation of boiler efficiency by direct method are :

- Quantity of steam generated per hour (Q) in kg/hr.
- Quantity of fuel used per hour (q) in kg/hr.
- The working pressure (in kg/cm2(g)) and superheat temperature (°C), if any
- The temperature of feed water (°C)
- Type of fuel and gross calorific value of the fuel (GCV) in kCal/kg of fuel

The Indirect Method: *Where the efficiency is the difference between the losses and the Energy input.*



Combustion of Natural Gas

TABLE FOR MAKE AN ASSUMPTION AND CALCULATION

RECOMMENDED TDS LEVELS FOR VARIOUS BOILERS(ref-11)

	Boiler Type	Maximum TDS (ppm)*
1	Lancashire	10,000 ppm
2	Smoke and water tube boilers (12 kg/cm2)	5,000 ppm
3	Low pressure Water tube boiler	2000–3000
4	High Pressure Water tube boiler with superheater etc.	3,000–3,500 ppm
5	Package and economic boilers	3,000 ppm
6	Coil boilers and steam generators	2000 (in the feed water

Note: Refer guidelines specified by manufacturer for more details *parts per million

RECOMMENDED FEED WATER AND BOILER WATER LIMITS ARE SHOWN IN TABLE 2 AND TABLE 3(ref-11)

RECOMMENDED FEED WATER LIMITS

Factor	Upto 20 kg/cm^2	21 – 39 kg/cm^2	41 – 59 kg/cm^2
Total iron (max) ppm	0.05	0.02	0.01
Total copper (max) ppm	0.01	0.01	0.01
Total silica (max) ppm	1.0	0.3	0.1
Oxygen (max) ppm	0.02	0.02	0.01
Hydrazine residual ppm	-	-	-0.02-0.04
pH at 25°C	8.8-9.2	8.8-9.2	8.2-9.2
Hardness, ppm	1.0	0.5	-

RECOMMENDED BOILER WATER LIMITS (IS 10392, YEAR 1982) (ref-11)

Factor	Upto 20 kg/cm^2	21 – 39 kg/cm^2	40 – 59 kg/cm^2
TDS, ppm	3000–3500	1500–2500	500–1500
Total iron dissolved solids ppm	500	200	150
Specific electrical conductivity at 25°c (mho)	1000	400	300
Phosphate residual ppm	20-40	20-40	15-25
pH at 25°C	10–10.5	10–10.5	9.8–10.2
Silica (max) ppm	25	15	10

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TYPICAL VALUES OF EXCESS AIR SUPPLIED FOR VARIOUS FUELS ARE GIVEN IN TABLE(ref-11)

EXCESS AIR LEVELS FOR DIFFERENT FUELS		
Fuel	Type of Furnace or Burners	Excess Air (% by w/w)
Pulverised coal	Completely water-cooled furnace for slag-tap or dry-ash removal	15–20
	Partially water-cooled furnace for dry-ash removal	15–40
Coal	Spreader stoker	30–60
	Water-cooler vibrating-grate stokers	30–60
	Chain-grate and traveling-gate stokers	15–50
	Underfeed stoker	20–50
Fuel oil	Oil burners, register type	15–20
	Multi-fuel burners and flat-flame	20–30
Natural gas	High pressure burner	5–7
Wood	Dutch over (10–23% through grates) and Hofft type	20–25
Bagasse	All furnaces	25–35
Black liquor	Recovery furnaces for draft and soda-pulping processes	30–40

TABLE GIVES THE THEORETICAL AMOUNT OF AIR REQUIRED FOR COMBUSTION OF VARIOUS TYPES OF FUEL(ref-11)

THEORETICAL COMBUSTION DATA – COMMON BOILER FUELS					
Fuel	kg of air req./kg of fuel	kg of flue gas/ kg of fuel	m3 of kg of fuel/ kg of fuel	Theoretical CO2 % in dry flue gas	CO2% in flue gas achieved in practice
Solid Fuels					
Bagasse	3.2	3.43	2.61	20.65	10–12
Coal (bituminous)	10.8	11.7	9.40	18.70	10–13
Lignite	8.4	9.10	6.97	19.40	9–13
Paddy Husk	4.6	5.63	4.58	19.8	14–15
Wood	5.8	6.4	4.79	20.3	11.13
Liquid Fuels					
Furnace Oil	13.90	14.30	11.50	15.0	9–14
LSHS	14.04	14.63	10.79	15.5	9–14

1 kcal	3.968321 btu
1 btu	0.2519958 kcal
Lb	0.4535924 kg
Kg	2.20462 lb
Btu/lb	0.555 kcal/kg

CALCULATION OF GAS CALORIFIC VALUE OF BIO GAS

Bio-gas composition:

	v/v	w/w
Methane by difference	53%	29.6
CO_2	45%	69.15
Moisture and other gases	2%	1.25

Bio gas heating value (100% pure)=1002 btu/ft^3
=23879 btu/lb
c.v. =23875*0.296
=7067 btu/lb
GCV of bio gas =3926 kcal/kg
Approximately =3900 kcal/kg

CALCULATION FOR EVALUATING BY AIR REQUIRE PER KG OF BIOGAS FIRED IN BOILER:

Basis 1 kg of bio gas

Composition CH_4=0.296(w/w)
CO_2 =0.6915(w/w)
C content =12/16*0.296=0.222 kg
H_4 content =4/16*0.296=0.074kg
CO_2 content = 0.6915 kg

O2 required

For C =32/12*0.222=0.592 kg
For H_2 =16/2*0.074=0.592 kg
Total O_2 required= 1.184 kg (4 times CH_4)
Total air required=5.15kg(theoretical)

Flue gas composition

CO_2 =0.222*44/12=0.814 kg
H_2O =0.074*18/12=0.67 kg
N_2 =5.15-1.184=3.966kg
Incoming with CO_2 biogas=0.6915 kg

On dry basis:

From fuel combustion CO_2 =14.88%
Incoming with bio gas CO_2 =12.69%
Total =27.52%(w/w)
Total mass of CO_2 in flue gases =0.814+0.6915
=1.5kg
=0.034moles
Total mass of N_2 in pure gas=3.966 kg
=0.14 moles
% CO_2 in flue gases= 19.54(v/v)
% N_2 in flue gases=80.46%(v/v)
Avg % CO_2 measured during efficiency trials= 16.0%(v/v)
% CO_2 in flue gases =19.54-16.00
=3.54%(v/v)
%excess air =19.86(v/v)
=20.236(w/w)

Air to fuel ratio in boiler for bio gas=6.19 kg/kg

CALCULATION FOR EVALUATING KG AIR REQUIRED PER KG OF FURNACE OIL FIRED IN BOILER:

Basis 1 kg of furnace oil composition

C=82%

H_2=13%

O_2=2%

S=3%

Moisture=nil

Calorific value=10650 kcal/kg

Minimum air required for complete combustion

=(11.6*%C)34.8(%H2-% O_2/8)+(4.35*%S)

=14.2 kg/kg (Theoretically)

O_2 required = 2.186+1.04+0.003

=3.26kg

Flue gas composition

CO_2=0.82*44/12=3.0 KG

H_2O=0.13*18/2=1.17KG

N_2=14.2-3.26=10.94KG

SO_2=0.03*64/32=0.06KG

Total air required = 5.15+14.2=19.35 kg

Total O_2 required = 1.182+3.26=4.444kg

Total flue gas composition

CO_2 =0.814+0.6915+3.0

=4.5 kg

H_2O =0.67+1.17=1.84 kg

N_2 =3.966+10.94=14.9kg

SO_2 =0.06 kg

On dry basis

From fuel combustion CO_2=19.66%(w/w)

Incoming with bio gas CO_2=3.55%(w/w)

Total = 23.15(w/w)

Total mass of CO_2 in flue gases

= 4.5 kg=0.102 mole

Total mass of N_2 in flue gases

= 14.9kg=0.53 mole

%CO_2 in flue gases =16.0%(v/v)

%N_2 in flue gases=84.0%(v/v)

Avg % CO_2 measured during efficiency trial

=15.45%(v/v)

% O_2 in flue gases=16-15.45-0.55%(v/v)

%excess air=2.53%(*v/v)

=2.54(w/w)

Air to fuel ratio in boiler

=19.35*1.0254=19.84kg/kg

Efficiency calculation for boiler:

Avg. steam drum pressure=9.1 kg/cm^2

Avg. bio gas firing pressure=485 mm WC

Avg.bio gas CO_2 =45%

GCV of bio gas =3926 kcal/kg

Flue gas Avg temp.=221.8 0C

Avg. CO_2 in flue gas =15.45%

Avg. fuel G.C.V.=7200 kcal/kg

CALCULATION:

Dry gas losses

=[W*0.24*(221.8-3.6)]*100/G.C.V.

=[19.84*0.24*(221.8-36)]*100/7200

=12.3%

Wet gas losses

={ (9*H_2%+% O_2)[(100-t_2)+540+0.5*(221.8-1)]}/ G.C.V.

={(9*0.13+0.02)[(100-68)+540+0.5*(221.8-1)]}/7200

=11.9%

Radiation losses =2%(assumption)

Total losses =12.3+11.9+2

=26%@

Indirect efficiency=100-losses=74%

By optimization of boiler efficiency

We can save

=[optimizing efficiency-actual efficiency]*100 /actual efficiency

=[78-74]*100/74

=5.4%

ACKNOWLEDGMENT

Boiler optimization is done by

1. By increasing CO_2 % in flue gas up to 18%.
2. By reducing flue gas temperature up to 210^0C.
3. By reducing excess air.
4. By reducing steam pressure of boiler.

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