NOx Emission Reduction in Flue Gas of Coal Fired Thermal Power Station and its Control Measures by Secondary Measures

T. P. Meikandaan, M. Hemapriya, V. Vidhya

Abstract*: *The ever increasing demand for power is mostly met out by electricity produced with the available resources. One such source where generation of power is by making use of the fossil fuel such as coal. Thermal generation using coal accounts for 69% of the total power produced in India. Flue Gases emitted from coal fired thermal stations consists of CO2,(Carbon-di-oxide),SOx (Oxides of Sulphur), NOx (Oxides of Nitrogen), PM (Particulate matter) along with carbonaceous material, soot and Fly ash. These gaseous pollutants are considered as environmental burden which ultimately results in smog formation, formation of acid rain, eutrophication and global warming which has to be controlled and regulated within the permissible limits as stipulated by MOEF &CC (Ministry of Environmental Forest and Climate Change). This project describes about the analysis of reduction of NOx Emission in Flue Gas of Coal fired thermal stations and the measures to control the NOx emission within the permissible limits for the new thermal power plants by treating the flue gas emitted from the stack. The secondary measure to reduce the NOx emission is achieved by treating the flue gas with urea or ammonia which bring about 90% NOx emission reduction. The application of Low Nox Burner with Over Fire Air Technology along with Selective Catalytic Reduction in the new thermal power plant reduce the emission of NOx to a considerable extent and to meet the norms.

Key words: Low NOx Burner, Over Fire Air, SCR,SNCR, NSCR.

I. INTRODUCTION

The increasing population together with industrial development warrants to meet out the power generation demand. The most probable solution is setting up large thermal power plants to meet the consistently growing electricity demand, since the land requirement is very less, easy to maintain, economical cost of generation and most of all consistent power generation.

The major portion of power generation worldwide is through coal. India's electricity sector is dominated by fossil fuels, and in particular coal, which during 2017-18 produced about three fourths of all electricity. The main advantage of setting up large thermal power plants, is such that it produces consistent power and unseasonal. India is majorly dependent on coal for its energy needs. We have vast resources of high-grade coal in several states. Coal is the main source of energy in India as it fulfils almost 67 per cent of the total commercial energy consumed in the country [1-7].

A. Classification of coal

Coal, the world's most plentiful fossil fuel often known as 'Black Gold'. is originated from organic matter wood. Due to decomposition of forests and due to heat from below and pressure coal takes centuries to complete. Based on the carbon content present in the coal, they are classified as follows:

Type of coal	Carbon Content	Calorific Value
Anthracite	**80-95%**	**Very high**
Bituminous	**60- 80%**	**High**
Lignite	**40-55%**	**Medium**
Peat	**>40%**	**Low**

The coal utilized for age in India is for the most part sub-bituminous coal, which has low Sulfur, low calorific esteem and high debris content and is broadly utilized for creating steam control and modern reason. All things considered, the Indian power plants utilizing India's coal supply devour about 0.7 kg of coal to create a kWh, moderately lower calorific worth, combined with high debris content and wasteful ignition advancements exasperates outflow of ozone depleting substances and different toxins from India's coal and lignite based warm power plants [8-12].

B. Composition of coal

The coal is analysed both qualitatively and quantitatively by Proximate and Ultimate Analysis. [13-18].

Proximate analysis of coal examines the chemical composition of a coal sample. Moisture, Volatile compounds, Ash content, Fixed carbon. Proximate analysis used to ascertain "Rank" of coals as the above parameters will indicate the Heating value of the coal.

Moisture in the fuel determines the amount of water present in fuel. 10

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Typical compositions and analysis of (mass percentages) of coal include :

Proximate Analysis

Inorganic mineral matter (ash) - > 50%. Moisture levels - 2 to 20%,

Volatile matter and fixed carbon.

Ultimate Analysis

Carbon - 65-95% ,

Hydrogen - 2-7%

Oxygen - up to 25% oxygen

Sulphur - 10% and

Nitrogen - 1-2%%.

II. FORMATION OF NOx

Nitrogen and oxygen are available in a lot of sum in the ignition space and during burning high temperature is delivered to encourage the oxidation of nitrogen and consequently NOx is created.

Overwhelming impact in the development of NOx are temperature and oxygen fixation, the higher the temperature and higher the home time at high temperature in the chamber, the more noteworthy is the measure of NOX produce.

The development of NO is impacted by the grouping of oxygen (which relies upon the overabundance air) in the framework, the fire temperature, the ignition conditions and nitrogen content in coal. Burning of coal changes over the nitrogen bound in coal to frame items, for example, nitric oxide (NO), nitrogen dioxide (NO2) and nitrous oxide (N2O). These items are on the whole called oxides of nitrogen (NOx)— a significant contamination. By and large, 90–95 % of NOx discharged from coal control plants is as NO. In all burning there are three open doors for NOx arrangement. They are:

1. Fuel NOx - Fuel NOx is formed by the reaction of nitrogen in the fuel with oxygen in the combustion air. Fuel NOx contributes about 70– 80 per cent of the total NOx formed when coal combustion occurs in boiler at typical temperature ranges.

$$O + N2 = NO + N$$

2. Thermal NOx - Warm NOx is shaped when nitrogen and oxygen in the burning air consolidate with each other at the high temperatures in a fire. Warm NOx makes up most of NOx framed during the burning of gases and light oils and record for around 5–25 percent of the NOx shaped during coal ignition.

3. Prompt NOx - Brief NOx is shaped from atomic nitrogen noticeable all around consolidating with fuel in fuel-rich conditions which exist, somewhat, in all ignition. Brief NOx represents under 5 percent of the complete NOx emanations [19-22].

III. IMPACT OF NOx ON ENVIRONMENT

NOx contributes to Acid Rain leading to damage to vegetation and Aquatic Life.

- NOx is affecting Ozone (O3) balance, is a precursor for photochemical smog contributors (Ozone, PAN, HNO3) in troposphere which causes damage of the human respiratory system (lungs).
- NOx can contribute to eutrophication and influences ecosystem by nutrient overload.

IV. EFFECTS OF COMBUSTION OF COAL IN THERMAL POWER PLANTS

Setting up the coal before sustaining into the kettle is a significant advance for good ignition. Further to the abovementioned, size of coal has a significant influence to guarantee productive ignition. Appropriate coal estimating, with explicit significance to the sort of terminating framework, helps towards consuming, decreased debris misfortunes and better ignition proficiency.

The vent gas comprises of different air toxins discharged from warm power plants which depend to a great extent upon the attributes of the fuel copied, temperature of the heater, real air utilized, and any extra gadgets to control the outflows. Some new plants utilize low NOx burners for high temperature (> 1500 K) ignition advances if smokestack tallness is less than 275 meters.

As per the new environmental regulations dated 7.12.2005, the MOEF & CC has stipulated that the NOx emission has to be within 300 mg/Cubic Nm for

the thermal power plants commissioned between 2004 and 2016 and 100 mg/Nm3 for the thermal power plants commissioned after 2017.

V. IMPACT OF NOx ON ENVIRONMENT

A. INDIAN STANDARD METHOD FOR MEASUREMENT OF NOX FROM STATIONARY SOURCES

There are two types for Monitoring and measurement of the gaseous pollutants emitted from the power plants namely, Continuous Emission Monitoring System(CEMS) Predictive mission Monitoring System (PEMS)

Out of the above, CEMS-Records emissions continuously over an extended and uninterrupted period of time as cited vide reference (1).The CEMS data provides the most accurate emission. The system employed for monitoring is Non Extractive In-Situ System and stack sampler is used for measurement of NOx. Vide ref (7) the Colorimetrically using phenoldisulphonic acid (PDA) method employed is based on the Indian Standards : IS 11255 (Part 7) : 2005 Methods for measurement of Emission of xides of Nitrogen from Stationary sources [23-25].

B. PRINCIPLE OF COLLECTION OF SAMPLE

The guideline is to gather a snatch test in a weaken Sulphuric corrosive hydrogen peroxide engrossing arrangement and the nitrogen oxides, aside from nitrous oxides are estimated colorimetrically utilizing the phenoldisulphonic corrosive.

The apparatus employed for collection of a grab of sample is done through a probe and analysed in the lab as shown below

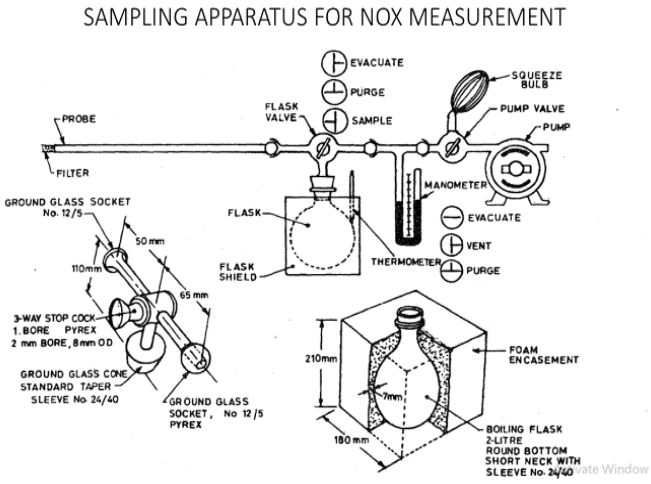

Fig 1. Sampling Train

C. DATA COLLECTED

Samples were collected at the stack at two different pass and the NOx emitted in the flue gas is measured. The initial readings taken at the stack are as detailed below:

Table I : Initial readings of Nox emitted at stack

PASS	Sample No.	Stack Temp. (°C)	Velocity (m/s)	Actual Values	
				NO2 (mg/Nm3)	Oxygen as O2 (%)
PASS A	Sample I	129	11.9	724	8.92
	Sample II	130	12.5	912	9.21
PASS B	Sample III	127	13.2	895	10.70
	Sample IV	131	13.7	785	10.32

D. OXYGEN CORRECTIONS

The results of NO2 has been compared with MoEF&CC Emission Norms (2015) for Thermal Power Plants. It is observed that value of NO2 is exceeding the norms, where the stack temperature is in the range of 127 to 131 °C and the oxygen measured is in the range between 8.92 to 10.70 % as can be seen from the data collected.

The excess air may be considered reason for dilution of flue gas and reducing the stack temperature < 135 ° C. This low stack temperature causes condensation in exhaust duct line and stack. This may result into acid corrosion in flue gas path. There may be leakage from Air Pre Heater (APH) tubes, Electrostatic precipitator (ESP) – hopper bottom flange and multiple inspection window and fan inlet flange connection. Hence the exact value of NOx emitted could be obtained only after applying Oxygen Correction.

Oxygen corrections are applied at 6% Oxygen to the flue gas emissions for Nitrogen Di Oxide (NO2) from the measured O2% by using CPCB Guidelines on Methodologies for Source Emission Monitoring, LATS/80/2013-2014. An amendment was issued vide GOI, MoEF & CC Extraordinary Gazette dt. 29.06.2018. for O2 correction. The data of NO2 at measured O2 and calculated at 6% O2.

Concentration values in mg/Nm3 =

Actual Concentration in mg/Nm3 x [(21-Os)/(21-Om)]

(Corrected Values with 6% O2)

E. READINGS AFTER OXYGEN CORRECTIONS

After applying Oxygen correction the values are tabulated as below:

Table II : Calculated Readings after oxygen correction

PASS	Sample No.	Stack Temp. (°C)	Velocity (m/s)	Corrected Values with 6% O2
				NO2 (mg/Nm3)
PASS A	Sample I	129	11.9	899
	Sample II	130	12.5	1160
PASS B	Sample III	127	13.2	1303
	Sample IV	131	13.7	1103

Analysis of nox emitted

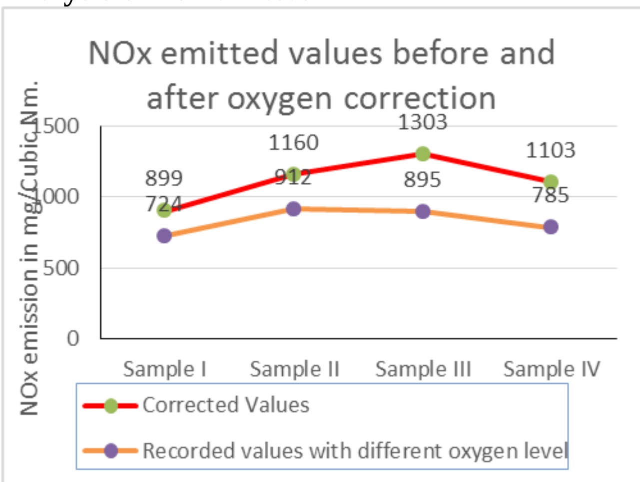

Fig. 2. Analysis of NOx Emitted

VI. TECHNOLOGY TO CONTROL EMISSION OF NOX

Various control technology are being employed to regulate the emission of NOx emitted in the flue gas. Primary techniques are applied to reduce emissions at source. The innovation of denitrification during ignition ordinarily embraces the low NOX innovation as the universal path for it's well-created innovation and the ease. By and by, the NOX expulsion effectiveness is for the most part beneath 40%. The innovation, which uses the NOx burners as its initial step to diminish the half substance of NOx in the vent, at that point utilizes the denitrification after ignition as the subsequent advance to finish the denitrification, is broadly utilized in nations that are exacting with the NOx emanation. For this it makes use of various techniques such as

- Low NOx Burner (LNB)
- Over Fire Air (OFA)
- Burners Out Of Service (BOOS)
- Flue gas recirculation (FGR)
- Staged Combustion
- Fuel Reburning

Secondary Techniques treat pollutants after they are released into flue gases.

VII. SELECTION OF OPTIMUM MEASURES

Various control measures are analysed and the optimum control measure is selected for implementing the same to achieve the NOx emission reduction within the permissible norms.

The plants that have to meet the NOx emission limit of 100 mg/Nm3 will be required to go for post combustion NOx control. However, even these plants should first consider adopting primary NOx control technologies as they can significantly reduce the operating costs associated with post combustion control technologies.

Managing the catalyst in SCR system is a serious concern that merits stringent storage and disposal regulations and close oversight by the PCBs. Majority of coal in India is of poor quality and thermal power industry has raised concerns about the suitability of SCR for NOx control in Indian context. Independent experts believe that SCR technology will work for Indian coal, however, the erosive ash components such as silica and alumina will have an impact on the SCR and its catalyst causing a faster deactivation of the catalyst [26, 27].

VIII. RESULTS

For the thermal power plants commissioned after 2017 the latest technology for reduction in NOx emission well below 100 mg/Nm^{3}, is to make use of Low Nox Burners along with Over Fire Air Port which reduces NOx during combustion. Further to this NOx reduction upto 95% is achieved by making use of post combustion treatment ie. By using Selective Catalytic Reduction that reduces the NOx to Nitrogen and Water. Power stations across the country have now begun the process of implementing the secondary control measure by using Selective Catalytic Reduction. This method is considered to be cost effective and reduction is achieved upto the maximum level [28].

A. LOW NOX BURNER (LNB) AND OVERFIRE AIR PORT

A. Kettle burners are the focal component of successful ignition framework structure which incorporates fuel readiness, air fuel dissemination, heater plan and ignition control. A burner supplies required measure of fuel and air and makes a state of quick blending and produce fire. The blending of air and fuel legitimately influences the fire security, shape and discharge.

B. LOW NOX BURNER

The technique involved in the Low Nox Burner is that it comprises of two stages namely Split up of flame and Air staging

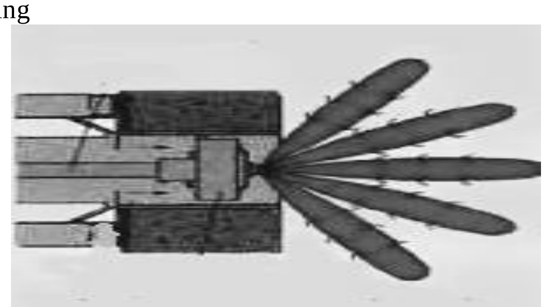

Fig 3 Split up of flame in LNB

Air stagging (AS). The combustion air staging is realized by a nozzle set, by injecting the secondary air directly into each portion of flame.

The LNB can reduce the emission of NOx upto 60% maximum. This can be one of the least expensive pollution prevention technologies.

C. OVER FIRE AIR (OFA)

Divert typically diverts 20-30% of the combustion air from the burners to the upper furnace to stage the combustion process beyond what can be achieved with low-NOx burners i.e a portion of the combustion air away from the primary combustion zone minimizing the formation of fuel NOx.

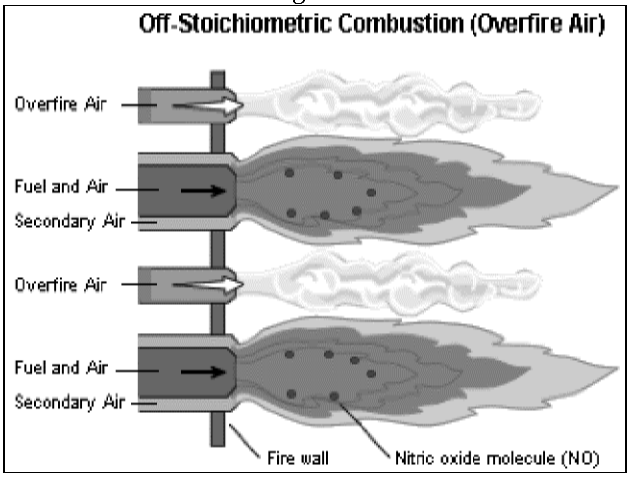

Fig. 4 Over Fire Air

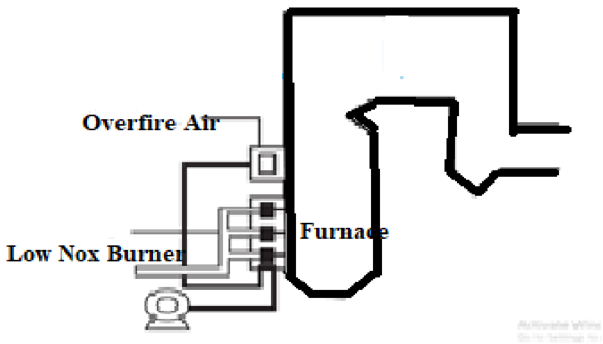

Fig.5. Line Diagram of position of low NOx Burner and OFA

D. SECONDARY CONTROL MEASURE

The most common secondary measures are –

- SCR (Selective catalytic reduction) :-
- SNCR(Selective non catalytic reduction) :-
- NSCR - Non-selective Catalytic Reduction

A. SELECTIVE CATALYTIC REDUCTION (SCR)

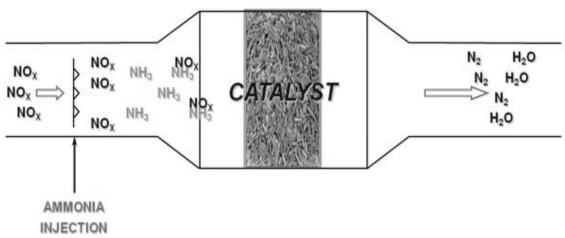

Fig 5. NOx Abatement

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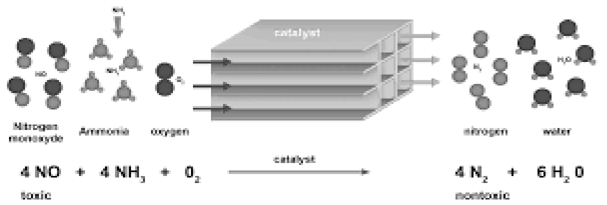


Fig 6. SCR REDUCTION PROCESS

E. TECHNOLOGY BEHIND SCR

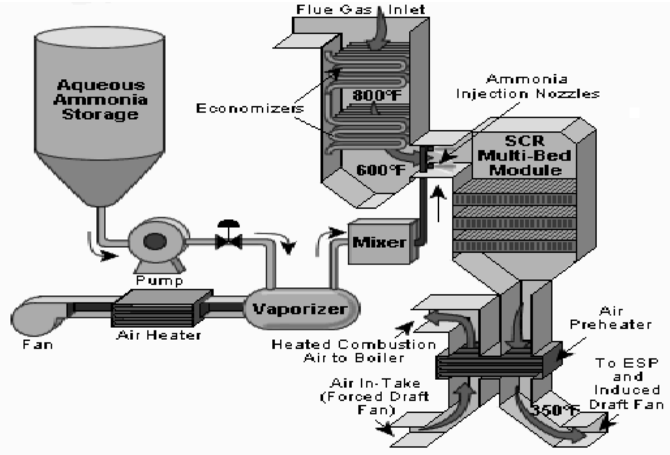


Fig 7. NOx Removal in SCR

The catalyst system can be of honeycomb, metal plate or corrugated design.

Ammonia is used as part of neutralizing NO, according to the following chemistry:

$4NO+4NH_3+O_2 \rightarrow 4N_2+6H_2O$

$6NO+4NH_3 \rightarrow 5N_2+6H_2O$

The proper design of the ammonia injection system is critical for complete mixing in the flue gas steam.

F. TYPICAL DIAGRAM OF POWER PLANT USING SCR FOR NOX REMOVAL

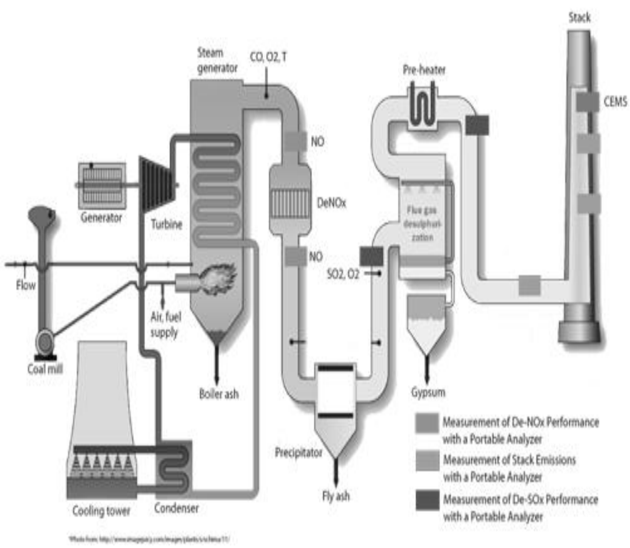


Fig 8. Diagram of Thermal Power plant fitted with SCR

G. ADVANTAGES and DISADVANTAGES OF SCR OVER SNCR

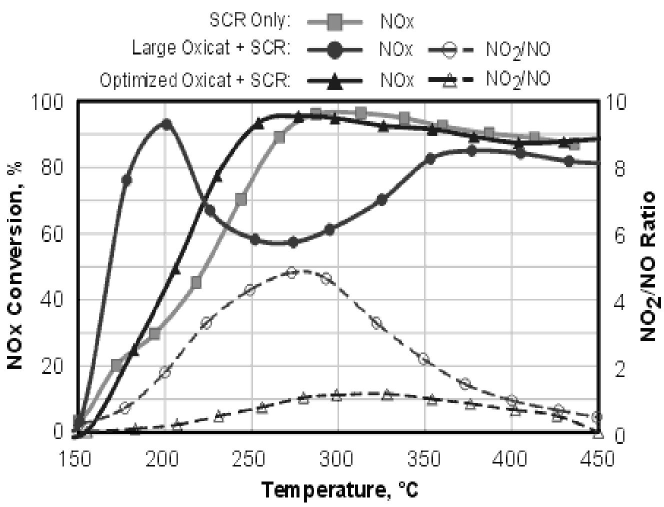
The advantages of SCR are

- Very high NO_x removal (as much as 97%) with less ammonia slip (<10 ppm).
- Operates at a comparatively lower temperature between 150 – 600 deg [29, 30].

Disadvantages include

- High Capital and Investment cost
- Safety concerns with storage and handling of ammonia,
- Higher flue gas pressure drop, especially if the catalyst bed gradually gets plugged.
- Major Plot area required
- Disposal of Spent Catalyst
- Very short life of the catalyst which means maintenance within short period

From the various study it is seen that even though the initial cost and operating cost are very high for thermal plant fitted with Selective Catalytic Reduction, the NOx reduction efficiency is proved to be around 95% at a lower temperature which is as shown below:



Apart from the above, the particulate matter is also removed to some extent.

H. LIMITATIONS OF SCR

- SCR technology has a high initial cost.
- Catalysts used in SCR have a finite life in flue gas and some ammonia "slips through" without being reacted.
- SCR systems are sensitive to contamination and plugging during normal, and abnormal, operations.
- Certain pollutants in flue gas can render the system ineffective at NOx reduction, or cause oxidation of ammonia present (forming more NOx).
- SCR systems have operational difficulty with binding of the catalyst by fly ash. Because of these issues, SCR catalysts have a limited operational lifetime of 16 to 40 thousand hours in coal-fired power plants, depending on the flue gas composition.

• Though SCR systems have been documented as more effective in NOx removal, SNCR systems are often favored due to their lower cost since they do not use a catalyst.

IX. CONCLUSION

The results showed reduction of various exhaust gas not only NOX. If using catalytic converter the most harmful gases should be minimized. Pollution should be controlled.

Almost all the new thermal power plants commissioned after 2017 are to be fitted with Low NOx Burner along with Over Fire Air Port to reduce combustion in the source and to achieve the maximum NOx Reduction emission the effective secondary measure such as Selective Catalytic Reduction has to be installed since the reduction in NOx emission has been fixed as 100 mg/Cubic Nm, wherein the reduction efficiency works out to 95%.

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