TO CALCULATE AND IMPROVEMENT IN THE EFFICIENCY OF FBC BOILER

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Abstract- *Boiler is an essential component for industry. Performance of boiler is very much concerned now a day because of energy crises. It is not only required to improve the effectiveness of plant but also to improve the profitability and productivity of the industry. With the growing energy demands in the power sector, Fluidized bed combustion (FBC) technology is continuously gaining importance due to its ability to burn different low grade coals. Boiler is a most useful device for any industry for process and production. It is very necessary to calculate the efficiency. There are basically two methods to calculate the efficiency of boiler, direct method and indirect method. Both the methods give different values as direct method does not consider any losses whereas indirect method gives the result by calculating all the losses. Efficiency for different GCV has been shown in this paper for FBC boiler and this paper also gives the description of calculation of efficiency for FBC boiler. Here calculation has been done for the 100TPH FBC boiler used in the Prakash Industries AFBC type using Indian lignite coal having a different chemical composition and properties.*

Keywords: *boiler efficiency, GCV of coal, methods to calculate efficiency, increase in efficiency, efficiency improvement opportunity.*

1. INTRODUCTION

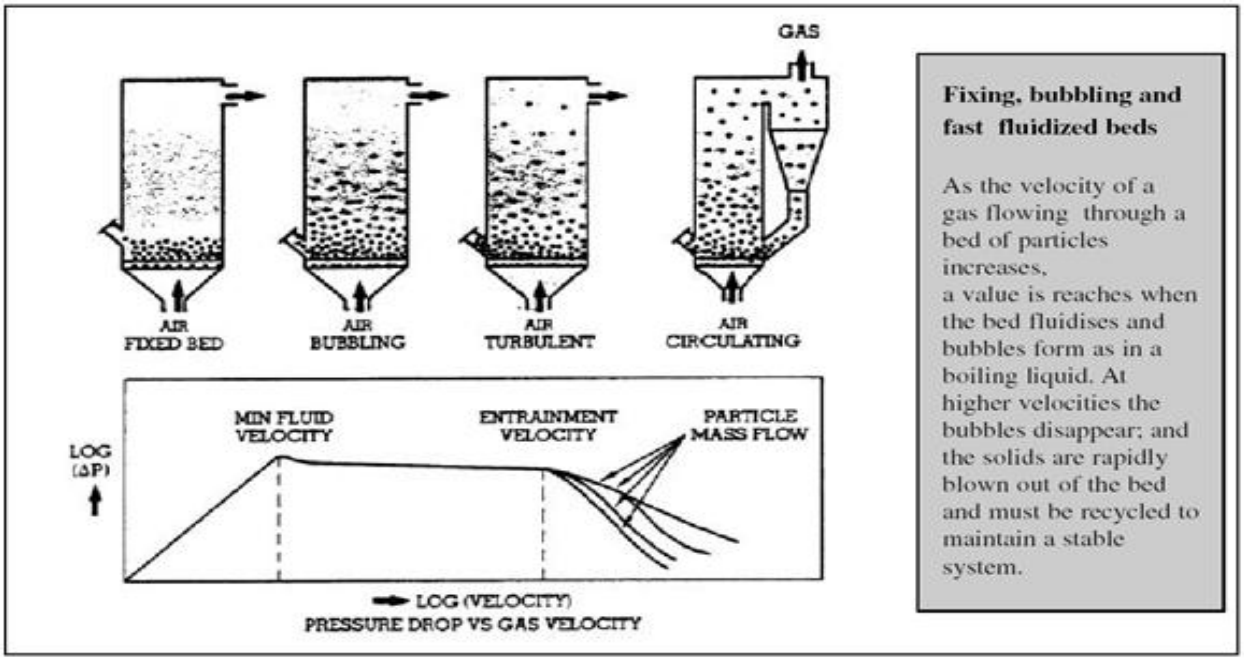
Boiler is a steam producing equipment, which produce steam with burning of fuel. Mostly coal is used as fuel in boiler. Efficiency of the boiler should be determined by two method, direct method and indirect method. It required miscellaneous parameters for determining the efficiency. These specification are chemical analysis result of coal, feed waters analysis, coal feeding rate, steam pressure, steam producing per hour, flue gas analysis, and whether any heat recovery devices are added or not, if added, than its data, fuel utilization rate per hour, humidity factor etc. These all are interconnected to each other and necessary for calculation. Fluidized bed combustion has arised as a viable option and has important advantages over traditional firing systems and offers various benefits compact boiler design. Fuel flexibleness, higher combustion efficiencies and reduced emission of harmful pollutants such as So_x and No_x . The fuels burnt in these boilers contain coal, washery scraps , and other farming wastage. The fluidized bed boilers have a large capacity range 0.5 T/H to over 100T/H.

1.1 MECHANISM OF FLUIDIZED BED COMBUSTION

When an equally distributed air or gases move upward through a finely divided bed of solid particles such as sand sustained on a fine mesh, the particles are unmoved at low velocity. As air velocity is slowly increased, a stage is arrived when an particular particles are delayed in a air stream –the bed is called fluidized. With farther increase in air velocity there is bubble formation intense turbulence the very quick mixing and formation of solid define bed surface. The bed of solid particles shows the properties of boiling liquid and consider the presence of a fluid –"*bubbling fluidized bed*".

At higher velocity bubbles vanish and particles are blown out of a bed. Therefore some quantity of particles have to be redistributed to maintain a constant system-"circulating fluidized bed".

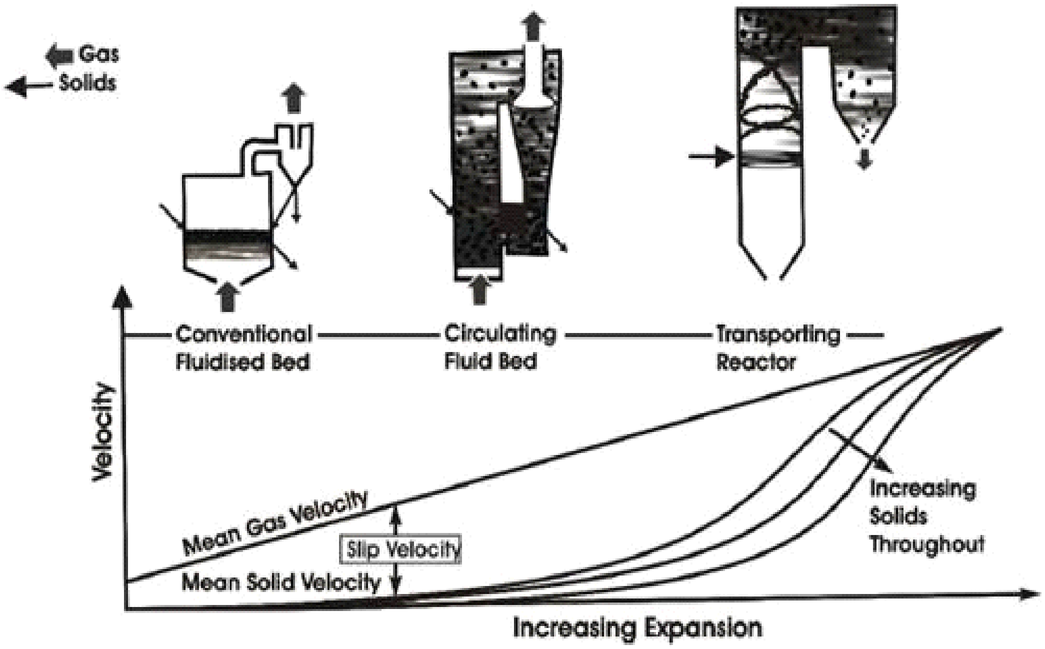
This principle of fluidization is illustrated in fig.



Fixing, bubbling and fast fluidized beds

As the velocity of a gas flowing through a bed of particles increases,
a value is reaches when the bed fluidises and bubbles form as in a boiling liquid. At higher velocities the bubbles disappear; and the solids are rapidly blown out of the bed and must be recycled to maintain a stable system.

Fluidization depends mostly on the particle size and air speed. The average solids speed increase at a slower rate then does the gas speed as illustrated in fig. The difference between the average solid velocity and mean gas velocity is called as slip velocity. Maximal slip velocity between the solids and the gas is beneficial for good heat transfer and intimate contact. If sand particles in a fluidized state is heated to the oxidation temperatures of coal and coal is feeded step by step into the bed, the coal will ignite fastly and bed achieve a uniform temperature. The fluidized bed combustion(FBC) takes place at about 870^{o}C to 950^{o}C.Since this temperature is much down the ash fusion temperature, melting of ash and related problems are avoided. Combustion process need the three “T”s that is time, temperature And turbulence in FBC turbulence is developed by fluidization. Enhanced mixing generates equally distributed heat at lower temperature Thus an FBC systems discharge heat more effectively at lower temperatures.



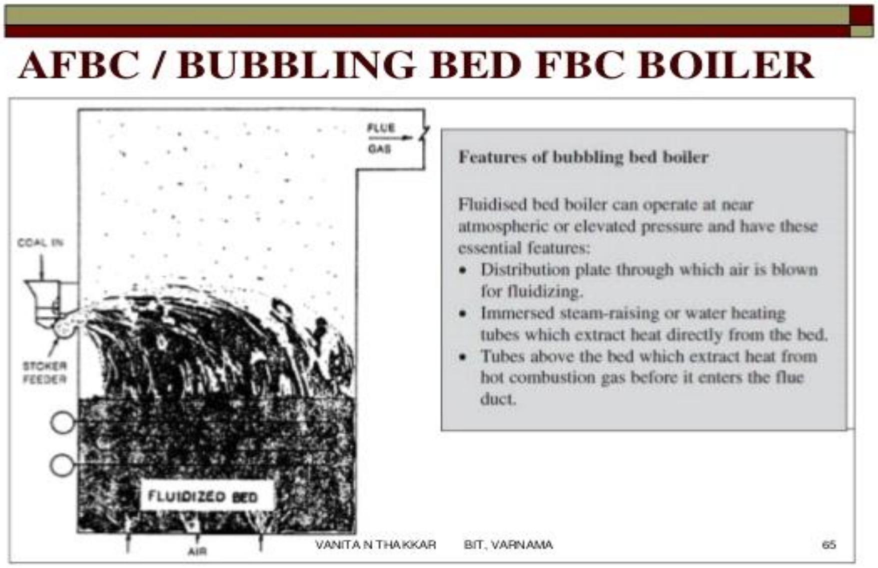
1.2 TYPES OF FLUIDIZED BED COMBUSTION BOILERS

There are three basic types of fluidized bed combustion boilers.

1.Atmospheric classic fluidised bed combustion system.(AFBC)
2.Atmospheric circulating (fast)fluidized bed combustion system.(CFBC)
3.Pressurised fluidized bed combustion system.(PFBC)

1.2.1. AFBC/Bubbling Bed

In AFBC coal is crumble through a diametre of 1 to 10mm depending on the rank of coal type of fuel injected and fed into the combustion chamber. The atmospheric air which works as both the fluidization air and combustion air is passed at a pressure and flows by the bed after being preheated by the exhaust flue gases. The percentage at which air is low through the bed ascertain the quantity of fuel that can be reacted. The bed deepness is generally up to 1.9m deep and the pressure drop medium about 1 inch of water per inch of bed depth. Very few materials leaves the bubbling bed-only about 3 to 5 kg of solids are recycled per ton of fuel burnt. Conventional fluidized bed combustors of these types are shown in fig.



AFBC / BUBBLING BED FBC BOILER

Features of bubbling bed boiler

Fluidised bed boiler can operate at near atmospheric or elevated pressure and have these essential features:

- Distribution plate through which air is blown for fluidizing.
- Immersed steam-raising or water heating tubes which extract heat directly from the bed.
- Tubes above the bed which extract heat from hot combustion gas before it enters the flue duct.

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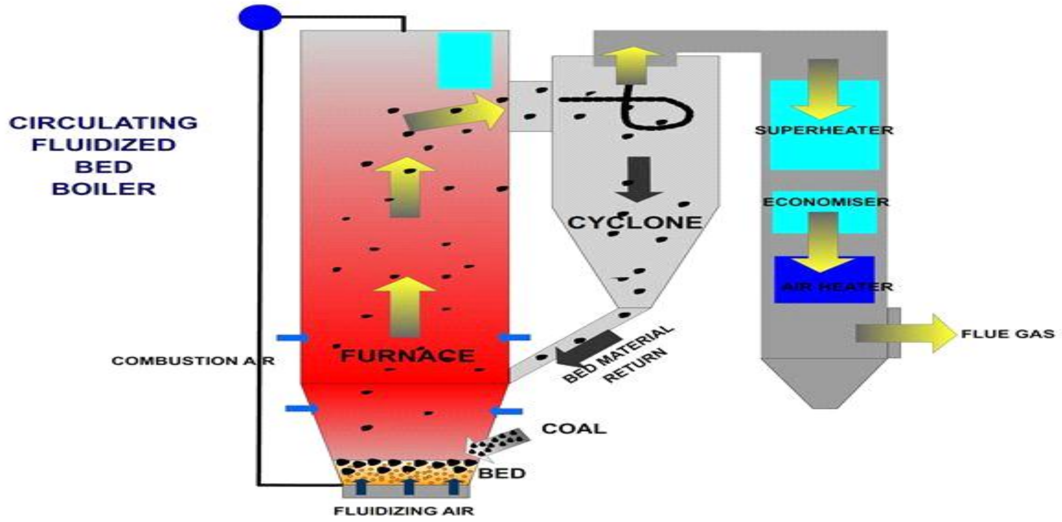
1.2.2. CIRCULATING FLUIDISED BED COMBUSTION (CFBC)

This CFBC mechanism uses the fluidized bed principle in which squash (7-13 mm size) fuel and limestone are feeded into the furnace or combustor. The particles are suspended in a stream of upward flowing air (70-80% of the total air), which comes in the base of the furnace through air distribution nozzles. The fluidising speed in circulating beds is between 5 to 8 m/sec. The balance of combustion air enteres above the bottom of the furnace as secondary air. The combustion proceeds at 870-920^{o}C, and the solid particles (<470 microns) are escaped out of the furnace with flue gas velocity of 5-6 m/s. the particles are then taken by the solids separators and flow back into the furnace. Solid recycle is about 55 to 105 per kg of fuel burnt. There are no stream generation tubes involved in the bed. The circulating bed is formed to move a lot of solids outside of the furnace area and to attain maximum amount of heat transfer outside of the combustion zone-convection zone, water surfaces, and at the exit of the riser. Some circulating bed system even have external heat exchangers. For larger system, the high furnace characteristics of CFBC boiler provides better space utilization, larger fuel particle and sorbent dwelling time for effective combustion methods for NOx control than AFBC generators. CFBC boilers are said to attain better calcium to sulphur utilization- 2 to 3 for the AFBC boilers, even though the furnace temperatures are almost the same. CFBC boilers are mostly claimed to be more cost effective than AFBC boilers for industrial uses requiring more than 80-110 T/hr of steam. CFBC needs huge mechanical cyclones to aquire and recycle the high amount of bed material, which need tall boiler. Fig. shows CFBC bed boiler.

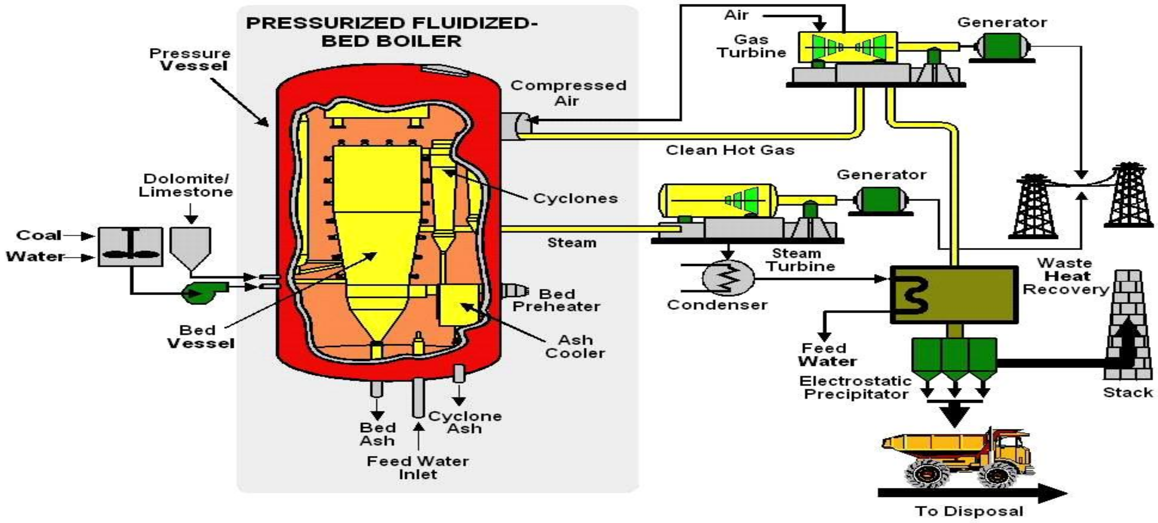


1.2.3. PRESSURISED FLUID BED COMBUSTION (PFBC)

Pressurised Fluidised Bed Combustion (PFBC) is a deviation of fluid technology that means for large scale coal burning applications. In PFBC, the bed vessel worked at pressure up to 18 kg/cm^2.

The outer gas from the fluidized bed combustor operates the gas turbine. The steam turbine is driven by steam raised in tubes involved in the fluidized bed. The condensate from the steam turbine is pre-heated using waste heat from gas turbine exhaust and is then taken as feed water from steam generation.

The PFBC set up can be used for co-generation or combined cycle power generation. By mixing the gas and steam turbines in this manner ,electricity is produced more effectively than in conventional system. The total conversion efficiency is higher by 6% to 10%.



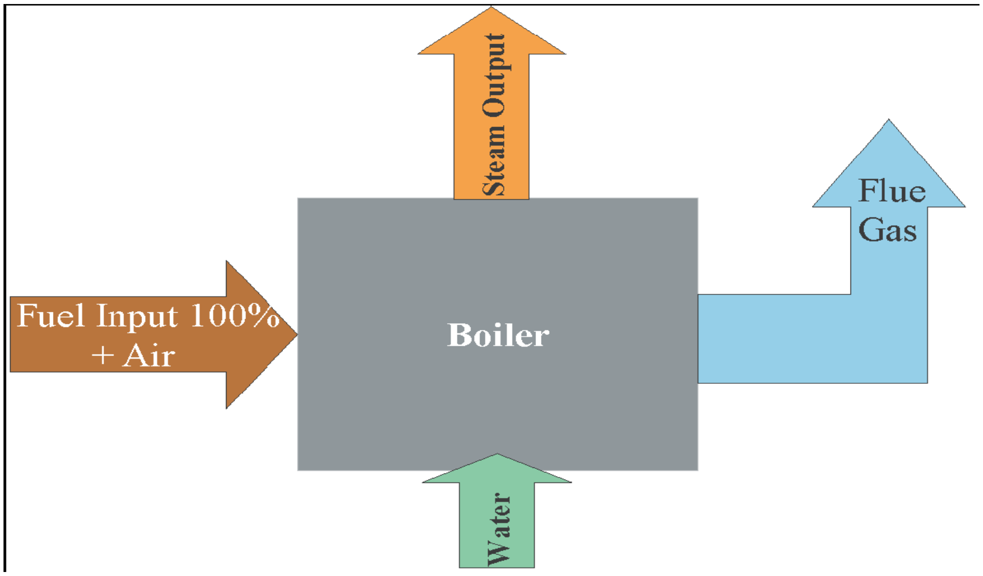
2. METHODOLOGY

2.1. METHODS TO ESTIMATE BOILER EFFICIENCY

2.1.1.Direct method - Where the energy gain of the working fluid (water & steam) differ from the energy content of the boiler fuel,it is also known input-output method. it requires only the useful output (steam) and the heat input (fuel) for determining the efficiency.This efficiency can be determined using the formulae:

- Boiler Efficiency=Heat output/Heat input X 100
- Steam Flow Rate,Kg/hr X (Enthalpy of Steam – Enthalpy of Feed Water) X 100 Quantity of coal consumed,kg/hrX Gross Calorific Value of Fuel

The Direct Method Testing



$$\text{Boiler Efficiency} = \frac{\text{Heat Output}}{\text{Heat Input}}$$

$$\text{Efficiency} = \frac{\text{Heat addition to Steam} \times 100}{\text{Gross Heat in Fuel}}$$

2.1.2. Indirect method - Where the effectiveness is the difference between the losses and the energy input, it is also known as heat loss method. The efficiency can be measured in a easy way by checking all the losses appearing in the boilers using the principle to be described. The drawbacks of the direct method can be over thrown by this method, which calculates the various heat losses associated with boilers. The efficiency can be shown by subtracting the heat loss part from 100.An important benefits of this method is that the errors in measurement do not make important changes in efficiency.

Thus if the boiler efficiency is 90%,flaw of 1% in direct method will result in important change in efficiency. In indirect method,1% flaw in measurement of losses will result in

Efficiency=100-(10±0.1)= 90±0.1+89.9 to 90.1

Efficiency = 100-(1+2+3+4+5+6+7+8) (by Indirect method)

The following losses are applicable to liquid,gas and solid fired boiler

L1-Loss due to dry flue gas (sensible heat)

L2-Loss due to hydrogen in fuel (H_2)

L3-Loss due to moisture in fuel (H_2O)

L4-Loss due to moisture in air (H_2O)

L5-Loss due to carbon mono-oxide (CO)

L6-Loss due to surface radiation, convection and other unaccounted*

*Losses which are insignificant and are difficult to measure.

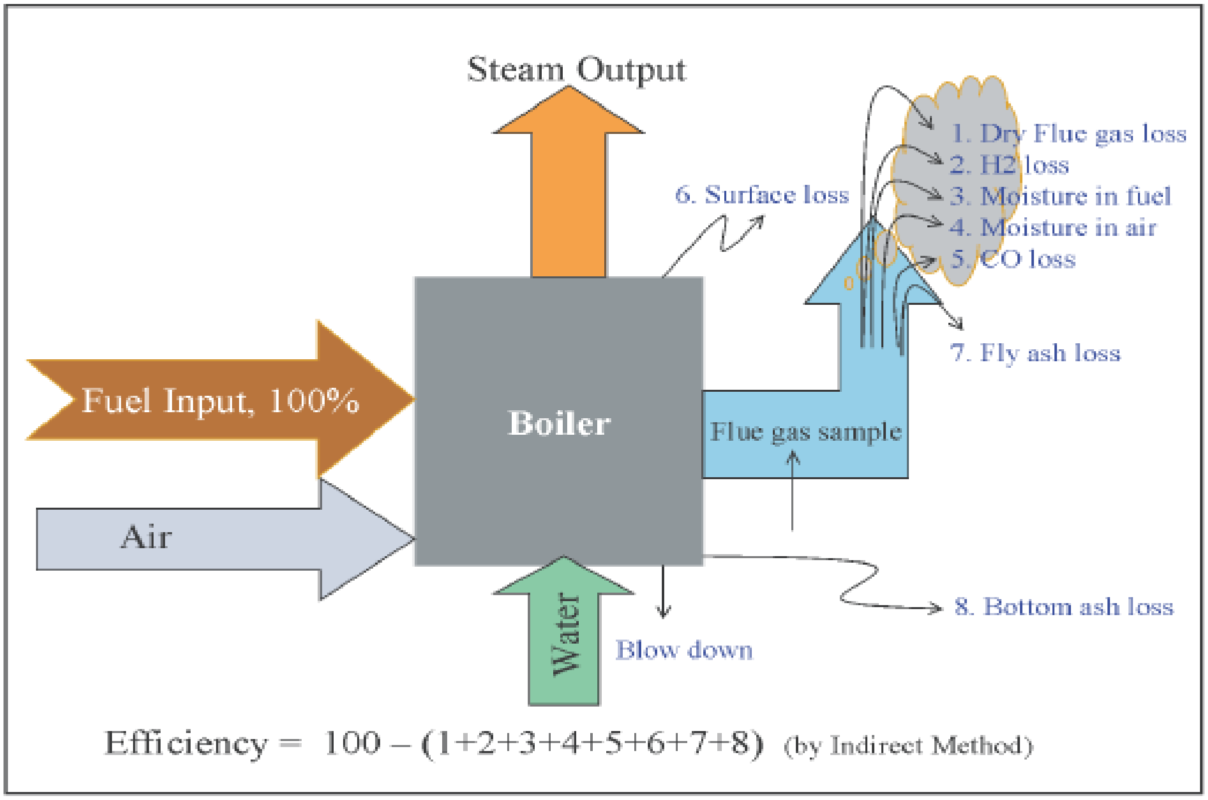
The following losses are applicable to solid fuel boiler in addition to above.

L7-Unburnt losses in fly ash (carbon)

L8-Unburnt losses in Bottom ash. (carbon)

Boiler efficiency by indirect method =100-(L1+L2+L3+L4+L5+L6+L7+L8)

The Indirect Method Testing



2.2.Boiler efficiency computing by indirect method: Calculation procedure formulae

STEP-1 Find theoritical Air

Theoritical air required for complete

combustion = 4.35 [(8/3 C + 8H_2 +S) – O_2]/100 Kg/kg of coal

C=Carbon %

H_2=Hydrogen %

S=Sulphur %

O_2=Oxygen %

C_p = Specific heat of flue gas (0.23 kcal/kg ^{0}C)

2 % heat loss due to evaporation of water formed due to H_2 in fuel (L_2)

STEP-2 To Find Excess Air Supplied

$$\% \text{ Excess air supplied (EA)} = \frac{O_2}{21 - O_2\%} \times 100$$

O_2=Oxygen %

STEP-3 to Find Actual Mass of Air Supplied

Actual mass of air supplied={1+EA/100} X theoritical air kg/kg of coal

EA=Excess air supplied

STEP-4 to Find Actual Mass of Dry Flue Gas

Mass of dry flue gas= Mass of CO_2 in flue gas+ Mass of N_2 content in the fuel + Mass of N_2 in combustion air supplied + Mass of O_2 in flue gas + Mass of SO_2 in flue gas

STEP 5- To Find All Losses

- **% heat loss in dry flue gas (L_1)**= $\dfrac{m \text{ X } Cp \text{X} (T_f – T_a)}{\text{G.C.V of fuel}}$ X 100

  m = mass of dry flue gas in kg/kg of fuel

  C_p = Specific heat of flue gas (0.24 kcal/kg ^{0}C)

% heat loss due to evaporation of water formed due to H_2 in fuel (L_2)

$$= \frac{9 \text{ X } H_2 \text{ X } [584 + Cp (T_f – T_a)]}{\text{GCV of fuel}} \text{ X } 100$$

Where, H_2 – kg of H_2 in 1 kg of fuel

C_p – Specific heat of superheated steam (0.45 Kcal/Kg^{0}C)

T_f – Flue Gas Temperature

T_a- Ambient Temperature

- **% heat loss due to evaporation of moisture present in fuel (L_3)**

$$= \frac{M \times [584 + Cp(T_f - T_a)]}{\text{GCV of fuel}} \times 100$$

M – kg of moisture in 1kg of fuel

C_p – Specific heat of superheated steam (0.45 Kcal/Kg^{0}C)

584 is the latent heat corresponding to the partial pressure of water vapour.

T_f – Flue Gas Temperature

T_a- Ambient Temperature

- **% heat loss due to moisture in air (L_4)**

$$= \frac{\text{AAS} \times \text{humidity factor} \times Cp \times (T_f - T_a)}{\text{GCV of fuel}} \times 100$$

C_p – Specific heat of superheated steam (0.45 Kcal/Kg^{0}C)

T_f –Flue Gas Temperature

T_a-Ambient Temperature

% heat loss due to partial conversion of C to Co (L_5)

$$= = \frac{\% CO \times C}{\% CO + \% CO_2} \times \frac{5654}{\text{GCV of fuel}} \times 100$$

CO-Volume of CO in flue gas (%)

(1%=10000 ppm)

CO_2-Actual volume of CO_2 in flue gas (%)

C-Carbon content Kg/Kg of fuel

*Heat loss due to partial combustion of carbon,Kcal/Kg of carbon.

% **heat loss due to radiation & convection & other unaccounted losses(L_6)**

$$=0.548 \times [(T_s/55.55)4 - (T_a/55.55)4] + 1.957 \times (T_s - T_a)1.25 \times \text{sq. root of } [(196.85\, Vm + 68.9)/68.9]$$

L_6=Radiation Loss in W/m^2

V_m=Wind velocity in m/s

T_s=Surface Temperature(K)

T_a=Ambient Temperature(K)

- **% heat loss due to unburnt in fly ash (L_7)**

$$= \frac{\text{Total Ash collected/ kilogram of fuel burnt X GCV of fly Ash}}{\text{GCV of fuel}} \text{ X } 100$$

- **% heat loss due to unburnt in bottom ash (L_8)**

$$= \frac{\text{Total Ash collected /kilogram of fuel burnt X GCV of bottom ash}}{\text{GCV of fuel}} \text{ X } 100$$

3. RESULTS AND DISCUSSION

For calculating the boiler efficiency by direct method,data are collected from PIL (INDIA) LTD,100TPH boiler.The following data are observed during of boiler and tabulated in table as follows.

3.1. PARAMETRES FOR MEASURING BOILER EFFICIENCY BY DIRECT METHOD

Sr. No.	GCV of coal (Kcal/Kg)	Coal consumption (TPH)	Steam Generation (kg/hr)	Main stream pressure (kg/cm^2)	Superheated steam temperature (^oC)	Saturated feed water temperature (^oC)
1	2950	25	92000	102	515	232
2	3120	28	105000	108	518	236
3	3260	30	108000	112	522	240
4	3340	32	110000	118	528	246
5	3420	34	118000	123	532	252

3.2. CALCULATED BOILER EFFICIENCY BY DIRECT METHOD

Sr. No.	Gross Calorific Value of Coal (Kcal/Kg)	Coal Consumption (TPH)	Steam Generation (Kg/hr)	Enthalpy of superheated steam (KJ/Kg)	Enthalpy of saturated water (KJ/Kg)	Efficiency (%)
1	2950	25	92000	812.6	238.92	71.56
2	3120	28	105000	816.9	243.43	68.92
3	3260	30	108000	819.05	247.98	63.06
4	3340	32	110000	821.68	254.87	58.33
5	3420	34	118000	823.59	261.83	57.00

3.3. INDIRECT METHOD

3.3.1. ULTIMATE ANALYSIS OF COAL

S.No.	C%	H_2%	S%	N_2%	O_2%	Ash%	GCV (Kcal/Kg)
1	54	4	3	1	5	21	2950
2	57	4.7	3.6	1.7	5.6	17.4	3120
3	59	5.3	3.9	2.2	6.2	13.4	3260
4	61	5.9	4.3	2.8	6.7	10.3	3340
5	63	6.3	3.9	2.1	7.1	9.2	3420

3.3.2.FLUE GAS ANALYSIS

CO %	CO2 %	Moisture %	Unburnt in fly ash %	Unburnt in bottom ash %	Ambient Temperature (^{o}C)	Saturated Temperature (^{o}C)	Flue Gas Temperature (^{o}C)
0.0425	14	12	12	16	30	70	170
0.0472	16	10	14	18.2	32	73	172
0.0525	19	10	17	21.3	34	77	174
0.0580	22	9	21	24.6	35	81	175
0.0610	24	8.4	23	27.2	38	84	178

Humidity Ratio Kg/Kg of air	GCV of fly ash (Kcal/Kg)	GCV of bottom ash (Kcal/Kg)	Fuel firing rate (kg/hr)
0.01977	725	1325	5600
0.0205	780	1550	5625
0.0221	840	1670	5645
0.0320	920	1735	5670
0.0380	980	1920	5695

3.4. CALCULATED LOSSES AND BOILER EFFICIENCY BY INDIRECT METHOD

S.No	% Heat loss due to dry flue gas	% Heat loss due to formation From H2 in water	% Heat loss due to moisture in fuel	% Heat loss due to moisture in air	% Heat loss due to partial conversion of C to CO	% Heat loss due to radiation & convection & other unaccounted losses	% heat loss due to unburnt in flue ash	% heat loss due to unburnt in bottom ash	Calculated Efficiency %

1	11.66	7.89	2.63	0.419	0.313	0.417	0.619	1.509	75.14%
2	12.42	8.77	2.07	0.460	0.303	0.293	0.609	1.532	73.53%
3	12.85	9.46	1.98	0.520	0.281	0.294	0.586	1.462	72.55%
4	13.60	10.28	1.74	0.799	0.302	0.312	0.595	1.316	71.06%
5	14.13	10.72	1.58	0.989	0.264	0.287	0.606	0.404	70.00%

4. RESULTS AND DISCUSSION

Moisture in fuel vs efficiency of boiler

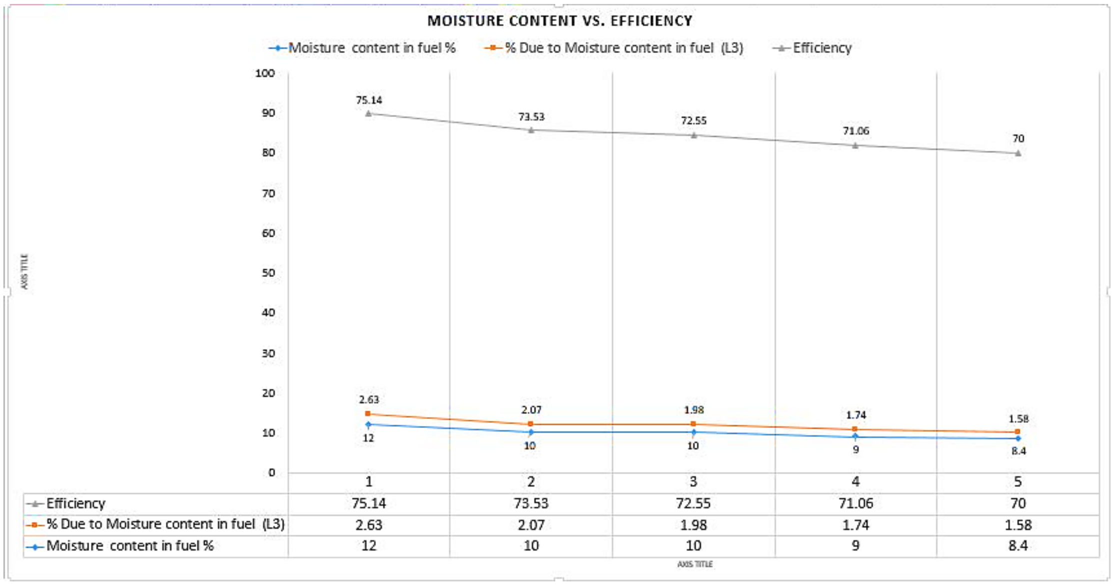


Fig. shows the effect of moisture content in fuel on the efficiency of the boiler. From figure, as moisture content deceases the efficiency gradually decreases and losses in flue gas increases.

Excess air vs efficiency of boiler

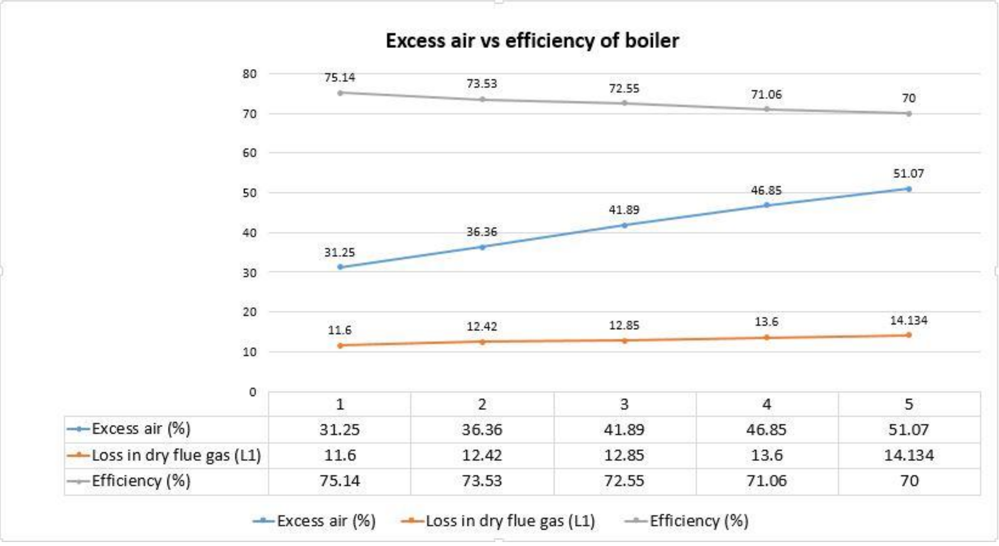
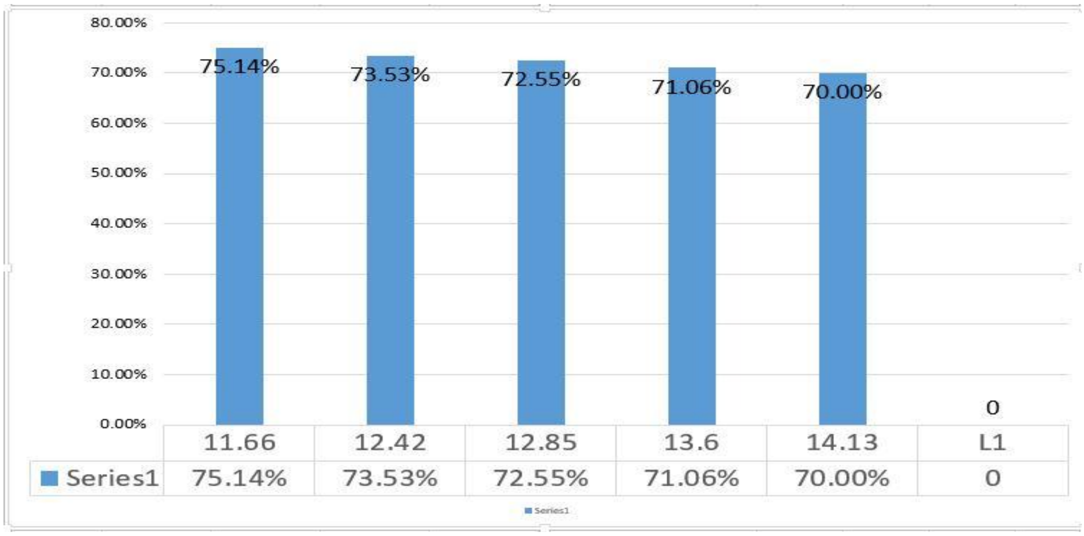


Fig. shows the effect of excess air supplied to the combustion chamber. As the excess supplied to the boiler, efficiency decrease and losses in dry flue gases increases. The efficiency of boiler can be easily increased up to 1-2 % if we can control the excess air supply from the graph. The excess air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

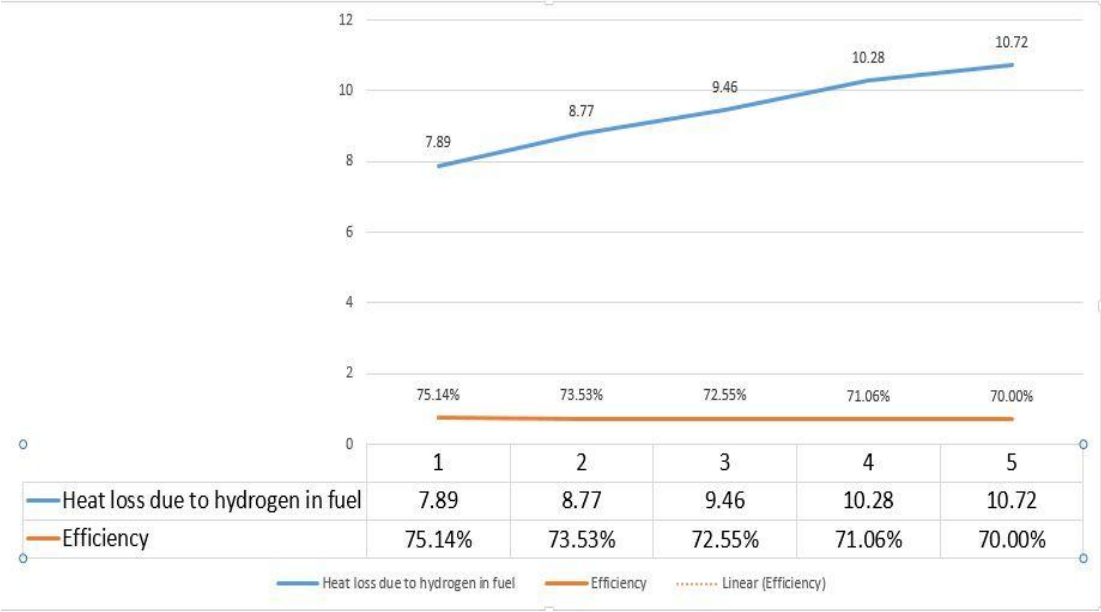
Heat Loss In Dry Flue Gas % (L1) Vs Efficiency %



	11.66	12.42	12.85	13.6	14.13	L1
■ Series1	75.14%	73.53%	72.55%	71.06%	70.00%	0

Fig shows that within a specific range of values, Efficiency % and Heat loss in dry flue gas (%) are both inversely proportional to each other. Efficiency is tends to decreases when values of Heat loss in dry flue gas (%) increases.

Heat Loss In Hydrogen In Fuel% (L2) And Efficiency %

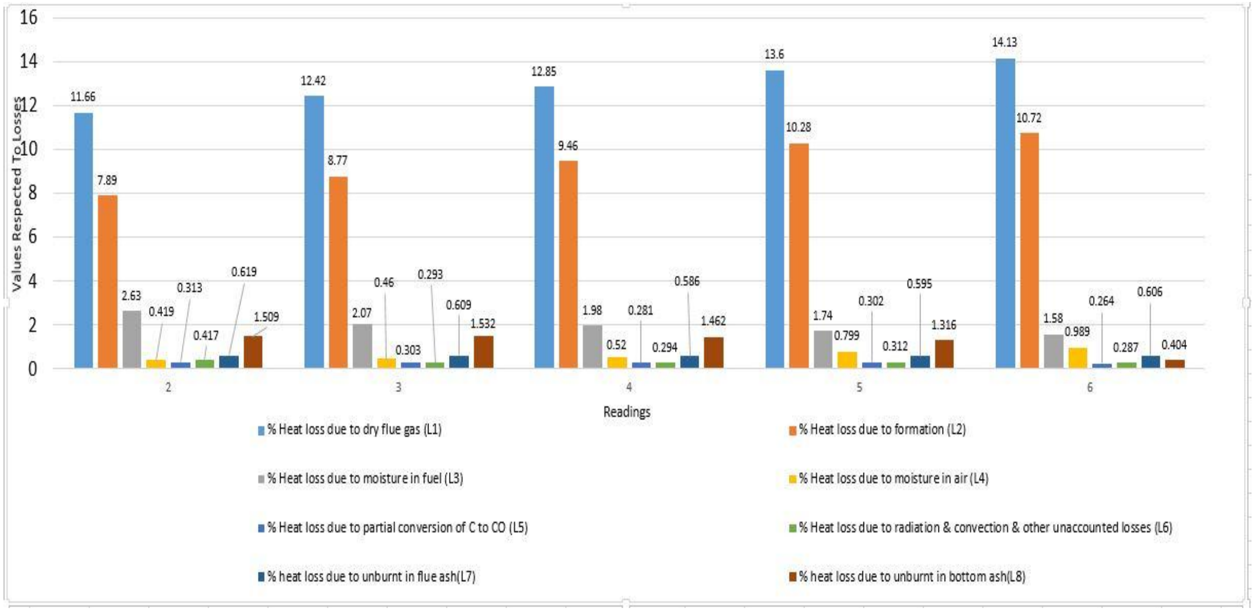


	1	2	3	4	5
Heat loss due to hydrogen in fuel	7.89	8.77	9.46	10.28	10.72
Efficiency	75.14%	73.53%	72.55%	71.06%	70.00%

- It is seen that in fig. Efficiency % and Heat loss due to hydrogen in fuel (%) (L2) are both directly proportional to each other.

- But after a specific range Efficiency (%) is decreases when values of Heat loss due to hydrogen in fuel (%) (L2) suddenly increases.

Comparison of losses



- In fig. it is seen that heat loss due to dry flue gas in fuel and heat loss due to hydrogen in fuel having large values as compare with other losses. Therefore if these losses can be minimized then efficiency can be improved.

EFFICIENCY IMPROVEMENT IN FBC BOILER

Various parametres which use for improvement of boiler

1.Coal up gradation technology

It ascribe to a class of technologies developed to minimize moisture and certain pollutants from lower rank coals such as sub-bituminous coal and lignite coal and increase there calorific values because of fundamental high moisture content all lignite need to be dried earlier from combustion. Depending on the technology type drying is attained either via a indivisual operation or part of a process.

- Indirect touching drying in tubular dryers.
- Flash moisture less coal fines.
- Crushed coal with oil put together and, heating the mixture.
- Drying can be attain using lower temperature waste heat to give evaporative drying.

2. Proper water treatment

Various types of contaminations arise with water and they must be minimized before injecting to the boiler system by proper water treatment. Otherwise they proceed with water and concentrate in the boiler, as a result of deposition and scales are form which may minimize the boiler efficiency, increase the operation & management cost & damage the tubes.

I)TDS control

Total dissolves solids enter with feed water into the boiler, where water is heated & transformed into the steam but TDS remain in the boiler and concentrated, eventually reach at a level where their solubility in the water is exceeded and they deposit from the solution. Thus they form scale and minimize heat transfer and also overheat the tubes and punture those tubes. Thus TDS control is important by manual blow down or automatic blow down system.

ii)pH control

pH is the measurement of how acidic or basic the feed water. Feed water must be neutral which conserves the energy. pH is controlled by either eliminating impurities or adding other chemicals to neutralized the water or by blow down of water.

3)Proper fuel preparation

Fuel pollutant (dirt, dust, suspended particles, moisture etc),they must be eliminated by proper fuel treatment otherwise they forms the scales and minimize the heat tranfer rate or maximum moisture uses lot of energy as required to change the phase and this energy carried over with flue gas as loss. A quality feed into the boiler raise the efficiency level of boiler and also minimize the maintenance costs.

4)Fuel Selection

The proper fuel specification also effect on the efficiency. In case of gaseous fuel, greater the hydrogen content the more water vapour is formed during combustion, which leads greater heat loss due to evaporation of water form by hydrogen in fuel. To get an detailed efficiency calculation a fuel specification that represents the job site fuel to be heated must be used.

5)Eliminate incomplete combustion

The heat generated from incomplete combustion of fuel is less compared to complete or good combustion of fuel. It is ultimately a heat detriment.

The main reasons of incomplete combustion are:

- Excess of material supply such as fuel, air.
- Lack of combustion air.
- Inappropriate firing of fuel.
- Inappropriate sizing of fuel (in case of solid fuels)
- Poor atomization of fuel (in case of liquid fuels)
- Poor combination of fuel and air.
- In effective turbulence and dwelling time of fuel in the furnace.

6) Preheat the combustion air

The waste hot flue gas has enough heat to increase the temperature of combustion air before using for the combustion. Thus waste heat can be redeemed from the boiler flue gas. Approximately 1% thermal efficiency will be maximized by raising air temperature by 20^{o}c.

Preheated combustion air is supplied to the burner which properly mix this air with fuel and fires into the boiler. Most oil and gas burner in the existing boiler system cannot withstand high air temperature. Which can be raised the combustion efficiency of boiler.

7) Reduces scale and soot formation

Formation of deposits (scale and soot) on water sides or gas side can minimize the heat transfer and raise the flue gas temperature. The deposits are like thermal insulation on the tubes, they must be cleaned periodically for better heat transfer and better efficiency.

Minimization of scaling on water side:

- By water treatment
- Cleaning the tube set shutdown period.

8)Minimize surface heat losses

Losses can be minimized by establishing a proper thermal insulation over the outside surface and good refractory lining into the boiler furnace. The boiler surface temperature is bigger then surrounding atmospheric temperature. Hence heat is naturally flows from upper temperature zone to lower temperature zone. Wind speed also affects these losses.

Surface temperature loss are depending on :
- Difference of temperature between boiler surface and ambient.
- Surface area
- Wind velocity

Surface temperature losses are fixed energy losses and do not depend on the boiler loadings. Its value is approximately 1-6% at full load but be contribute about 7% of total losses at 25% load. These losses can be minimized by installing a proper thermal insulation over the outside surface and good refractory lining inside the boiler furnace.

9)Controlling the excess air

Excess air is the extra air supplied beyond the theoretical air to insure the complete combustion of fuel so that C,H,S of fuel are changed into CO_2, H_2O and SO_2 respectively. Extra air is supplied to the combustion of fuel because a boiler firing without sufficient air or “fuel-rich” is working in the potentially dangerous condition. So, extra air which is supplied to the burner to provide a safety factor above the actual air required for combustion. A quality model will allow firing at lower excess air levels of 15% (3% of O_2). O_2 represents oxygen in the flue gas, excess air is measured by O_2 in the excess air and shows the 3% measurement.

The optimum excess air level is depending on burner design and type, furnace design ,fuel and process variables, It can be estimated by conducting various performance test with different fuel/air ratios.

10) Boiler capacity fluctuation :

The load on the boiler is changing in nature. The efficiency of boiler vary according to load. All of sudden as load is increased, steam demand is also raised and pressure will be dropped. Burner is start to burn at its full rate to fulfill this demand, but pressure continues to fall because boiler is taking some time to respond. Similarly, if load is suddenly decreased, steam demand is reduced and steam pressure is increased, burner immediately minimize the firing rate, but again it will take some time, so that steam pressure over shoots the relief valve setting. The maximum efficiency of boiler will occur at nearly 70-85% of full load. Beyond the load limits, the efficiency will be minimized.

- As the load falls, the fuel & air supply is reducing ; hence mass so flue gas will be reduced. The decrement in flow rate of flue gas for some heat transfer area will also reduce the exit flue gas temperature. These all increase the efficiency of boiler.
- As the load drops below 50% most combustion appliances need more excess air to burn the fuel completely. This raised the sensible heat loss and lowers the boiler efficiency.

Thus, boiler should be worked near to full load for achieving the maximum efficiency.

5. CONCLUSION AND FUTURE SCOPE

The performance analysis performed, provides efficiency calculation for 100 TPH boiler by direct & indirect method and by calculation of results following conclusion has been done:

By direct method efficiency for 2950,3120,3260,3340Kcal/kg GCV of fuel for FBC boiler is 71.56%,68.92%,63.06%,58.33% & by indirect method efficiency at same GCV of fuel is 75.14%,73.53%,72.55%,71.06%.

Therefore efficiency by indirect method of FBC boiler is greater than by direct method for same GCV of the coal.

The dry flue gas loss in is always higher than any other loss. Therefore dry flue gas loss should be minimized by maximum heat extraction in the convective surfaces of the Boiler. The efficiency calculation by indirect method is the best way to account all the Boiler losses. The important step to improve the performance of Boilers is the detailed study of the Boiler in the plant and then performing the efficiency calculation. When the flue gas loss is reduced, efficiency of the Boiler can be as high as 80 percent.

Performance Improvement: From the above, we have find the significant changes in efficiency. The losses that occur in a lot of heat energy is wasted from dry flue gas & hydrogen loss. Hence we have to extract Dry flue gas loss & at the same time, it has to be kept in mind that decreasing Hydrogen loss the flue gas temperature will increase acid corrosion at the Moisture in fuel cold end of the Boiler. Therefore by decreasing hydrogen loss & dry flue gas loss efficiency can be improved.

FUTURE SCOPE

Boiler efficiency is very necessary to calculate because from this the entire performance of the boiler can be known. It can be seen indirect method gives better efficiency. By indirect method efficiency can be calculated in a detailed manner. Therefore this method is very much useful to calculate boiler efficiency because from this method the entire losses can be known. It can be said there is ample scope for future research work in this field. The proposed method can be effectively and efficiently used for all FBC boilers regardless of the capacity of the boiler. As it can be seen there is not much drop in efficiency of boiler by indirect method either during start-up or during normal operation. The proposed method allows safe and smooth operation of the boiler. This method is effective when lack of oxygen in the furnace and Increases the efficiency of the Boiler. The concept of indirect method can also be used for performance analysis of other types of boilers with different capacities such as AFBC,CFBC,PFBC and supercritical boilers of different capacities. Also, it is an energy conservation methodology.

6. REFERENCE

1.Patel,C.T.,"calculating the efficiency of boiler for different GCV of the coal", International journal of Innovative Research in Science,Vol-2 ISSN:2319-8753 (May 2013).

2.Yadav,P.J.,"calculated the efficiency of boiler in rice mill using husk and coal as a fuel and showed comparision between them",S-JPSET:ISSN:2229-7111,Vol.2 (2011).

3.Lang,F.D,"examines the effects of particle size on the calorific value of hydrocarbons, shedding light on the thermodynamics of pulverizing coal in a commercial power plant", The American Society of Mechanical Engineering,Power:2011-55216 (October 2011).

4.Bora,M.K,"The comparision with design value and enlisted some of the factors that effect the performance of the boiler", International Journal of Advanced Research Vol-2 ISSN:2320-5407(2014).

5.Zhou Jijun,"Improving boiler efficiency modeling based on ambient air temperature",ESL-HH-02-05-45 (May 2002).

6.Vakkilainen,E.K,"Modern method to determine recovery boiler efficiency", PAPEL Vol. 72,num. 12,pp.58-65 DEC 2011.

7.Jain,A.Kumar,"An approach towards efficient operation of boilers", International Journal of scientific and engineering research",Vol_3 ISSN: 2229-5518 (June 2012).

8.Jain Rakesh.,"Performace improvement of boiler through waste heat recovery from an air conditioning unit", International Journal of Innovative Research in Science,Vol-2 ISSN:2319-8753 (Feb 2013).

9. V. K. Gaudani, Energy Efficiency in Thermal System. Vol. III. IECC Press. Delhi 2009

10. J. Spisak, M. Cehlar, V. Jakao, Z. Jurkasova, M. Paskova. “Technical and Economical Aspects of the Optimization of the Steam Boiler”.ActaMetallurgica. Vol 18. 2012. No 2-3

11. Rahul Dev Gupta, SudhirGhai, Ajai Jain. “Energy Efficiency Improvement Strategies for Industrial Boilers: A Case Study”. Journal ofEngineering and Technology. Vol 1. Issue 1.

12. Kevin Carpenter, Chris Schmidt and Kelly Kissock. “Common Boiler Excess Air Tends and Strategies to Optimized Efficiency”. ACEEE Sumer Study On Energy Efficiency In Buildings.

13. Jorge Barroso, Felix Barreras, HippolyteAmaveda, Antonio Lozano on the “Optimization of Boiler Efficiency Using Bagasse as Fuel”. FUEL(82)2003. Elsevier Publication.

14.Thenmozhi Ganesan , Dr. Sivakumar Lingappan," A Survey on Circulating Fluidized Bed Combustion Boilers", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 8, August 2013, ISSN (Print) : 2320 – 3765, ISSN (Online): 2278 – 8875 .

15. Nan Zhang, Bona Lu, Wei Wang, Jinghai Li ,"3D CFD simulation of hydrodynamics of a 150MWe circulating fluidized bed boiler", Chemical Engineering Journal ,162 (2010) 821–828 .