ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

EFFICIENCY LOSSES DUE TO EXCESS OXYGEN IN HEATER TREATER PERTAIN TO DRY FLUE GASES

Reetesh Kocheta[1], Rajesh Gond[2]
Email: rkocheta@gmail.com
Department of Mechanical Engineering, Dr. K. N. Modi University, Newai, Tonk, Rajasthan (India)

Abstract- This paper pertains to the effect of Excess Oxygen on efficiency of heater treater pertain to the dry flue gas losses has been observed. There is Stoichiometric measure of air required for proper and complete combustion of NG. By and by ignition conditions are never perfect and abundance air must be provided for complete combustion of the fuel. It has been found that maximum efficiency of heater treater currently obtained are in the range of 24-78%, with range of excess oxygen between 17.5% to 5.9% and temperature range of 300^0C to 440^0C. In condition when excess oxygen is as low as 5.9%, temp as 236^0C efficiency is 77.2%, and when excess oxygen is 9.6%, and temperature is 192^0C, efficiency is about 77.3% which is closer to the designed efficiency. Direct method technique combined with yearly data is used for calculating the dry flue gas losses.

Keywords-Heater Treater, Flame tube combustion, Excess Oxygen, Efficiency Calculation.

1. INTRODUCTION

Strategic maneuvers an extraordinary part wherever man lives and works-in ventures, horticulture transportation and so on. power furnishes our homes with light and warmth. The expectation for everyday comforts and flourishing of a country specifically with increment being used of energy. As innovation is propelling the utilization of energy is consistently rising. The modern area utilizes around half of the aggregate business vitality accessible in India. Of the business wellsprings of vitality, coal, lignite, and oil and petroleum gas are principally utilized. The Indian vitality area is exceedingly vitality concentrated and proficiency is well underneath that of other industrialized nations. There is a developing need to realize change in the proficiency of vitality use in the modern area. More proficient vitality utilize can expand profitability and financial intensity and additionally bring down ozone depleting substance discharges per unit of yield. There is extensive degree for enhancing vitality productivity in businesses managing iron and steel, chemicals, bond, mash and paper, manures, materials, dairy and so forth. In the event that such enterprises can advance vitality protection. To take care of the demand – supply crevice in power, the path ahead unmistakably is to wipe-out widespread income spillage and routine burglary in the state-ruled power segment, and to lift limit expansion in era and supply. Simultaneously, what is required is change in warm proficiency of energy station, in order to produce greater power without proportionate increment in fuel utilization. Execution of the heater, similar to effectiveness and dissipation proportion decreases with time, because of poor burning, warm internationally most fossil-fuelled power creation is from (67%) and in India additionally, we have altogether higher offer of coal let go fossil -fuelled power era. As per Ministry of Power website, coal dominates the energy mix with 60% of total primary energy consumption.

Due to worst combustion performance of the Heater Treater, like efficiency, heat transfer rate reduces with time and requires high firing at all the times. It has also presented that the deterioration of fuel quality leads to poor performance of Heater Treater.

Richard Dolezal has stated that, the intention of injection of more air into furnace/any combustion chamber than theoretical is necessary for the complete combustion of fuel, as it permits enough of oxygen to be present at the flame tip. The quantity of Excess Oxygen must therefore be selected so that the sum of losses due to un-burnt carbon should be minimized, or in other words should be in range of 10-50 PPM.

In gist, it is precise and auto air to fuel ratio which controls the combustion uniformity rather than air and NG maneuvering using a visual and non monitored inspections. Combustion uniformity is the key to the best Heater Treater efficiency as well as the lowest emissions. To achieve this uniformity,

2. ANALYSIS OF EXCESS OXYGEN

There is Stoichiometric measure of air required for proper and complete combustion of NG. By and by ignition conditions are never perfect and abundance air must be provided for complete combustion of the fuel.

Excess Oxygen is an expression of how much more air is used for the combustion than strictly necessary. The calculation is based on the measured level of oxygen in the flue gases and the known concentration of oxygen in the air. Excess Oxygen is generally expressed as a percentage in the form, E.g. 17.3% Excess Oxygen means that a combustion process has about 400 % of the air needed for complete theoretical combustion.

ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

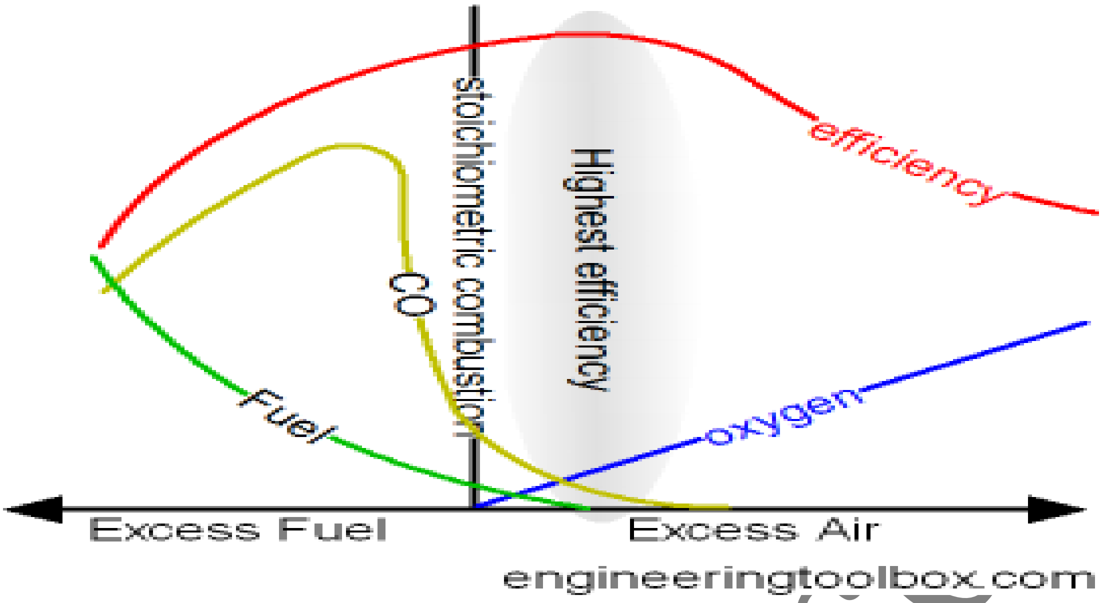

Fig. 2.1 Efficiency vs Excess Air/Fuel Ratio

In practice, a certain level of excess Oxygen is needed in to ensure complete combustion. This is around 1-2% for gaseous fuels. Excess Oxygen is basically a factor to reduce. The unwanted/excess air simply carries energy away from the combustion chamber is released in environment as waste. A fine line must always be drawn between too much Excess Oxygen and incomplete combustion.

3. GOVERNING EQUATIONS FOR ANALYSIS

Indirect Method: Major losses of heater treater are as follows.

3.1 Dry Flue Gas Losses

$$\mathrm{Ld} = \frac{\mathrm{m} * \mathrm{Cp} * \Delta\mathrm{T} * 100}{\mathrm{NCV}}$$

3.2 Heat Loss Due to Evaporation of Water Formed By H_2 in Fuel

This loss would not be considered as it will be compensated by the use of NCV (LHV) rather than using GCV for calculation

Where

m = Mass of Dry Flue Gases (kg/kg of fuel)

C_p = Specific heat of flue gas (kCal/kg°C)

$\Delta T = T_f - T_a$

T_f = Flue gas Temperature (°C)

T_a = Ambient air Temperature (°C)

G.C.V. = Gross Calorific value of fuel (kCal/kg)

N.C.V. = Gross Calorific value of fuel (kCal/kg) (9.73% less than G.C.V.)

Heat Losses due to moisture in air, Fuel are not considered, as this analysis will be extended across the period of one year, and the fuel is dried and is fed to system, ensures complete dry fuel inlet.

Moreover, heat losses due to radiation and convection are also not considered as the flame tubes are completely submerged into the liquid and total temperature rise of the instrument is not more than 50°C. And surface temperature of equipment is 50°C

No ash component is present in fuel.

4. ULTIMATE ANALYSIS OF NG

The data for ultimate analysis was taken from the cryptographic report of fuel.

Table- 4.1 Composition of Natural Gas

NG Composition	Percentage
C (Carbon)	74%
H (Hydrogen)	25%
O (Oxygen)	Traces

S (Sulphur)	-
N (Nitrogen)	0.75%
GCV (kCal/scm)	9350
Density (kg/m3)	0.74
GCV (kCal/kg)	12,635
NCV(kCal/kg)	11,405

$$\text{Theoretical amount of oxygen} = \frac{(2.67 \text{ x C}) + (8 \text{ x H}) + (1 \text{ x S}) - (\text{O})}{100}$$

$$= \frac{(2.67 \text{ x } 74) + (8 \text{ x } 25) + (1 \text{ x } 0) - (0)}{100}$$

= 3.98 kg O_2/kg of NG
Theoretical amount of air = 3.98*100/23.2
= 17.16 kg of air/kg of NG
Actual Air supplied = {1+(EA/100)}* theoretical air
Calculation of mass of dry flue gases in kg/kg of fuel = Mass of actual air supplied + 1 kg fuel

5. FLUE GAS ANALYSIS

Few selected data from different heater treaters or similar equipment are as follows

Table-5.1 Flue Gas Analysis 0f Heater Treaters

Flue Gas Constituents	Heater Treater 1	Heater Treater 2	Heater Treater 3	Heater Treater 4
O2 %	5.9	9	17.5	7.5
CO2 %	8.2	6.7	1.8	7.4
CO PPM	599	36	5	15
Excess air %	40	72	421	54
Ambient Temperature °C	34	27	35	37
Stack Temperature °C	236	105	342	480
Efficiency on flue gas analyzer	77.2 %	81.5%	23.6	57.4%
Location of Equipment	Lakwa, (Assam)	Nawagam (Gujarat)	Lakwa, (Assam)	Kalol (Gujarat)

Efficiency depicted in the table 1 is the efficiency related to stack sampling and is displayed in the flue gas analyzer.

6. CALCULATIONS OF LOSSES IN DRY FLUE GASSES

Solving the equations from a to c, we get following results

Table-6.1 Calculations

Flue Gas Constituents	HT 1	HT 2	HT 3	HT 4
O2 %	5.9	9	17.5	7.5
CO2 %	8.2	6.7	1.8	7.4
CO PPM	599	36	5	15
Excess air %	40	72	421	54
Ambient Temperature °C	34	27	35	37
Stack Temperature °C	236	105	342	480
Efficiency by flue gas analyzer	77.2	81.5	23.6	57.4
Stiochiometric ratio (kg air/kg ng)	17.16	17.16	17.16	17.16

Mass of air	24.02	29.51	89.40	26.42
Mass of fuel	1	1	1	1
Total mass (m)	25.02	30.51	90.40	27.42
Specific heat (kCal/kg °C)	0.264	0.264	0.264	0.264
Dry flue gas losses	11.70%	5.50%	64.24%	28.12%

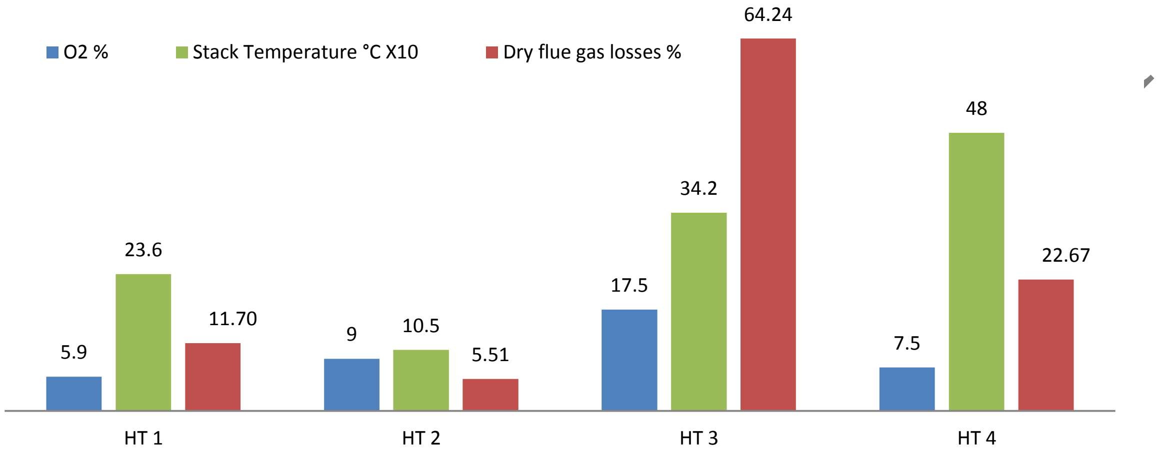

Fig. 6.1 Relation Between Excess Oxygen, Stack Temperature and Dry Flue Gas Losses.

7. OBSERVATIONS

The above graph states that if the excess oxygen along with high stack temperature can be reduced upto certain limits, which can reduce the energy wastage by about 59% as compared with HT3 to HT2.
Furthermore, HT 4 has lower oxygen percentage but energy losses have increased due to high temperature and low CO depicts that there is possibility of reduction of Excess Oxygen upto 7.5%.
With lowest achievable stack temperature of 105°C & excess oxygen to 7.5%, losses can be reduced to 4.3% (using the equations from a to c).
Now days, combustion management systems can further reduce the excess oxygen to 1.5-2%, which reduces dry flue gas losses to range of 3.3% to 3.5%. i.e. efficiency can be increased upto approx 83.5%.

8. ENERGY CONSERVATION OPPORTUNITY

The Major losses occurs either because of high excess air or due to high stack temperature, thus control over both is very important. To put a check over them following technologies can be used.

8.1 Combustion Management System/Combustion Control System

Larger burners are controlled with a combination of a CMS and a Burner Management System (BMS). The BMS determines if there will be a fire or not, and is primarily responsible to shut down the system if conditions become unsafe, as well as enforcing purge requirements on re-start.
The CMS determines how much fuel and air combination is to be infused for proper burning, and thus preventing unsafe conditions from happening, in the first place.
The O2 sensor detects the "excess air" - the percentage of oxygen present in the flue gas after combustion. Typically at high loads, 3-4% O2 is desirable (earth's atmosphere is 21% O2).
It is hazardous to reduce the excess air beyond certain limit because the by product of incomplete combustion that is the un-burnt fuel (H2 and CO) fuel could fill a space in the duct, may later mix with air and might result in uncontrolled combustion. Insufficient air also results in environmentally undesirable emissions.
Too much excess air is a major cause of inefficiency. So, it is required to control O2 at its ideal amount for the load. The burner manufacturer provides an O2 trim SP curve - this is used to set the SP of the O2 trim PID loop. Operators do not have the option to set the O2 Trim SP – when they put the loop in manual, when manoeuvre in auto, the SP should always come from the biased SP curve. The O2 trim loop will then adjust the air flow PV,

causing the air flow loop to add or subtract air, maintaining it at the same % as the fuel flow % and equipment master %. Burner O2 trim is typically limited to adjust the air by only +5% to +10%

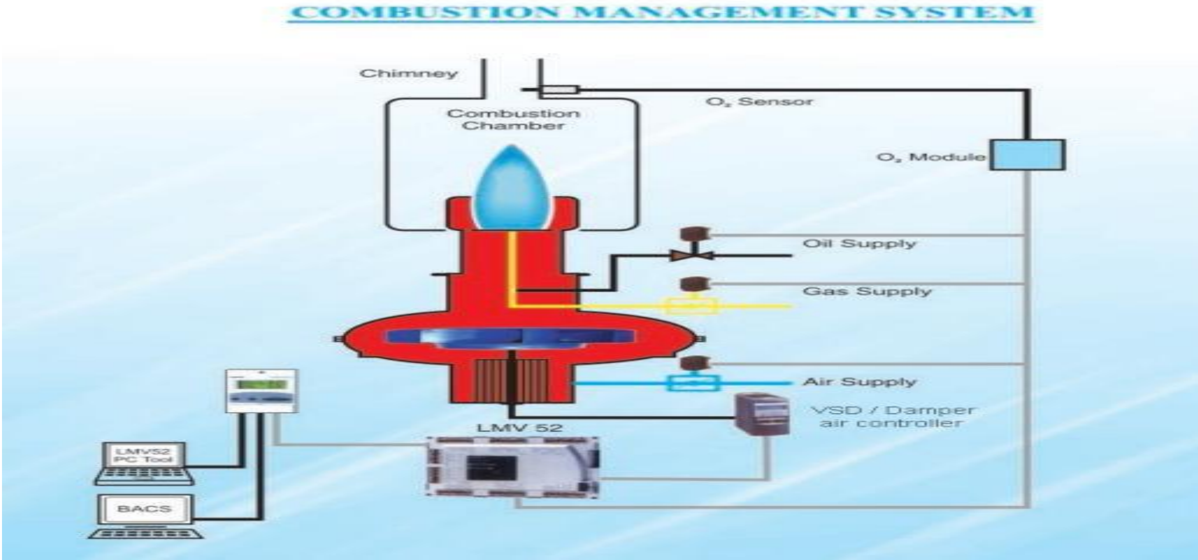

Fig. 8.1 Line Diagram of Combustion Management System

8.1 Stack Temperature

The stack temperature should be as low as possible.. It also indicates scaling of heat transfer / recovery equipment and hence urgency of taking an early shut down for cleaning. In case of cleaner fuels like natural gas, LPG etc. the stack temperature can be reduced to even as low as 120oC using economiser.

8.2 Combustion Air Pre-Heat (NO PRE HEATING)

Combustion air pre-heating is another alternative of pre-heating. It can be achieved by installing a recuperator. For every 20oC rise in combustion air an improvement of about 1% in fuel consumption can be achieved.

8.3 Feed Liquid/Air Pre-Heating (PREHEATING UPTO 12 DEG C)

The effluent has considerable amount of energy, so use of liquid to liquid heat exchanger is advised. This will preheat the incoming liquid, recycling the energy which will reduce the fuel consumption.

8.4 Radiation and Convection Heat Loss

Hot external surfaces (more than 20oC of ambient) lose heat to the surrounding depending on the surface area and difference in temperature. Generally these losses are 1.5% at full rating, but will increase to 6% if system operates at only 25% output. Repairing or augmenting insulation can reduce heat loss through HT plant walls and piping.

8.5 Proper Scheduling

Since the optimum efficiency of thermal systems occurs at 65-85% of full load, it is usually more efficient on the whole, to operate fewer numbers of HT at higher loads, than operating a large number at lower loads.

CONCLUSION

Maximum efficiency of heater treater for current natural draft setup is found at 9% of excess oxygen, with temperature of 105°C. Whereas achievable range is about 7-7.5% excess oxygen and temperature range of 105°C. With fine tuning and use of forced draft with PID control attainable excess oxygen range lies within 1.5-2% of excess oxygen, i.e. 5-10% excess air, and use of pre-heater can reduce stack temperature well within the range of 110 -150°C. Increase in excess air also reduces the flame as well as temperature inside and through the flame tube, thus heat exchange is also drastically reduced. With lower excess air, higher would be the temperature and lower would be the flow rate of gases, thus will ensure higher heat exchange and eventually higher stack temperature. The rise in stack temperature can be controlled by using air/fluid pre-heater. This paper has successfully created an environment of reducing energy losses in heater treater with a practical approach.

REFERENCES

[1] http://www.pipeflowcalculations.com/tables/flue-gas.php
[2] https://beeindia.gov.in/sites/default/files/2Ch1.pdf

[3] http://www.em-ea.org/guide%20books/book-2/2.1%20fuels%20and%20combustion.pdf
[4] http://hydrogen.pnl.gov/tools/lower-and-higher-heating-values-fuels
[5] https://www.thermexcel.com/english/ressourc/fuelgas.htm
[6] http://www.powermin.nic.in/
[7] http://www.narayanburners.com/digital_combustion.html
[8] P.Chattopadhyay, Boiler Operation Engineering, Tata McGraw Hill Publication, 2008.
[9] ASME Standard:PTC-19-10 Performance Test Code for flue Gas and Exhaust Gas Analysis.,1981
[10] British Standards,BS845: 1987
[11] Thermodynamics 5th Edition by Cengel and Boles,Book.
[12] P. K. Nag, Power Plant Engineering, Book,2nd Edition.
[13] http://www.ijrat.org/downloads/june-2014/paper%20id-26201420.pdf
[14] Richard Dolezal, Large Boiler furnaces, PP-79-84.,1980