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PERFORMANCE ANALYSIS OF ATMOSPHERIC FLUIDIZED BED COMBUSTION BOILER

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ABSTRACT
This paper present an approach for the efficiency improvement of Atmoshpheric Fluidized Bed Combustion Boiler,of Ruchi Soya India Ltd. Durgachak.Haldia.West Bengal.data taken from 3 shift log book of 24 hour average basis.& applying indirect method of heat losses and find that upon decreasing of 31^0C, efficiency improved by 1^0C. This paper address the various approach for efficiency improvement of a boiler

KEYWORDS: AFBC Boiler, Heat loss method, flue gas temperature, Efficiency, feed water temperature, Excess air

I. INTRODUCTION
In the Atmoshpheric Fluidized Bed Combustion Boiler (AFBC) low velocity of air is used for fluidization. Air from FD fan is used for this. Air is approximately about 50 -60% of the total air supplied to the compartment through the nozzle to create fluidization of bed. Coal is crushed to a size of 1mm to 10 mm. depending on the rank of coal, type of fuel feed to the combustion chamber. Mostly coal is feed by priming air (PA) fan . the bed of the boiler is divided into sections. Individual sections called compartments have their own coal feeder and fluidized air supply.Depending upon the load on the boiler. Some sections may be taken out of service. This is called as bed slumping. Some time it is required to maintain the temp. of the slumped section for this air is charged & some fuel is feed to the bed for some time.this paper present an approach for analysis of AFBC boiler of working pressure 65 kg/cm^2& working temperature 480^0C of 30 Tone per hour Capacity.of Ruchi Soya India Ltd,Durgapur West Bengal. [1][2]

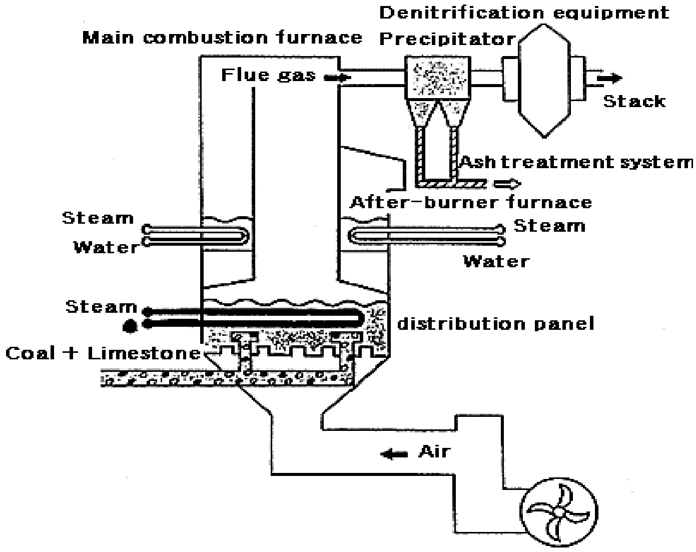

Fig -1.1 Atmospheric Fluidized Bed Combustion Boiler (AFBC)

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II. IDENTIFICATION OF PROBLEM

When the combustible products contain any unburnt fuel or components such as C, H_2, CO, or OH. For example hydrocarbon that is not completely oxidized forms partially oxidized Compounds. such as carbon monoxide, instead of water & carbon dioxide. Oxygen has greater tendency to combine with hydrogen than with carbon. So fuel normally burns to completion forming H_20. As a result, some carbon ends up as carbon monoxide or just plain carbon particles, soot, in the products. Incomplete combustion means that fuel is inefficiently and can even be hazardous due to formation of carbon monoxide (Cengel & boles,2006) Inefficient amount of oxygen is an obvious reason for incomplete combustion. Other reason are too low flame temperature. Inefficient reactants residence time in the flame and inefficient mixing in the combustion chamber during limited time that fuel and oxygen are in contact.[3]In order to achieve complete combustion in an actual process. The amount of oxygen has to exceed the theoretical level by a certain percentage. The amount of air that exceeds theoretical amount is referred to as excess air. Air contain 79% nitrogen and 21% oxygen (by volume)only oxygen is required for combustion.it is required to handle large volume of air to get required quantity of oxygen. Large quantity of heat is required to heat is required to heat this total air.so, efficiency of system decreases. also, if less air is supplied than complete combustion of combustible material may not take place. Efficiency decreases in this case also.[3][4]

III. EFFICIENCY CALCULATION OF AFBC BOILER

There are two methods to calculate the efficiency
1) Direct method
2) Indirect method

Direct method:-

$$\eta_{boiler} = \frac{Output}{Input}$$

$$= \frac{Net\ heat\ added\ to\ the\ steam\ at\ the\ boiler}{Heat\ energy\ supplied\ by\ the\ fuel\ in\ the\ boiler}$$

$$= \frac{steam\ flow\ X\ (heat\ available\ in\ steam - heat\ in\ the\ feed\ water)}{Coal\ flow\ X\ G.C.V}$$

Indirect method:-

$\eta_{boiler} = 100$-(L_1+ L_2+ L_3+ L_4+ L_5+ L_6+ L_7+ L_8)

Step-1 Theoritical (Stoichiometric)air requirement(TA):=

$$\frac{11.6xC + 34.8(h2xO2/8) + 4.35xS}{100} kg/kg\ of\ fuel$$

Step-2 %Excess air requirement(EA) $= \frac{o2\%}{21-02\%} x100$

$$= \frac{4.5}{21 - 4.5} x100$$

Step -3 Actual air (total air)requirement(AAR):

Theoretical air $X(1+\frac{EA}{100}) \frac{kg\ of\ air}{kgof\ fuel}$

$= 4.85X(1+\frac{27.27}{100}) \frac{kg\ of\ air}{kgof\ fuel}$

Step -4 Find all losses:

1) L_1 % of heat loss due to dry flue gas $= \frac{mxCp1(tf-ta)}{G.C.V} X100$

$$= \frac{7.17x.24(156 - 36.75)}{5300} X100$$

Where, "m" equals to mass of air supplied/kg of fuel +1 kg of fuel.

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

$= \frac{9xH2X[584+Cp2X(tf-ta)]}{G.C.V} X100$

$$= \frac{9x.029X[584 + .45X(156 - 36.75)]}{5300} X100$$

3) L_3% of heat loss due to evaporation of moisture in fuel

$$=\frac{MX[584+Cp2(tf-ta)}{100}x100$$

$$\frac{0.15X[584+0.45(156-36.75)]}{100}x100$$

4) L_4% of heat loss due to moisture in combustion air

$$=\frac{AARXhumidity\ factorXCp2(tf-ta)}{G.C.V}x100$$

$$=\frac{6.17X.021X.45(156-36.75)}{5300}x100$$

5) L_5% of heat loss due to unburnt in fly ash.

$$\frac{maXG.C.V\ of\ fly\ ash}{G.C.V\ of\ fuel}x100$$

$$=\frac{30.88X700}{5300}x100$$

6) L_6% of heat loss due to unburnt in bottom ash

$$=\frac{maXG.C.V\ of\ bottom\ ash}{G.C.V\ of\ fuel}x100$$

$$=\frac{7.72X150}{5300}x100$$

7) L_7% of heat loss due to partial combustion

$$=\frac{\%COxC}{\%CO+\%co2}x\frac{5744}{G.C.V\ of\ fuel}$$

$$=\frac{.42x36.4}{.42+11.6}x\frac{5744}{5300}$$

8) L_8% of heat loss due to radiation & convection
2% for higher capacity.
Total loss= 100-(L_1 +L_2 +L_3 +L_4 +L_5 +L_6 +L_7 +L_8)
= 100-(3.87%+3.14%+1.804%+0.13%+0.87%+1.01%+1.37%+2%) = **85.806%**

IV. EFFICIENCY IMPROVEMENT OPPORTUNITY OF A BOILER

The efficiency of a boiler systems is important in several ways. By maximizing the amount of energy extracted from the fuel decrease the fuel usage thereby reduces the cost as well as reduces the harmfull emission from the system such as Sox NOx etc. Control scheme for a boiler include combustion, heat transfer, available losses, auxiliary power consumption, water quality, & blow down. Therefore energy efficiency opportunity in boiler related to the following :[2][3]

a) Stack Temp. Control

The stack temp. (the temp. of the flue gases leaving the last point of heat recovery)should be as low as possible. However, it should not be so low that water vapour in the exhaust condenses on the stack walls. This is important in fuel containing significant sulphur as low temp. can lead to sulphur dew point corrosion. Stack temp. greater than 200°C indicates potential for recovery of waste heat. It also indicate the scaling of heat transfer/recovery equipment & hence the urgency of taking an early shut down for water/flue side cleaning.[3]

b) Feed Water Preheating Using Economizer

Typically the flue gases leaving a modern 3-pass shell boiler are at temp. of 200 to 300°C .Thus there is potential to recover heat from these gases . the flue gas exit temp. from a boiler is usually maintained at a minimum of 200°C So that the sulphur oxides in the flue gas do not condense & cause corrosion in heat transfer surface.[3]

c) Preheating The Combustion Air

The waste hot flue gas has enough heat to raise the temp. of combustion air before using for the combustion **.** thus waste heat can be recovered from the boiler flue gas, approximately 1% thermal efficiency will be increased by raising air temp. by 20.C Preheating combustion air is supplied to the burner, which properly mix this air with fuel & fires into the boiler. Most oil & gas burner in the existing boiler system cannot withstand high air temp. which can be raised the combustion efficiency of boiler.[5]

d) Incomplete Combustion

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

The main causes of incomplete combustion are:

- Excess fuel supply
- shortage of combustion air
- improper firing of fuel
- improper sizing of fuel(in case of soild fuel)
- poor atomization of fuel(in case of liquid fuel)
- poor mixing of fuel & air.

A proper selection, operation and good servicing of burner system can reduce the problem of incomplete combustion. In coal firing system, unburnt coal found in the bottom ash or carried over the flue gas or fly ash. This un –burnt coal is known as unburnt losses.

In chain grate stokers, large lump will not burn out completely, while small pieces is pulverized firing system may block the air passage, thus causing poor air distribution.

In gas fired system, vapourizes light oil contained in the gas can condense, when the gas is expanded in a pressure reducing station. The condensed oil can carborized in the gas burner & cause poor fuel distribution, which causes incomplete combustion.[5]

e) Excess Air Control

The excess air is the additional air supplied beyond the theoretical air to ensure the complete combustion of fuel, so that C,H & S of fuel are converted into CO_2, H_2O & SO_2 respectively.excess air is supplied to the combustion of fuel because a boiler firing without sufficient air or "fuel-rich " is operating in a potential dangerous condition. So, excess air is supplied to the burner to provide a safety factor above the actual air required for combustion. A quality design will allow firing at minimum excess air level of 15% (3.1 of O_2) O_2 represent oxygen in the flue gas. Excess air is measured by sampling the O2 in the flue gas. If the 15% excess air exist, the oxygen analyzer would measure the O_2 in the excess air and shows a 3% measurement. The optimum excess air level is depending on burner design & type, furnace design , fuel and process variables. It can be estimated by conducting various performance tests with different fuel/air ratios.[5]

f) Radiation & Convection Heat Loss Minimization.

The external surface of a shell boiler are hotter than the surroundings . the surface thus loss heat to the surroundings depending on the surface area and the difference in temp. between the surface & the surroundings. The heat loss from the boiler shell is normally a fixed energy loss, irrespective of the boiler output with modern boiler design, this may represent only 1.5 % on the gross calorific value at full rating, but will increase to around 6% if the boiler operates at only 25% output. Repairing or augmenting insulation can reduce heat loss through boiler walls & piping.[2]

g) Automatic Blow Down Control

Uncontrolled continous blow down is very wastefull. Automatic blowdown controls can be installed that sense and respond to boiler water conductivity & PH. A lot of blowdown in a 15kg/cm2 boiler results in 3% efficiency loss. A PH is the measure of how acidic or basic the feed water. Feed water must be neutral which save the energy. PH is controlled by either removing impurity or adding other chemicals to neutralize the water or blow down of water.

TDS (Total dissolve solids) comes with feed water into the boiler, water is heated & converted into steam but TDS are remaining in the boiler and concentrated, and eventually reach at a level where their solubility in the water is exceeded and they deposit from the solution. Thus they form scale and reduce heat transfer and also overheat the tubes and puncture those tubes. This TDS control is essential by manual blow down or automatic blow-down.[2][5]

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h) Reduction Of Scaling & Soot Losses

If combustion conditions are not correct, particulary if too little air is used, fuel combustion will not be complete, so , excessive amounts of CO and particles of carbon (Soot) will form.In oil & coal- fired boilers soot builtup on tubes acts as an insulator against heat transfer. Excessive stack temp. may indicate excessive soot built-up. An estimated 1% efficiency loss occure with every 22.C increase in stack temp. or 1mm layer of soot will cause a 10% increase in energy i/p to the boiler to meet the same heat demand. Integrated soot blowers are often installed in boiler to provide cleaning of radiant furnace surfaces, boiler tubes banks, economizer & air preheaters however, these will need to be checked regulary to ensure good working.[2][6]

i) Reduction Of Boiler Steam Pressure

This is an efficient means of reducing fuel consumption, if permissible, by as much as 1 to 2%. Lower steam pressure gives a lower saturated steam temp. and without stack heat recovery, a similar reduction in the temp. of the flue gas temp. result.

Steam is generated at pressure normally dictate by the highest pressure/temp. requirement for a particular process. In some cases, the pressure does not operate all the time and ther are periods when the boiler pressure could be reduced. But it must be remembered that any reduction of boiler pressure reduces the specific volume of the steam in the boiler, and effectively dearates the boiler output. If the steam load exceed the dearated boiler output, carryover of water will occur. The energy manager should therefore consider the possible consequences of pressure reduction carefully, before recommending it pressure should be reduced in stages, and no more than a 20 % reduction should be considered .[2]

j) Variable Speed Control For Fans, Blowers & Pumps.

Variable speed control is an important means of achieving energy savings, generally combustion air control is affected by throttling damper fitted at forced and induced draft fans. Though dampers are simple means of control, they lack accuracy, giving poor control characteristics at the top and bottom of the operating range. In general, if the load characteristics of the boiler is variable, the possibility of the dampers by a VSD should be evaluated.[2]

k) Controlling Boiler Loading

The load on the boiler is fluctuating in nature. The efficiency of boiler varies according to load. As load is suddenly increased. Steam demand is also increased and pressure will be dropped. Burner is start to fire at its full rate to meet this demand, but pressure continues to drop because boiler is taking some time to respond. Similarly if load is suddenly decreased, steam demand is reduced and sream pressure is increased , burner immediately lower than the firing rate, but again it will take some time, so that steam pressure over soots the relief valve setting. The maximum efficiency of boiler will occur at nearly 70-85% of full load. Beyond or under this load limits,the efficiency will be decreased. As the load falls, the value of mass flow rate of the flue gas through the tube will be reduced. This reduction in flow rate for the same heat transfer area reduces the exit flue gas temp. by a small extent, reducing the sensible heat loss. As the load falls below half, the most combustion efficiency need more excess air to burn the fuel completely. This increase the sensible heat losses and lowers the boiler efficiency. The efficiency of boiler achieved at full load and avoid operate on below 25% of rated load operation.[5]

l) Proper Boiler Scheduling

Since, the optimum efficiency of boiler occur at 65 -85% of full load.it is usually more efficienct , on the whole, to operate a fewer number of boiler at higher loads, than to operate a large number at low loads,[2]

m) Boiler Replacement Or Retrofitting

Replacement of boiler for potential savings can be made from detailed energy audit, financial study, and feasibility reports. A change in a boiler plant should be done if existing plant is

- Old & inefficient.
- Over or under sized for present pressure requirements.
- Not capable of firing cheaper substitute fuel.
- Nit designed for ideal load conditions
- Excessive operation, complexity & management cost does not justify.
- Excessive pollution create from generating unit:[2][5]

Fuel saving=$\frac{\eta_{new}-\eta_{old}}{\eta_{new}}$

Where, η_{new} for new boiler& η_{old} for old boiler

V. CONCLUSION

Based on consequence presented in this paper following inference can be drawn:

- Efficiency of boiler depends on flue gas outlet temperature i.e, APH outlet temperature.
- On decreasing the flue gas outlet temperature (i.e,31^{0}C),sensible heat loss increases by 1^{0}C On decreasing sensible heat loss,efficiency improved by 1% of the boiler.

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