Variation of Boiler Efficiency and NO_x Emission Control Method Due to Excess Air in a Pulverized Lignite Fired Boiler of 210 MW Capacity

V. G. Ganesan[1], S. Shyam Sundar[2], P. S. Sivakumar[3]

[1] *Assistant Professor , Department of Mechanical Engineering, Easwari Engineering College, Chennai, Tamil Nadu, India.*
[2,3] *U.G. Student , Department of Mechanical Engineering, Easwari Engineering College, Chennai, Tamil Nadu, India.*

***Abstract*: NO_x is a major pollutant of atmosphere and hence to prevent the adverse effects that take place on life and property, it is necessary to keep NO_x emissions in control in power plants. Boiler efficiency of a 210MW boiler is found by varying the operating process and obtaining the corresponding NO_x emission. From these test data we will come to know that performance and NO_x emissions of the boiler are considerably impacted by operating process. Tangential firing boiler burning Lignite with a high combustion temperature and high excessive air ratio creates the highest NO_x emission among the tested boilers. Variation of lignite type and boiler operational parameters also have large effects on the boiler performance and the NO_x emission. This project will demonstrate the NO_x emission can be reduced by regulating the combustion conditions and also concentrates on the variation of the boiler efficiency on a day to day basis due to change in properties of lignite being inducted.**

***Index Terms*: Thermal Power Plant, NO_x emission, Selective Catalytic Reduction, Environmental Concern.**

I. INTRODUCTION

Tangential firing boiler burning Lignite with a high combustion temperature and high excessive air ratio creates the highest NO_x emission among the tested boilers. Variation of lignite type and boiler operational parameters also have large effects on the boiler performance and the NO_x emission. This project will demonstrate the NO_x emission can be reduced by regulating the combustion conditions and also concentrates on the variation of the boiler efficiency on a day to day basis due to change in properties of lignite being inducted.

The boiler is being inducted with the coal whose properties change on a day to day basis due to the volatile nature, thus causing a variation in the efficiency of the boiler on the same scale under consideration. In order to find the parameter which influences this condition and also to assure a steady state maintenance of the efficiency of the boiler, a manipulation should be made after identification of the influencing parameter.

If maintenance of the Low NO_x burner is to take place there is no stand by unit to counteract the temperature control. Hence possibility of increase in NO_X is predicted. A method should be proposed to provide a supplement for low NO_x burner during maintenance.

The following data depict the design and performance of the boiler:

Maximum flue gas temperature at outlet	980 degree Celsius
Maximum emission of NO_x	400mg/Nm^3
No. of coal and oil burners.	No. of coal and oil burners-12 and 8 respectively
Furnace cross sectional Dimension	13.259 x13.259m

1.1. GENERAL DESCRIPTION OF BOILER:

Rating (BMCR)

Capacity : 210 MW
Type of Boiler used : Sub-critical (drum)
Type of circulation : Natural Circulation
Type of firing : Tangential Type
Number of passes : Two pass, single reheating
Steam pressure at SH outlet : 158Kg/cm^3
Steam temperature at SH outlet : 540^0c
Main steam flow : 650T/Hr
Steam flow at RH outlet : 590T/Hr
Lignite fired (average) : 210 T/Hr
Lignite fired (worst) : 230 T/Hr
Lignite fired (best) : 185 T/Hr
Excess air (furnace outlet) : 18%
Cold gas recirculation : 110 T/Hr
RH inlet pressure : 36kg/cm^3
RH outlet pressure: : 33.5 kg/cm^3
RH inlet temperature : 330^0c
RH outlet temperature : 540^0c

II. EXPERIMENTATION

The experiment is done with respect to the properties of lignite observed on DAY 1 to 10 as SAMPLE 1 and DAY 11 to 20 as SAMPLE 2 and the boiler efficiency has been iterated for ten different values of excess air for samples 1 & 2. The lignite proximate analysis of DAY 1 sample is converted to ultimate analysis. The respective calculations for the ultimate analysis of samples is done and theoretical air and excess air requirement is found out. Thus the operating process of boiler is varied for the found out theoretical air and excess air requirement. From the obtained results of the respective boiler operation in full load working condition, the losses occurred is calculated. The above experiment is repeated for DAY 2 to 20 of SAMPLES 1 & 2. The results of the operating process for the calculated theoretical air and excess air requirement and losses is tabulated. Graphs are plotted by taking excess air as the major parameter in x-axis and the losses in y-axis. The graphs are shown below. The figures 2.1.1 to 2.1.6 shows the results for SAMPLE 1 and the figures 2.2.1 to 2.2.6 shows the results for SAMPLE 2.

Fig.2.1.1 Excess Air VS Loss due to Dry Flue Gas

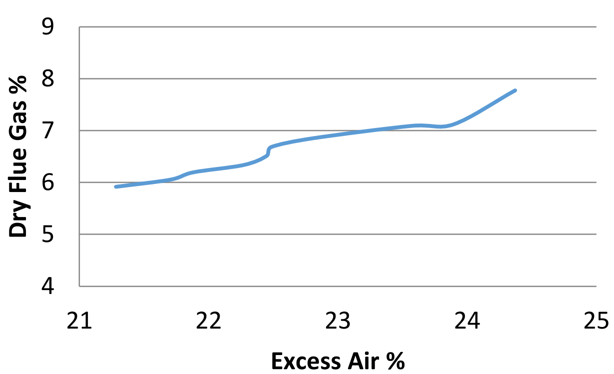


Fig 2.1.2. Excess Air VS Loss due to Moisture in air

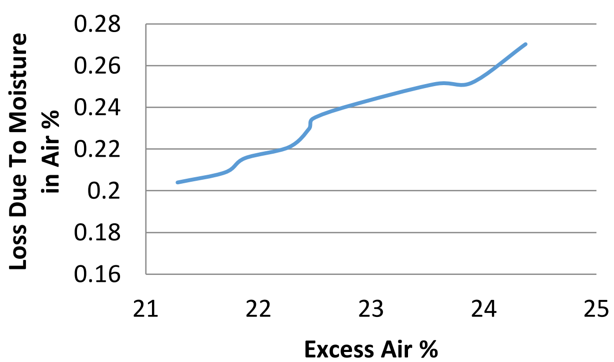


Fig 2.1.3. Excess Air VS Loss due to Partial Combustion CO to CO2

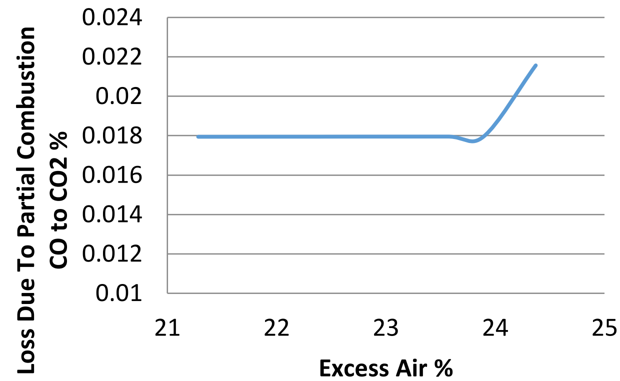


Fig 2.1.4. Excess Air VS Loss due to Unburnt in Fly Ash

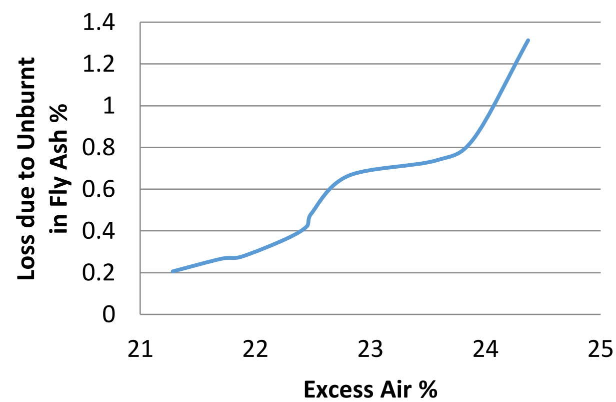


Fig 2.1.5. Excess Air VS Loss due to Unburnt in Bottom Ash

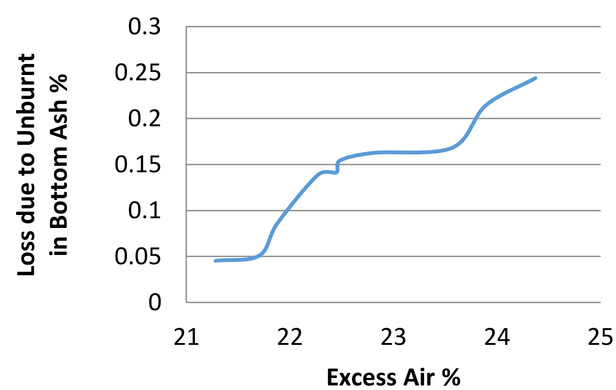


Fig 2.1.6. Excess Air VS Boiler Efficiency

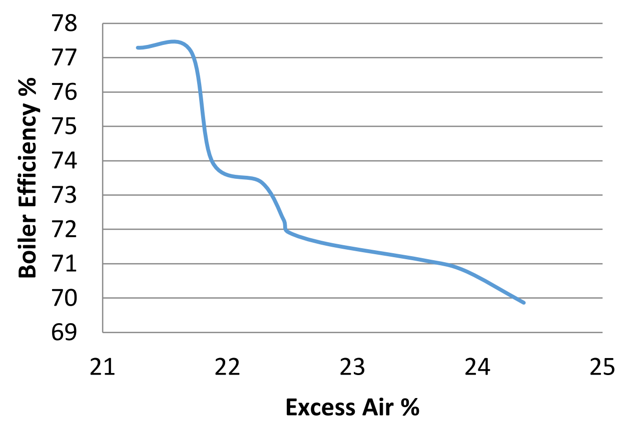


Fig 2.2.1. Excess Air VS Dry Flue Gas

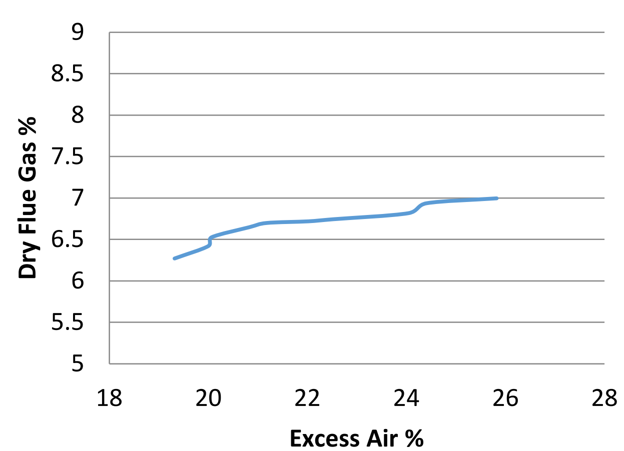


Fig 2.2.2 Excess Air VS Loss due to Moisture in air

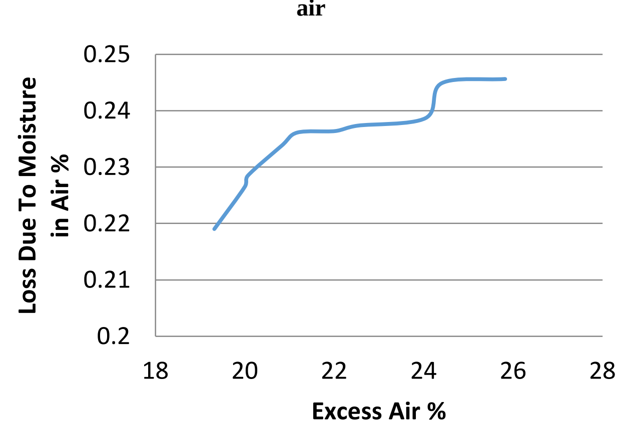


Fig 2.2.3 Excess Air VS Loss due to Partial Combustion CO to CO2

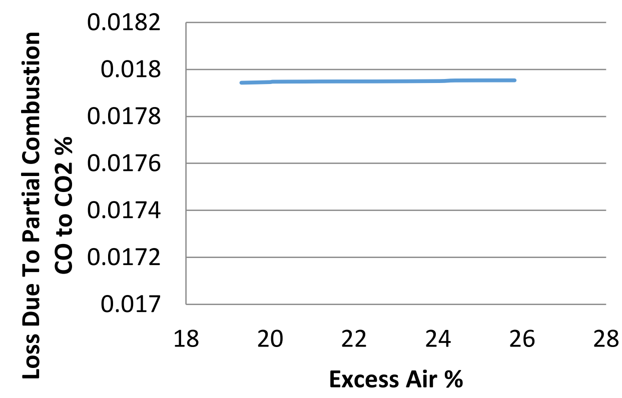


Fig 2.2.4 Excess air VS Loss due to Unburnt in Fly Ash

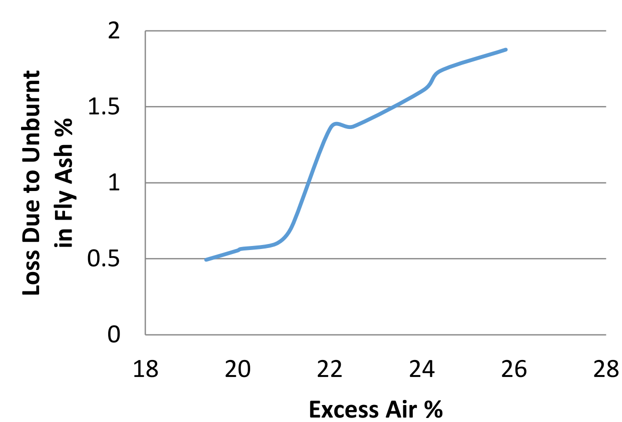
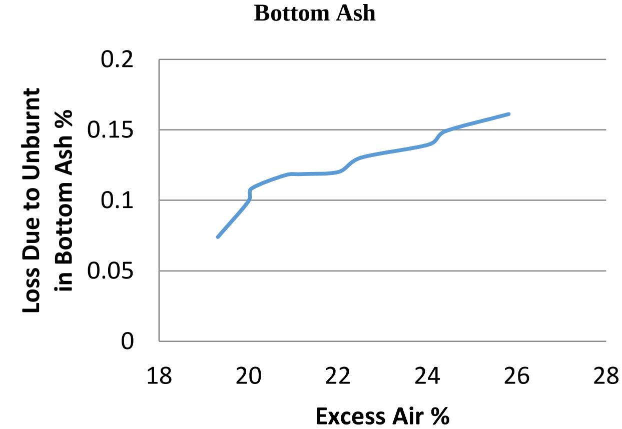


Fig 2.2.5 Excess air VS Loss due to Unburnt in Bottom Ash



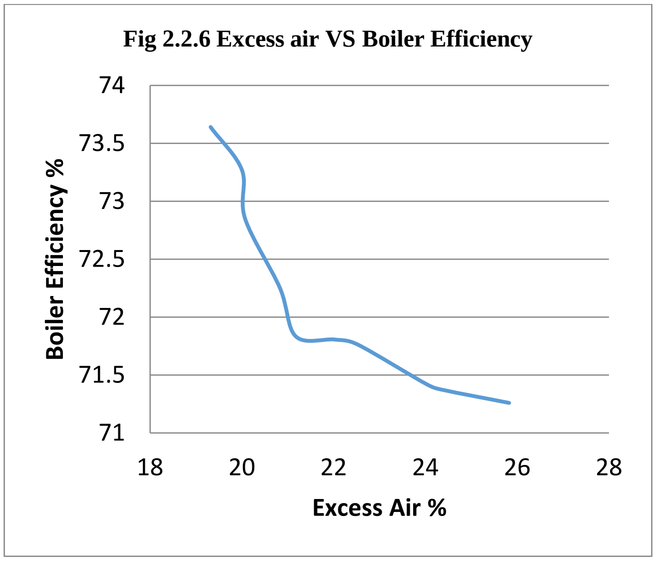


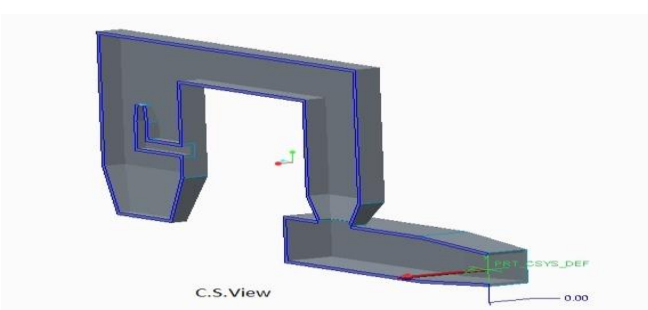
Fig 2.2.6 Excess air VS Boiler Efficiency

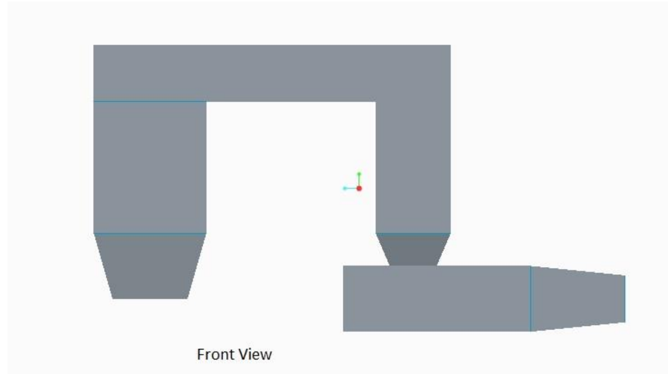
It is found from the above iterations is that the excess air varies directly with the losses in the boiler and inversely with the efficiency of the boiler. If excess air is increased or decreased correspondingly the efficiency decreases or increases and losses increases or decreases.

III. SIMULATION OF BOILER OPERATION WITH RESPECT TO NO_x

3.1. BOILER WITHOUT SELECTIVE CATALYTIC REDUCTION UNIT:

The boiler with pass systems and ducts with outlet ports are modeled using Uni-graphics software and the combustion characteristics were studied using FLUENT software. The coal properties from proximate and ultimate analysis of the coal were introduced into the software and solved. The following analysis showed the fact that excess air varies directly proportional to the temperature produced and NO_X emissions density. The modeling was done in the scale of 1:100 and primary air was given through the 16 nozzles (four in a group) located at the edges of the burner and the secondary air was inducted centrally through the inlet of secondary air-port and the value was varied for the excess air content variation of 0% to 30%. The temperature, NO_X density contours are shown below for different values of excess air percentage.





3.1.1 NO DENSITY CONTOUR:

Fig 3.1.1.a) 0% Excess Air

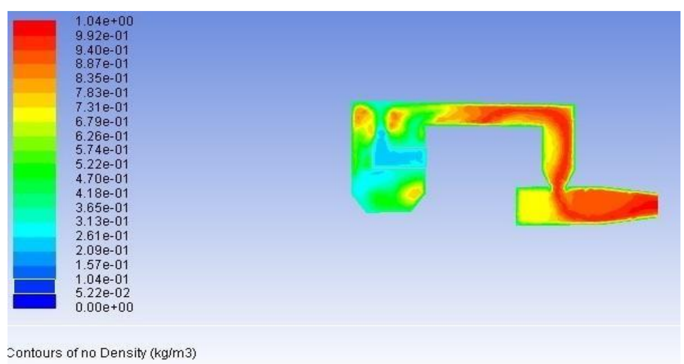


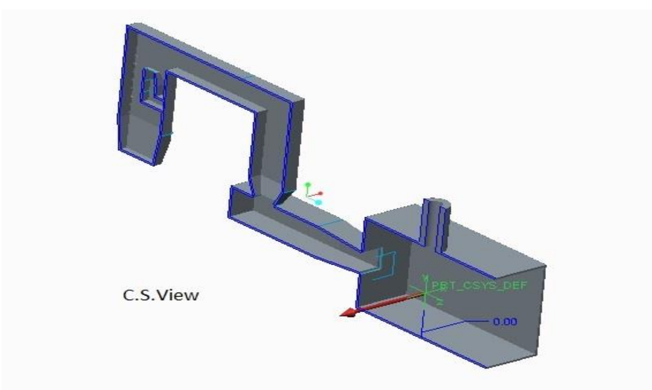
Fig 3.1.1 b) 10% Excess Air

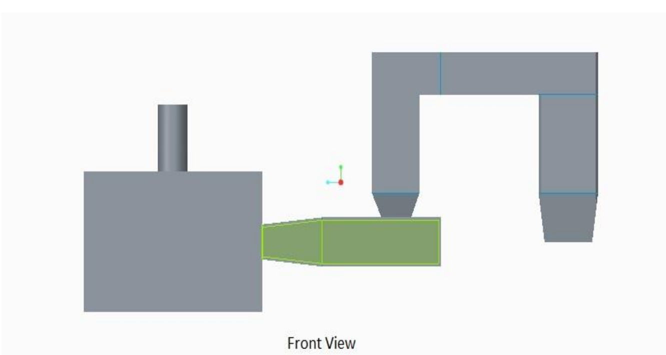
Fig 3.1.1 c) 20% Excess Air

Fig 3.1.1 d) 30% Excess Air

3.2 BOILER WITH SELECTIVE CATALYTIC REDUCTION UNIT:

The boiler system and its components in the prototype were made in the scale 1:100 with 16 nozzles (four in each group). The outlet duct of the boiler system is connected to SCR Unit with urea injector. The primary air and the secondary air was injected same as the boiler without SCR unit and urea injection was varied from 0.05gm/s to 0.15 gm/s according to the excess air variation from 0% to 30%. The NOX density contours is listed below also with the contours of N_2 and H2o formation which are the by- products of urea after reaction with the NO_x emissions. The entire analysis was made on FLUENT 15.0.





3.2.1 NO DENSITY CONTOURS:

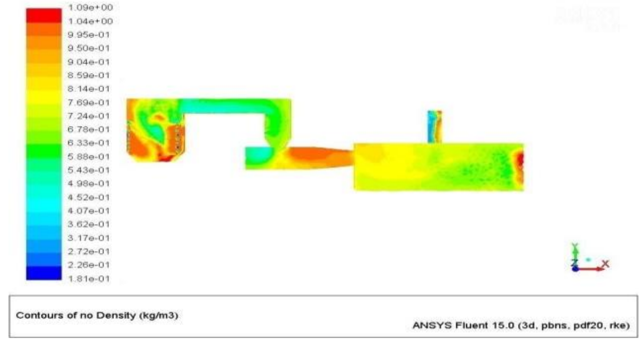


Fig 3.2.1 a) 0% Excess Air

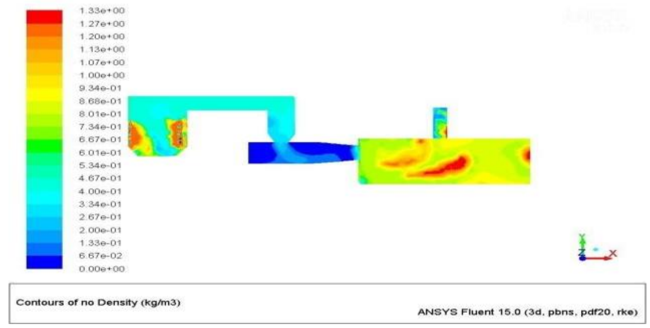


Fig 3.2.1 b) 10% Excess Air

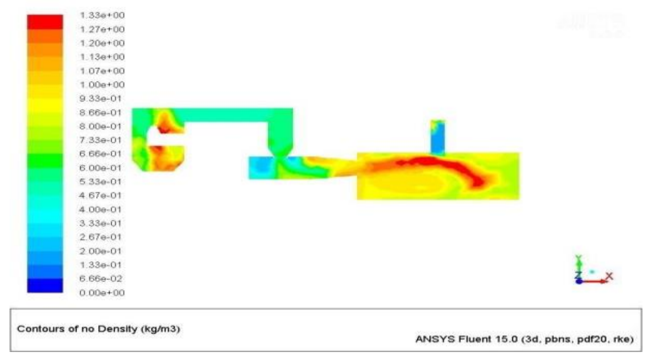


Fig 3.2.1 c) 20% Excess Air

Fig 3.2.1 d) 30% Excess Air

3.2.2 FORMATION OF N_2 AND H_2O:

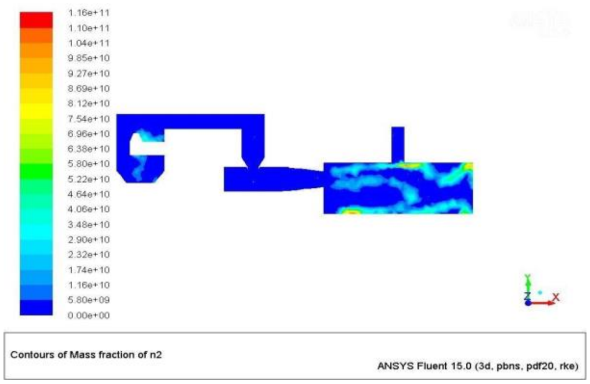


Fig 3.2.2 a) Formation of N_2

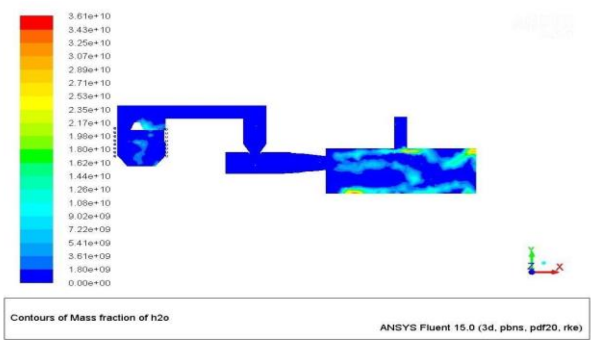


Fig 3.2.2 b) Formation of H_2O

IV. RESULTS AND DISCUSSIONS

Thus from the above analysis it is inferred that the urea injected at unit gets converted into nitrogen and water after reacting with NO_x emissions. The catalyst used was vanadium oxide. The efficiency of the unit is around 60% to 65% which is found using the difference in NO_x being let out at the output. The Tabulation given below indicates the effectiveness of SCR if it is implemented in the plant.

4.1 LIGNITE SAMPLE 1:

S.NO	EXCESS AIR	NOX AT SCR INLET (mg/Nm^3)	NOX AT SCR OUTLET (mg/Nm^3)
1	21.282	321.27	239.65
2	24.371	432.02	348.98
3	21.704	325.45	244.15
4	23.894	413.64	332.36
5	22.271	328.27	248.41
6	23.566	352.86	278.66
7	22.449	329.61	251.70
8	21.880	327.73	245.14
9	22.807	346.63	259.23
10	22.484	329.9	254.73

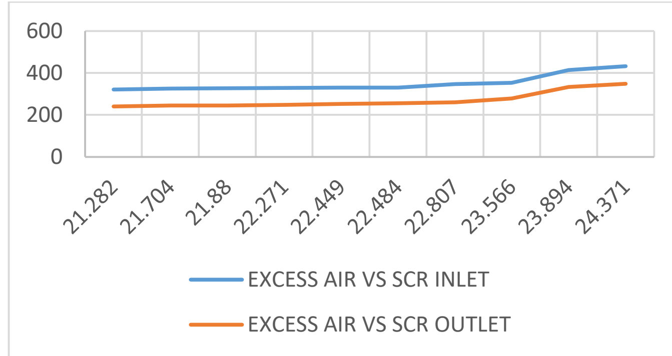


Fig 4.1 Excess air VS NO_x at SCR Inlet and Outlet

4.2 LIGNITE SAMPLE 2:

S.NO	EXCESS AIR	NOX AT SCR INLET (mg/Nm^3)	NOX AT SCR OUTLET (mg/Nm^3)
1	21.177	329.93	253.43
2	19.318	314.48	231.44
3	20.829	328.31	247.55
4	20.689	327.95	246.67
5	25.823	419.54	340.22
6	22.520	355.46	281.26
7	20.000	323.67	244.13
8	24.408	402.45	315.05
9	22.022	332.15	253.95
10	24.040	386.67	302.75

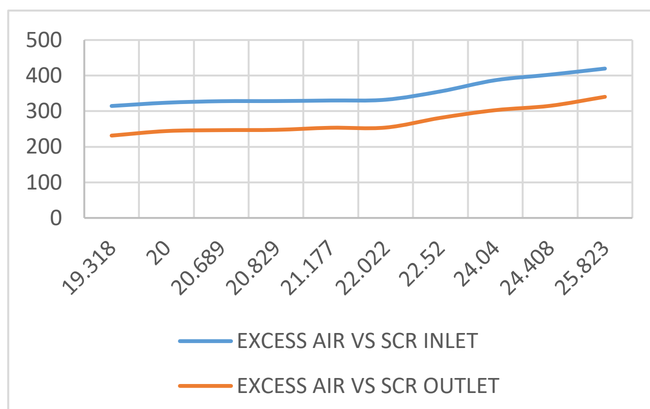


Fig 4.2 Excess Air VS NO_x at SCR Inlet and Outlet

V. CONCLUSION

The losses are directly proportional to variation in excess air and supplying less air leads to incomplete combustion which also ultimately leads to minimum efficiency. The steam production efficiency of boiler has been calculated for lignite used on different days (different GCV) and their value has been iterated over different values of excess air. The Table shows the variation of boiler's NO_x emission (steam production rate) with respect to excess air .From the graph it is evident that the NO_x emission can be reduced by decreasing the excess air percentage to 19%. The increase in the supply of excess air has resulted in increased NO_x emission from the boiler. To overcome this drawback, excess air shall be maintained at minimum level to reduce the NO_x level discharged to the atmosphere. Also Selective Catalytic Reduction unit is used at flue gas duct will further reduce the NO_x emission to the atmosphere. This reduces almost sixty percent of the NO_x emissions as per analysis. Also the use of calcium carbonate and other sorbents to de-toxicate the flue gas before exposing them to catalytic converter increases the life of catalyst and unit. This decreases the need for frequent replacement of catalyst and thus ultimately reduces the maintenance cost and adds economic value to the project.

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