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Investigation and Analysis of Heat Losses Due to Excess Air in Fluidized Bed Fuel Combustion of Boiler

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Abstract -The major part of the coal available in India is of low eminence, high ash content and low calorific value. The conventional grate fuel firing systems have got limitations and are not unviable to meet the challenges of future. Fluidized bed combustion as a viable alternative and has important advantages over conventional firing system and offers multiple benefits – compact boiler design, fuel flexibility, higher burning efficiency and reduced production of toxic pollutants such as SOx and NOx. The fuels burnt in these boilers include coal, watery rejects, rice husk, & other agricultural wastes. To enhance the boiler efficiency, excess air was supplied to avoid the unburned fuel. A study was conducted by varying the percentage of excess air from 10% to 31% with the interval of 3% and the various losses associated with boiler are calculated. The optimum quantity of excess air quantity is found
Keywords- Fluidized Bed Combustion, Boiler, Unburned Fuel, Excess Air

I. MECHANISM OF FLUIDIZED BED COMBUSTION

When an evenly dispersed air is passed upward through a finely separated bed of solid particles such as sand supported on a fine mesh, the particles are uninterrupted at low velocity. As air rate is gradually increased, a stage is reached when the individual particles are suspended in the air stream – the bed is called “fluidized”.

If air velocity increase, there is bubble formation, strong turbulence, rapid mixing and formation of thick defined bed surface. The bed of solid particles exhibits the properties of a boiling liquid and assumes the facade of a fluid – “bubbly fluidized bed”. At higher velocities, bubbles vanish, and particles are blown out of the bed. Therefore, some portions of particles have to be re scattered to preserve a stable system – “circulating fluidized bed”.

.Fluidization depends mostly on the particle size and the air speed. The mean solids speed increases at a slower rate than does the gas speed. The divergence between the mean solid velocity and mean gas velocity is called as slip velocity. Maximum slip velocity among the solids and the gas is pleasing for fine heat transfer and close contact. If sand particles in a fluidized status is heated to the ignition temperatures of coal and coal is injected constantly into the bed, the coal will burn quickly and bed attains a consistent temperature.

The fluidized bed combustion (FBC) occurs at around 840OC to 950OC. Since this temperature is much below the ash fusion temperature, melting of ash and connected troubles are avoided. The lesser combustion temperature is achieved because of high coefficient of heat transfer due to rapid mixing in the fluidized bed and efficient extraction of heat from the bed through in-bed heat transfer tubes and walls of the bed. The gas velocity is maintained between least fluidization velocity and particle entrainment velocity.

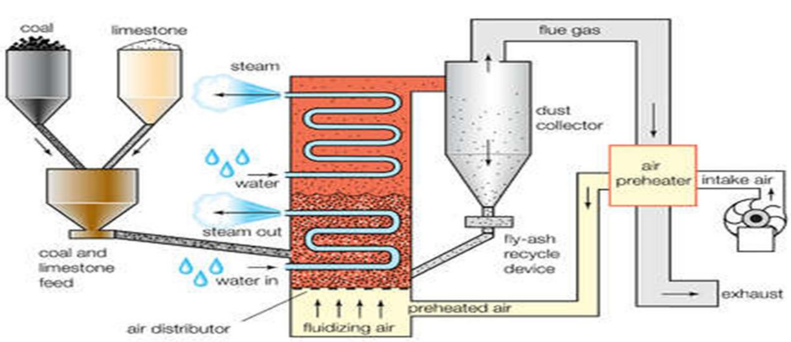

Fig. 1. Schematic arrangement of fluidized bed combustion boiler unit

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II. LOSSES IN BOILER

The efficiency of boiler is the ratio of heat absorbed by the fluid to the total heat supplied to the boiler. The heat utilized by fluid can be increases where by ensuring efficiency improvement. The following losses, which influence by Excess air Dry flue gas loss
Moisture loss
Unburned combustible loss
Blow down loss
Radiation loss
Unaccounted loss
Dry flue gas loss-This loss contributes a large proportion of the losses incurred in the boiler. It is due to the residual thermal energy constrained in the dry flue gas when its temperature is too low for further useful work. This loss is calculated as a function of the quantity of dry combustion gases, the temperature rise between Forced Draft fan inlet and the gas exit temperature, and the mean specific heat of flue gas at constant pressure.
Thus the loss can be influenced by any of this factor. However the quantity of excess air has the greatest influence because this causes deviation in both the weight of the flue gas and the final temperature. A change in the excess air quantity of 5% will change the loss by ±1%. The assessment of the specific heat of the flue gases is variable but dependent upon the SO_2 content of the gas.

$$\text{Dry gas loss} = \frac{\text{Dry gas} \times \text{Specific heat of dry gas} \times (\text{Temperature of dry gas leaving} - \text{Ambient temperature})}{\text{Gross Calorific value of fuel}}$$

Moisture loss-The total moisture loss is the thermal energy in the water vapour entrained in the flue gases leaving the boiler. The water becomes superheated steam if the exit gas temperature is above dew point at the stack base.
The total moisture loss is made up of water derived from three sources.
The sum of free and inherent moisture in the fuel as fired. (The moisture flashes off into superheated steam in the furnace)
The procts of the combustion of Hydrogen.
The moisture in the air for combustion includes excess air.

$$\text{Loss due to moisture and hydrogen in the fuel} = \frac{\text{Total moisture} \times \text{heat per kg.of moisture}}{\text{Gross calorific value of fuel}}$$

Loss due to air moisture = (Total dry air) x (mass of water vapour per kg. of air) x (Temperature difference of gas and air)
Unburned Combustible Loss (Mechanical Loss)-The main source of unburned fuel is carbon either in the bottom ash in the furnace hopper or that entrained by the flue gases flowing to the mechanical dust collector. The distribution ash is assumed to be 90% fly ash and 10% bottom ash. The calorific value of the combustible is normally taken to be that of carbon, i.e., 8077.8 Kcal/kg. Losses are due to incomplete combustion of Carbon in fuel.

$$\text{Loss due to Combustibles} = \frac{\text{Total combustible in ash} \times \text{Calorific value of carbon}}{\text{Gross calorific value of fuel}}$$

$$\text{Fly ash sensible heat} = \frac{\text{Fly ash} \times \text{specific heat of ash} \times (\text{Temperature of gas leaving} - \text{Ambient temperature})}{\text{Gross Calorific value}}$$

$$\text{Bottom ash sensible heat} = \frac{\text{Bottom ash} \times \text{specific heat of ash} \times (\text{Temperature of bottom ash} - \text{Ambient temperature})}{\text{Gross Calorific value}}$$

Radiation Loss-The loss due to radiation is normally taken from design standard of the boiler. This varies from 0.25% to 1.0%

III. EXPERIMENTATION AND METHODOLOGY

On any boiler, the art of achieving high efficiency combustion largely depends on supplying correct quantity of air at the right place. If too little air is supplied the fuel is not completely burnt. If too much air is supplied, heat is wasted by means of flue gas being carried to the stack in greatest quantities than normal. The only part of the air which takes part in combustion is Oxygen, the reminder being Nitrogen which is merely a percentage and very expensive gas because of the following:
It carries heat to the chimney
It requires more fan power

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It leads to NO_x pollution

The experiment was conducted with varying the excess air quantity; the losses due to excess air and boiler efficiency are calculated

The following parameters observed during the power generation are listed in table 1

Table1. Coal Analysis

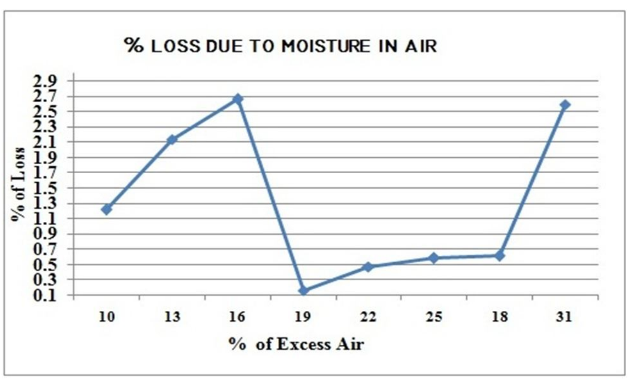
Proximate Analysis of Coal		Ultimate Analysis of Coal	
% of Moisture	6.05%	Ash	44.7%
% of Ash	42.66%	Carbon	36.9%
% of Volatile Matter	24.12%	Oxygen	8.18%
% of Fixed carbon	27.17%	Nitrogen	0.7%
		Hydrogen	3.02%
Gross Calorific value of fuel	3660 Kcal/ Kg	Sulphur	0.4%
		Moisture	6.1%

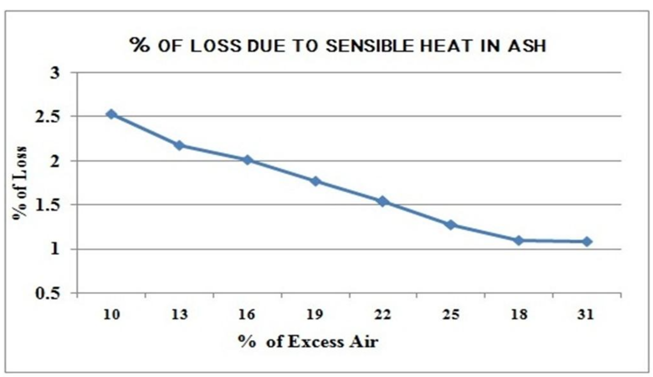
IV. RESULTS AND DISCUSSION

The calculated losses and efficiency for various percentage of excess air are tabulated in Table 2

Table2. Calculated Losses And Boiler Efficiency

Nature of losses due to excess air	% of Excess air							
	10%	13%	16%	19%	22%	25%	28%	31%
% loss due to dry Flue gas	5.7284	5.8954	6.1971	6.4268	6.7404	7.1459	7.3003	8.9652
% of loss due to moisture and H_2 in fuel	5.6851	5.6664	5.6875	5.6812	5.681	5.6986	5.6812	5.689
% of loss due to unburned carbon in Ash	2.8692	2.4278	2.1849	1.8759	1.6553	1.3242	1.1476	0.949
% of loss due to sensible heat in ash	2.5352	2.1787	2.0104	1.767	1.5346	1.2727	1.1	1.0841
% of loss due to excess air	0.4605	0.6115	0.7912	0.9629	1.1929	1.4482	1.648	1.9578
% loss due to moisture in air	1.2116	2.1317	2.6538	0.1562	0.472	0.5796	0.6074	2.589
Boiler efficiency %	79.8	79.99	80.9	81.42	81.45	81.99	82.02	80.7





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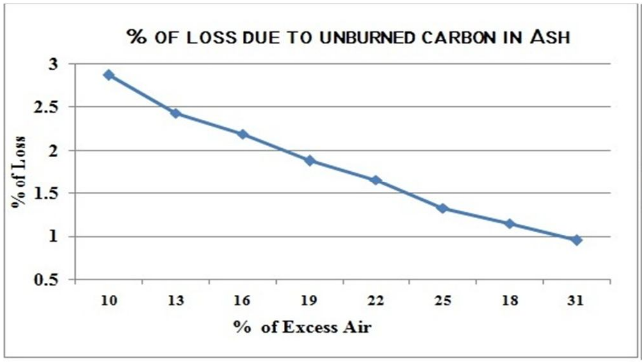

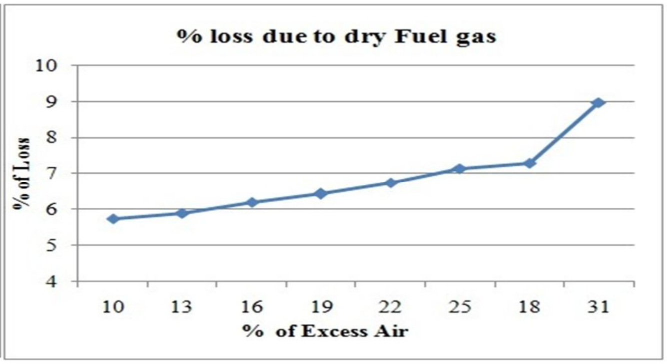

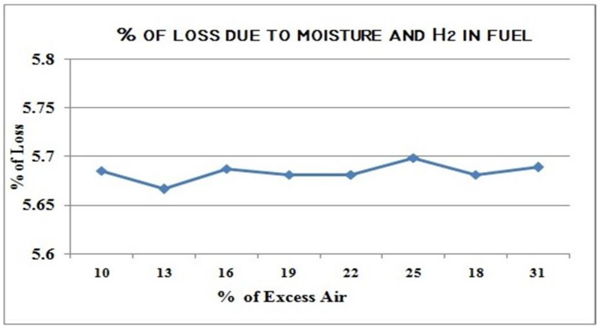

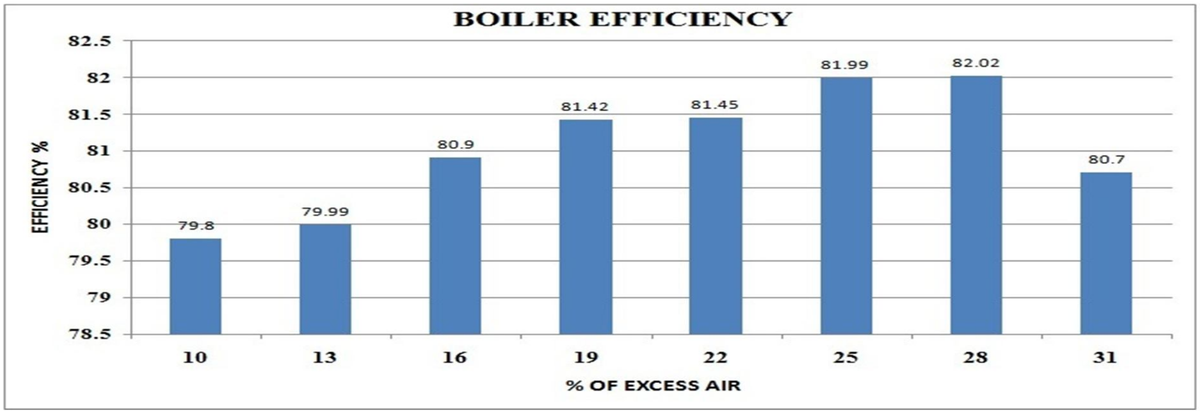

If the percentage of excess air increases, percentage of loss due to dry flue gas also increases. But, the percentage of loss due to un-burnt carbon in ash decreases with increase in percentage of excess air. The increase in percentage of excess air leads to decrease in percentage of loss due to sensible heat in ash. Losses due to moisture in air and H_2 in the fuel are fluctuating. The amount of oxygen present in the excess air helps in improved combustion of the fuel which intern increases the efficiency. It is found that the efficiency of boiler increased with the passage of excess air up to an extent beyond which the efficiency decrease of with increase in the percentage of excess air. This is due to the fact that the heat loss in excess air is more than the heat produced during combustion. It's found experimentally that the boiler showed a high percentage of 82.02% with the passage of 28% of excess air.

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