NEW ENVIRONMENT NORMS ON NO_X FOR THERMAL POWER GENERATION

MOEF Notification

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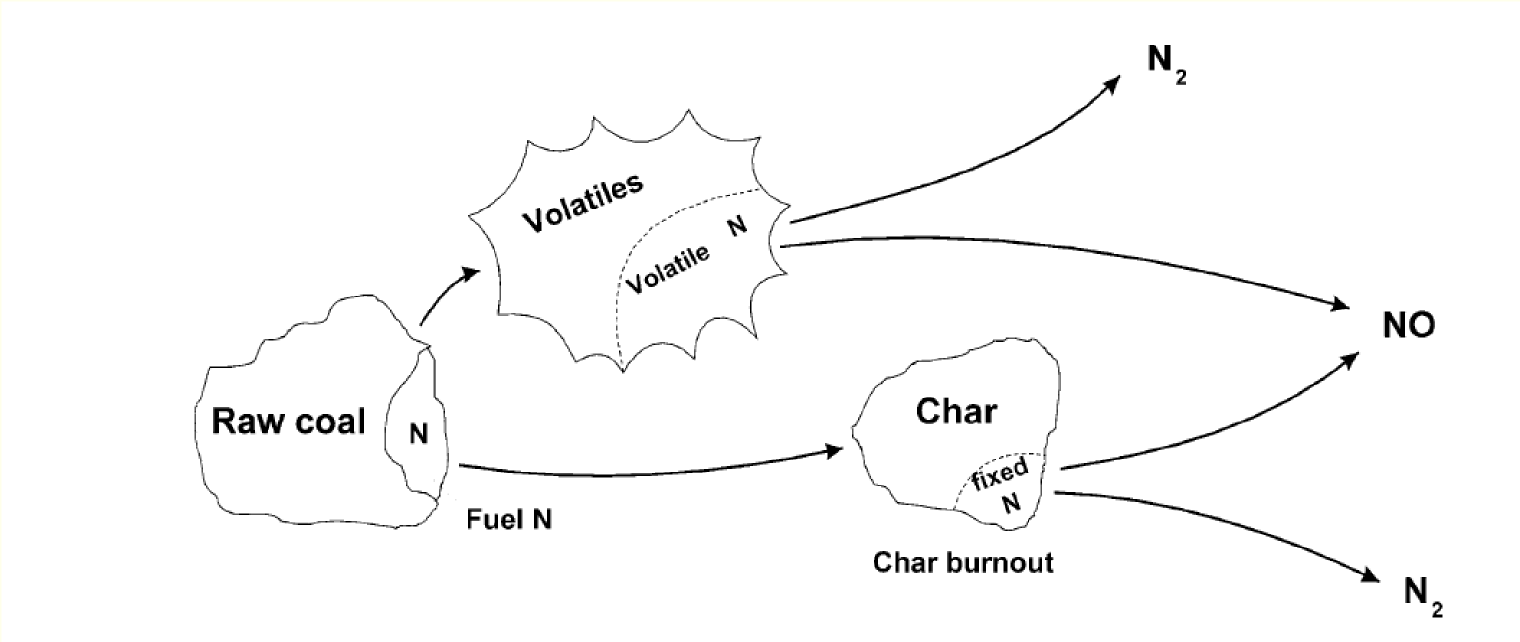
Pollutants	TPPs (units) installed before 31st December, 2003*	TPPs (units) installed after 1st January,2004, up to 31st December, 2016*	TPPs (units) to be installed from 1st January, 2017**
Particulate Matter (PM)	100 mg/Nm3	50 mg/Nm3	30 mg/Nm3
Sulphur Dioxide (SO2)	600 mg/Nm3 (Units Smaller than 500MW) 200 mg/Nm3 (for units having capacity of 500MW and above)	600 mg/Nm3 (Units Smaller than 500MW) 200 mg/Nm3 (for units having capacity of 500MW and above)	100 mg/Nm3
Oxides of Nitrogen (NOx)	600 mg/Nm3	300 mg/Nm3	100 mg/Nm3
Mercury (Hg)	0.03 mg/Nm3(for units having capacity of 500MW)	0.03 mg/Nm3	0.03 mg/Nm3

NOx Fundamentals

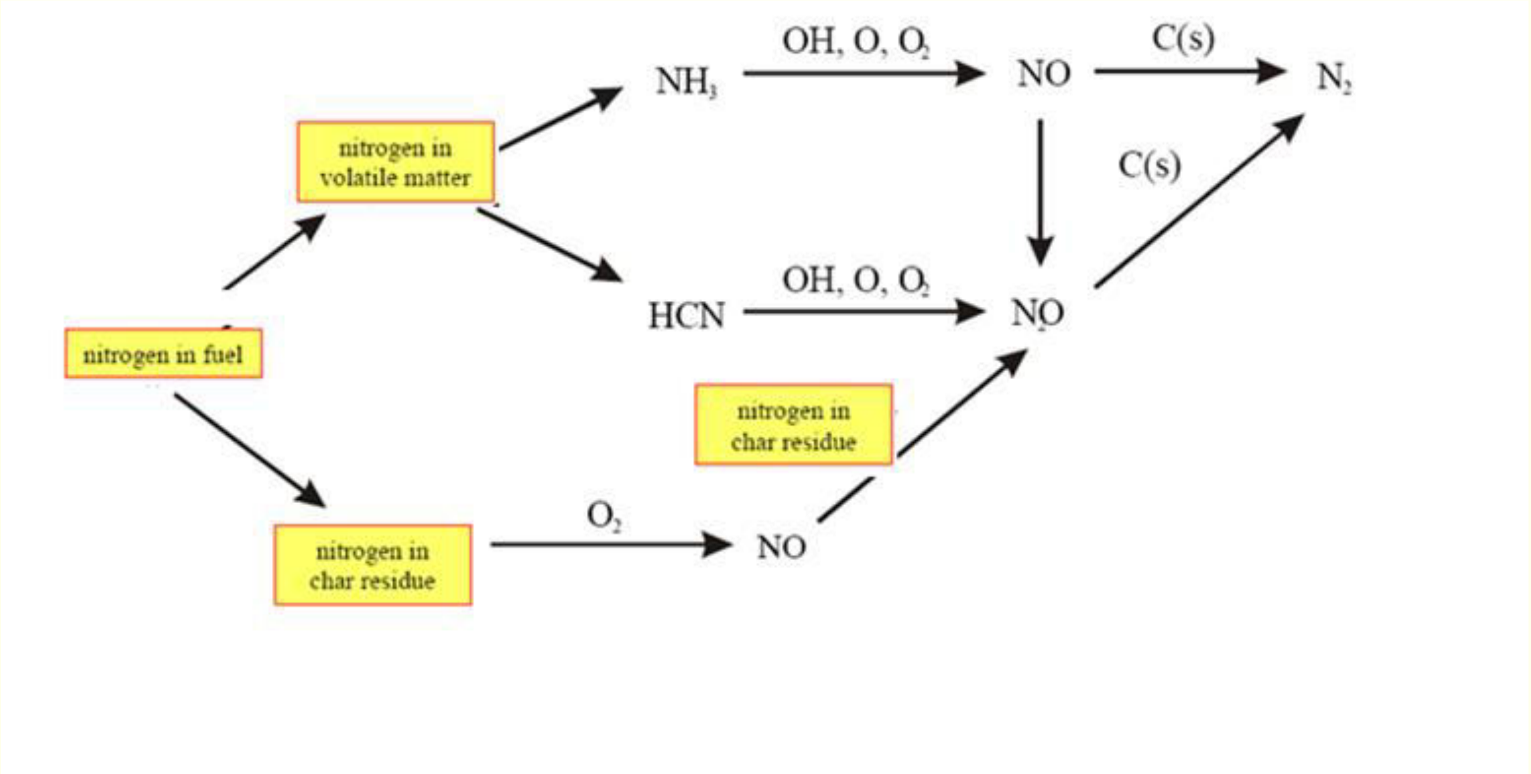
NOx Fundamentals– Forms of NOx

Formula	Name	Nitrogen Valence	Properties
N_2O	nitrous oxide	1	colorless gas water soluble
NO N_2O_2	nitric oxide dinitrogen dioxide	2	colorless gas slightly water soluble
N_2O_3	dinitrogen trioxide	3	black solid water soluble, decomposes in water
NO_2 N_2O_4	nitrogen dioxide dinitrogen tetroxide	4	red-brown gas very water soluble, decomposes in water
N_2O_5	dinitrogen pentoxide	5	white solid very water soluble, decomposes in water

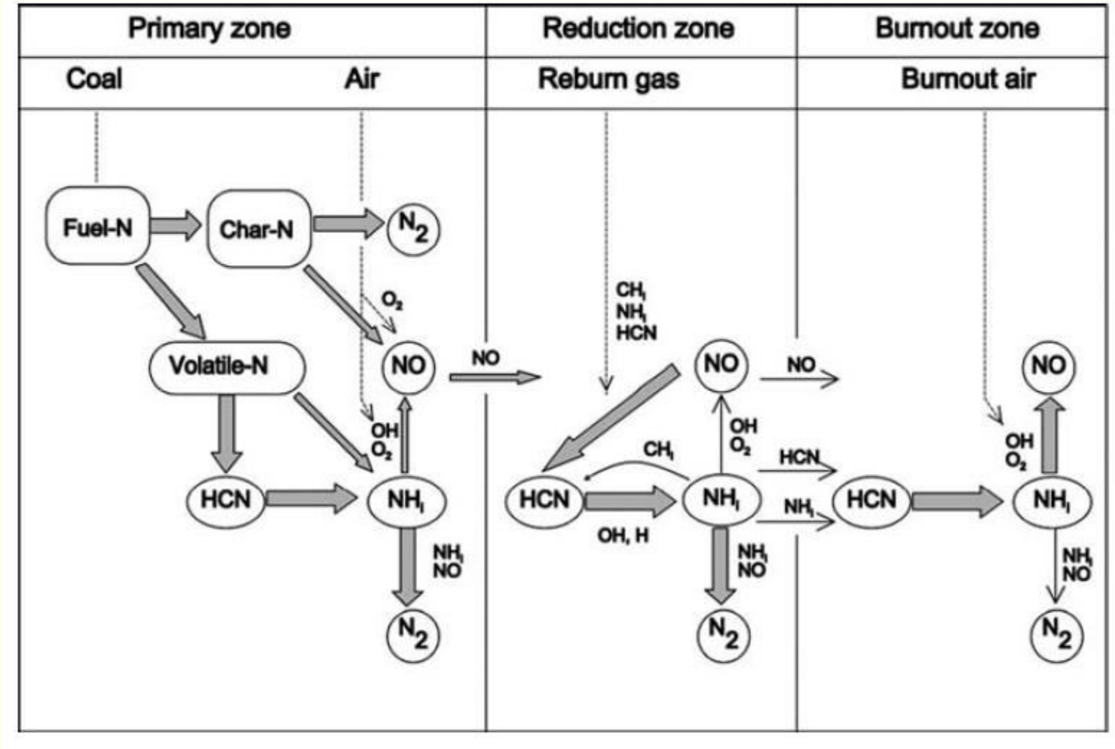
DISTRIBUTION OF FUEL NITROGEN DURING PYROLYSIS



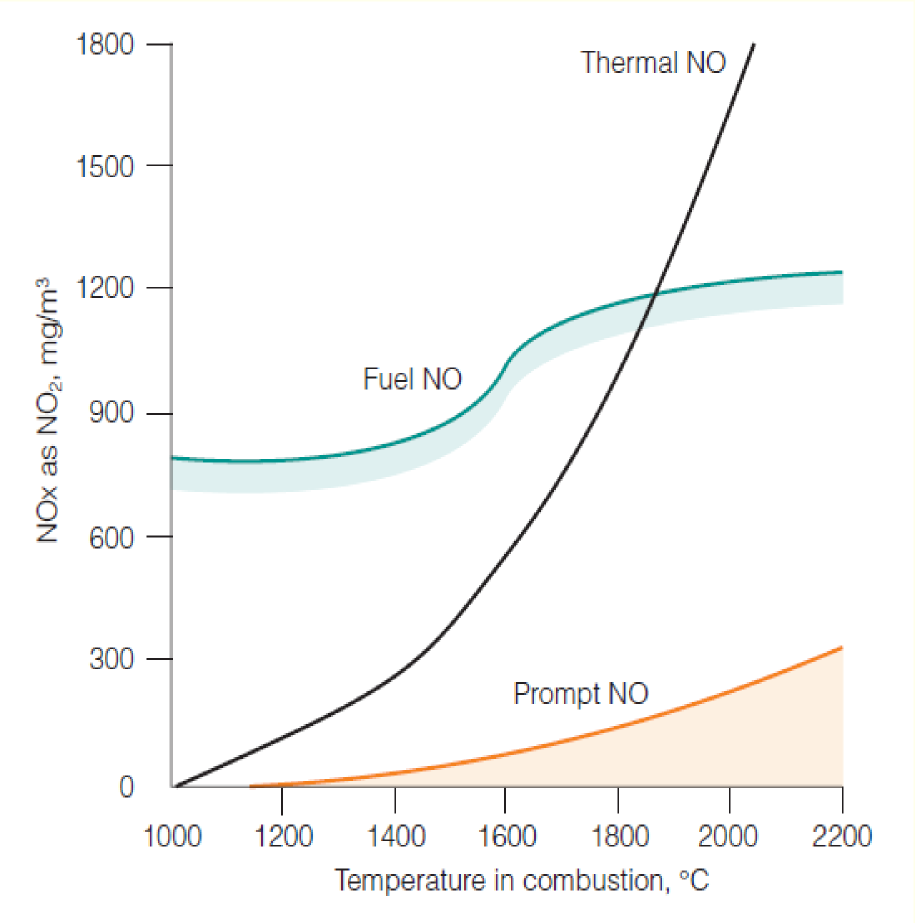
FUEL NITRIC OXIDE FORMATION DURING COAL COMBUSTION



Reactions of nitrogen formation and reduction in fuel staging with pulverised fuel as the primary fuel and gas as the reburn fuel



NOX FORMATION IN BOILERS



Factors influencing NO_x emissions in PC combustion (van der Kooij and others, 1997)	
Boiler design	boiler type (wall-fired, tangential) capacity burner type (convential, low NO_x burners) number and capacity of the burners burner zone (specific) heat release residence times presence of overfire air ports
Boiler operation	load mills in operation excess air level burner tilt burner operation (swirl number, primary to secondary air ratio)
Coal properties	volatiles release fuel ratio (fixed combustibles/volatile matter) calorific value carbon/hydrogen ratio (rank) nitrogen content

MAJOR NOx REDUCTION TECHNIQUES

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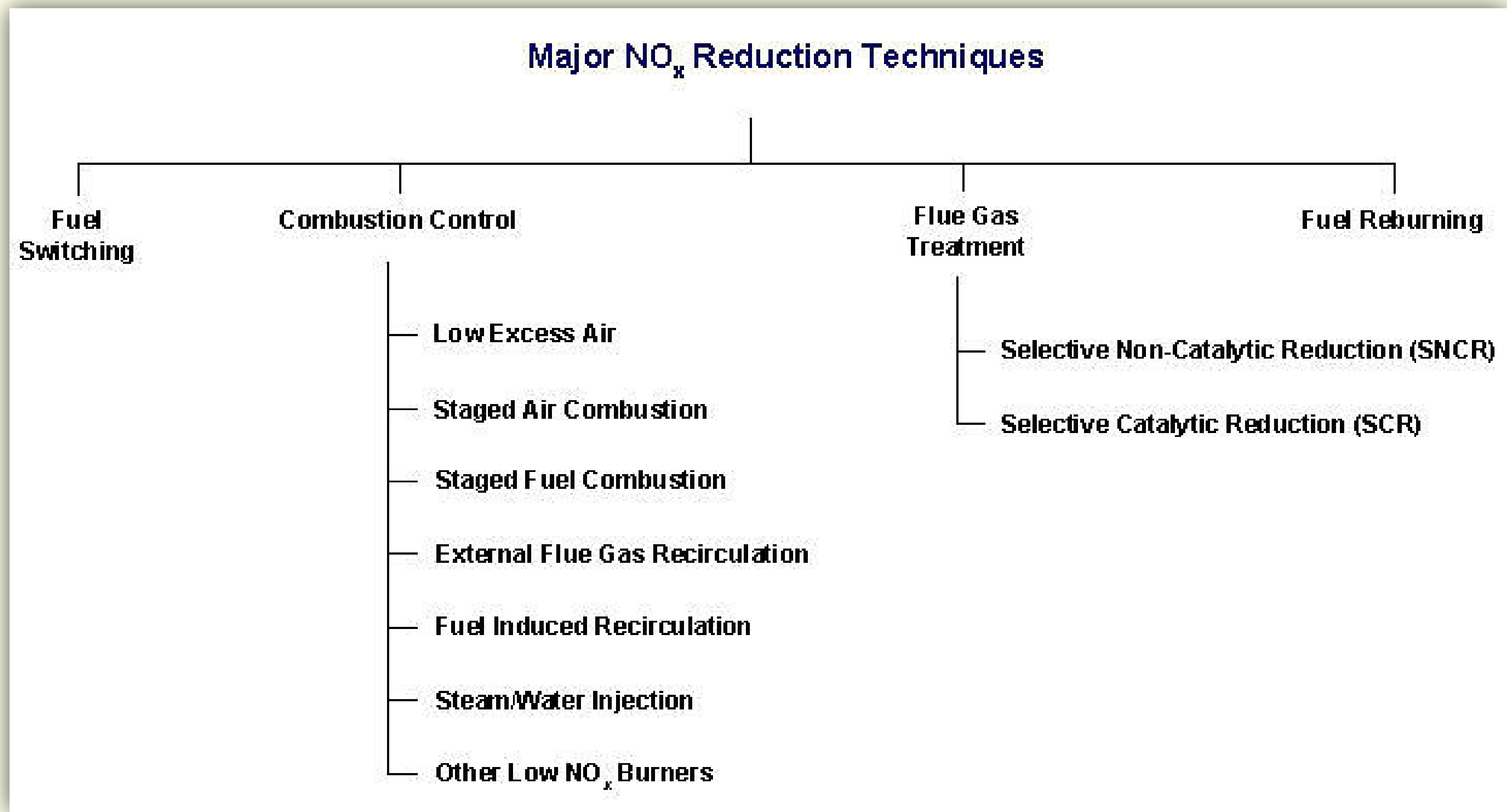
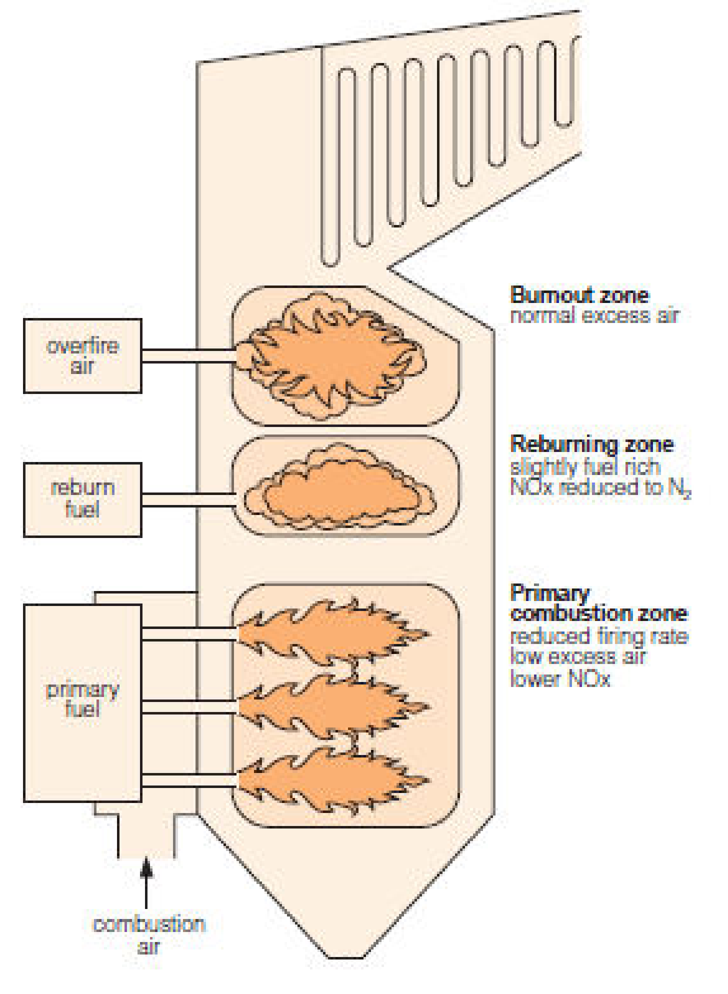


FURNACE FUEL-STAGING (REBURN)

FURNACE FUEL-STAGING (REBURN)

- Reburn is a comparatively new technology, which combines the principles of air and fuel staging.
- It can be applied to combustion systems fired with any fuel including coal, oil, gas, orimulsion, and others.
- As the process does not require modifications to the existing main combustion system, it can also be applied to all boiler types (wall, tangential, or cyclone-fired)
- In the reburn system, fuel and combustion air are supplied in stages in the furnace. This creates three distinct combustion zones which operate under fuel-lean, fuel-rich and fuel-lean conditions respectively.



COMBUSTION CONTROL

FLUE GAS RECIRCULATION

- In conventional applications, 20–30% of the flue gas is typically extracted from the boiler outlet duct upstream of the air heater (usually at 300–400°C). The flue gas is then returned through a separate duct and a hot gas fan to the combustion air duct that feeds the windbox.

- This decreases the peak flame temperature and oxygen concentration and thus helps to reduce the formation of thermal NOx. However, this process does not influence the formation of fuel NOx to any significant extent.

- The technology has been one of the most effective methods of reducing NOx emissions from gas and oil fired boilers since the early 1970s. It can achieve up to 60% NOx reduction in industrial boilers.

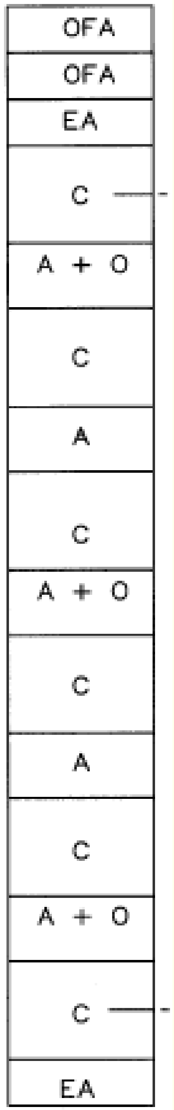
- In coal-fired units, the NOx reduction achieved is less than 20%, due to a relatively low contribution of thermal NOx to total NOx formation.

- FGR can be used in combination with low-NOx burners, overfire air or air/fuel ratio control, achieving substantial overall NOx reductions

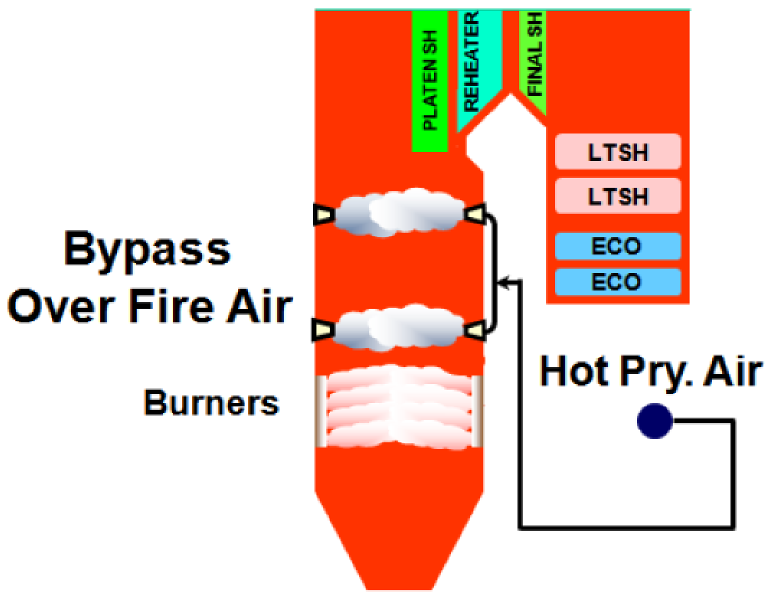
- A major consideration for FGR is the impact on the boiler thermal performance. The reduced flame temperature lowers the heat transfer, potentially limiting the maximum heating capacity of the unit.

FURNACE AIR-STAGING

- Furnace air-staging (overfire air) is a well proven commercially available technology for NOx reduction at coal-fired power plants.
- The process is equally applicable to both wall-fired and tangentially-fired boilers.
- Furnace air-staging involves staging the supply of combustion air, with 70–90% being supplied to the burners (primary air) and the rest to the furnace at a level above the burners (overfire air).
- The primary air is mixed with the fuel, producing a relatively low-temperature, oxygen-deficient, fuel-rich zone near the burner. This helps to reduce the formation of fuel-NOx.
- The overfire air is injected above the primary combustion zone, through a special windbox with overfire air ports and/or nozzles mounted above the top level of burners, to achieve complete combustion.
- A relatively low-temperature secondary combustion zone limits the formation of thermal-NOx.

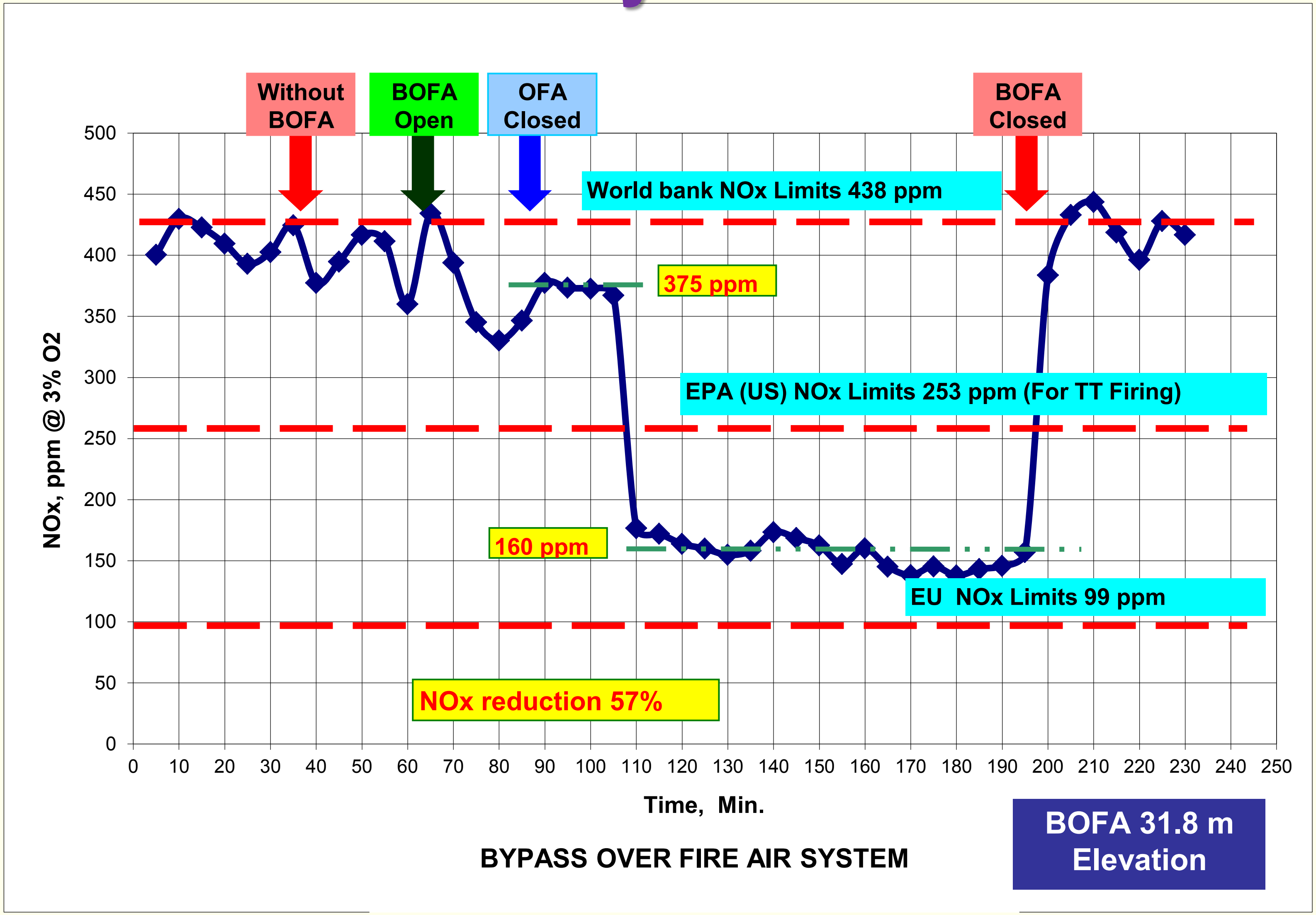


BOFA System



Furnace Air Staging- Vertical
Bypass Over Fire Air (BOFA) System

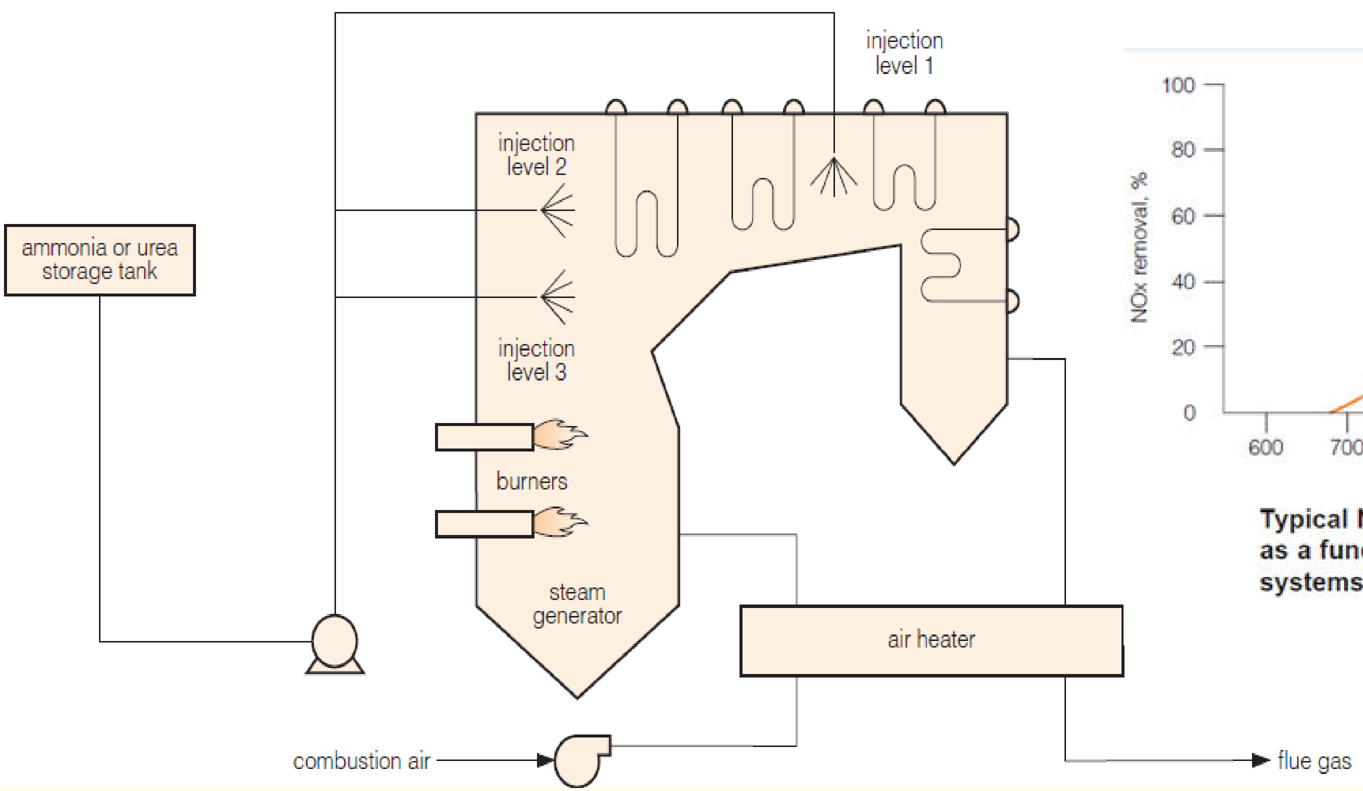
BOFA System

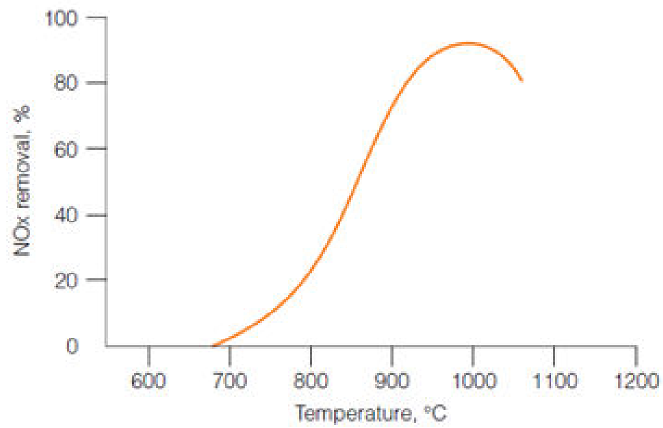


Without BOFA
BOFA Open
OFA Closed
BOFA Closed
World bank NOx Limits 438 ppm
375 ppm
EPA (US) NOx Limits 253 ppm (For TT Firing)
160 ppm
EU NOx Limits 99 ppm
NOx reduction 57%
NOx, ppm @ 3% O2
0
50
100
150
200
250
300
350
400
450
500
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
Time, Min.
BYPASS OVER FIRE AIR SYSTEM
BOFA 31.8 m Elevation

FLUE GAS TREATMENT – POST COMBUSTION

SELECTIVE NON CATALYTIC REDUCTION



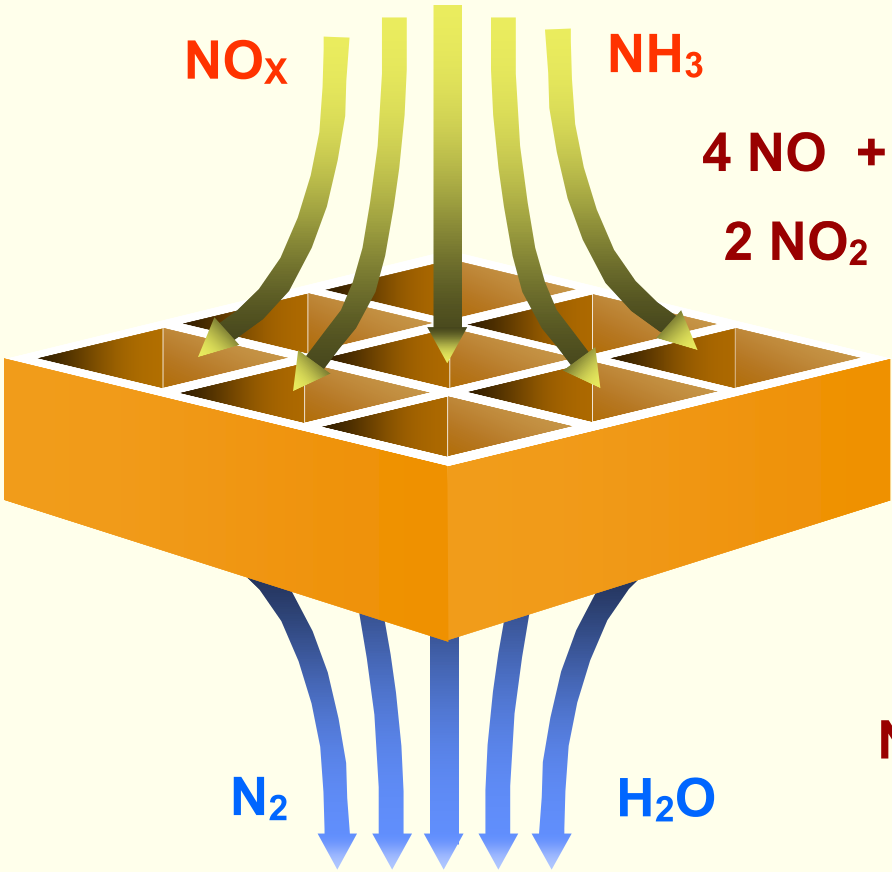


Typical NOx removal effectiveness curve as a function of temperature in SNCR systems (ICAC, 2008)

- ❑ **A SNCR process may also produce nitrous oxide (N_2O) which contributes to the greenhouse effect.**
- ❑ **Capital cost for SNCR installation is low compared to SCR. However, most of the cost of using such a system is the operating expense.**
- ❑ **A typical breakdown of annual costs for utilities is 25% for capital recovery and 75% for operating expense.**

SELECTIVE CATALYTIC REDUCTION

In an SCR system, vaporised ammonia (NH3) is injected into the flue-gas stream at about 300–400°C, which is then passed over a catalyst. The catalyst promotes reactions between NOx and NH3 to form molecular nitrogen and water vapour.



Basic Reactions

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

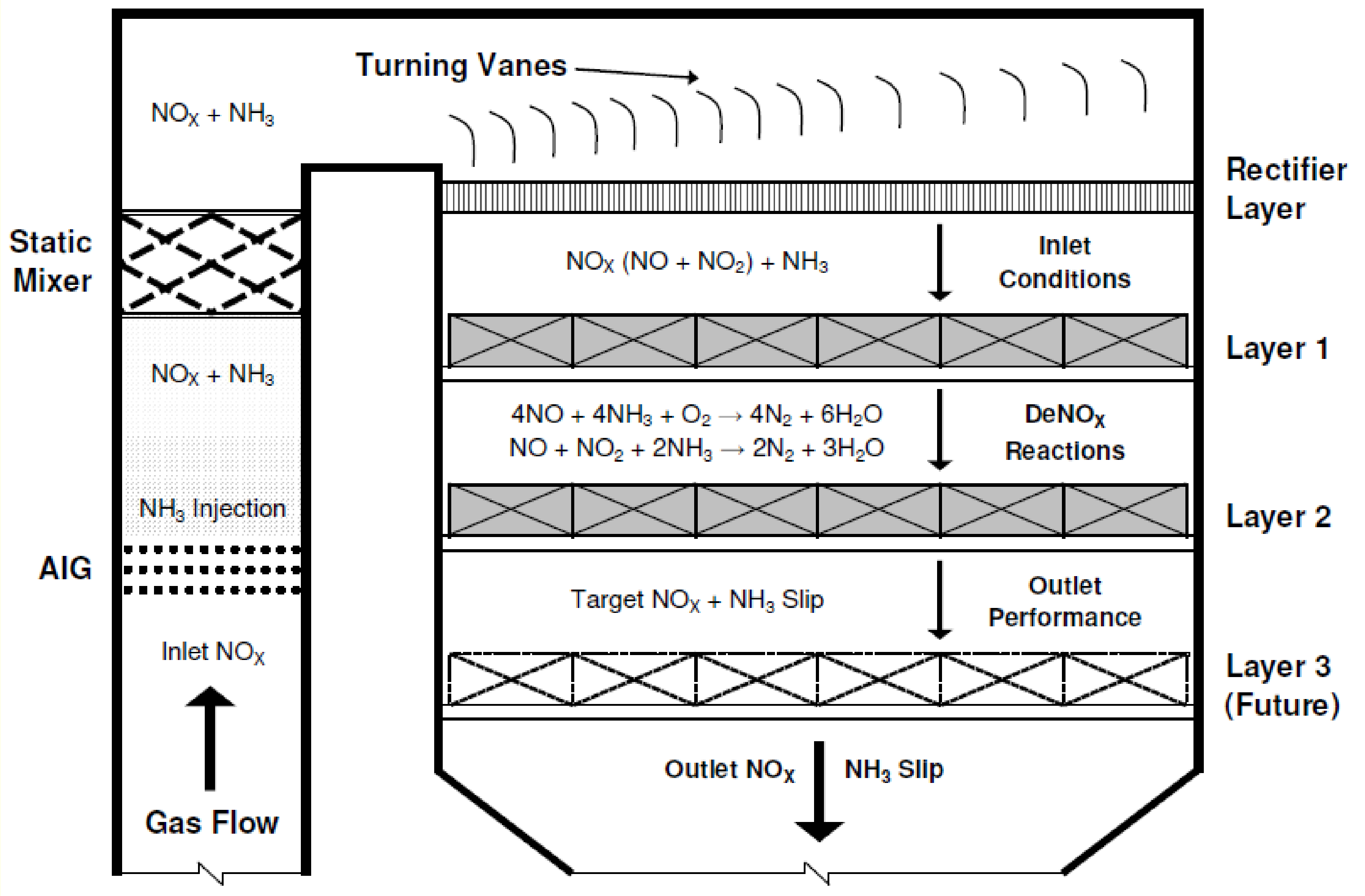
$$2\,NO_2 + 4\,NH_3 + O_2 \rightarrow 3\,N_2 + 6\,H_2O$$

Undesired Parallel Reactions

$$SO_2 + 1/2\,O_2 \rightarrow SO_3$$

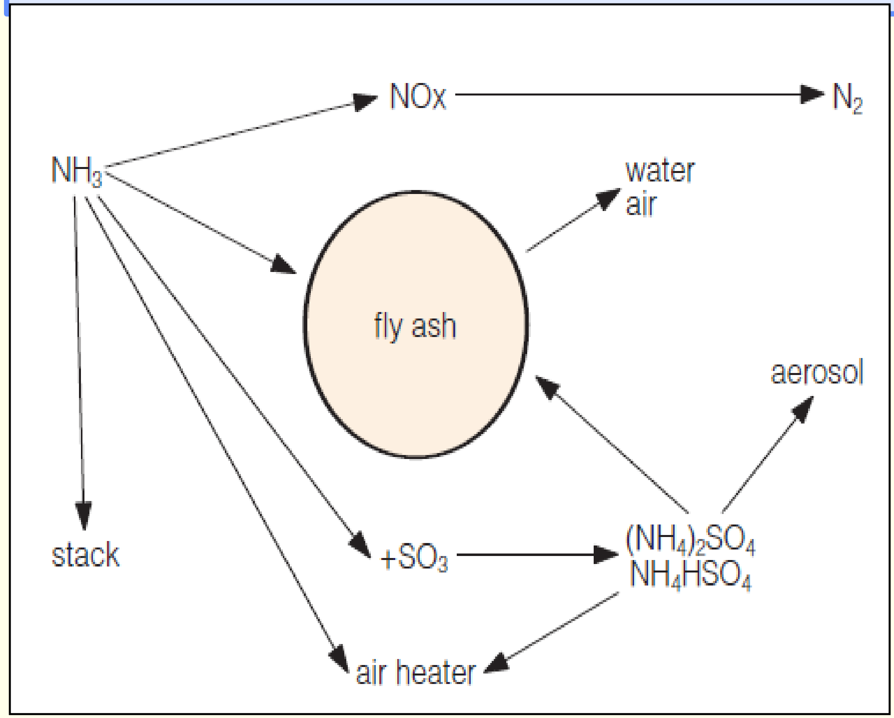
$$NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$$

SELECTIVE CATALYTIC REDUCTION ARRANGEMENT

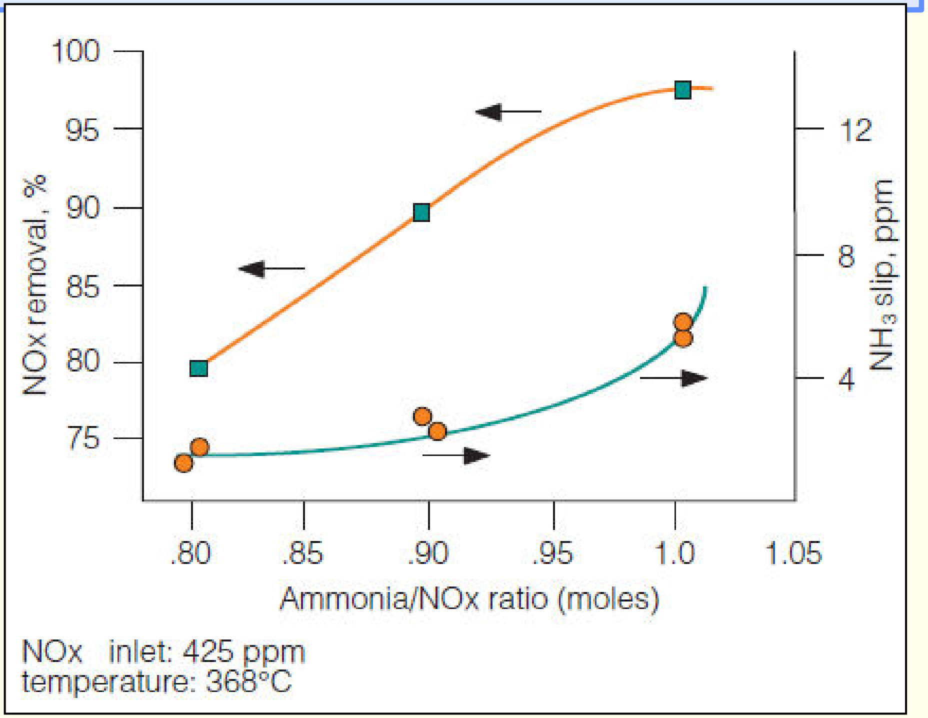


SELECTIVE CATALYTIC REDUCTION

SCR is a commercially available technology, primarily for low-sulphur (<2%) coals. Having been used widely at coal-fired power plants, the technology is also being retrofitted to many existing power plants



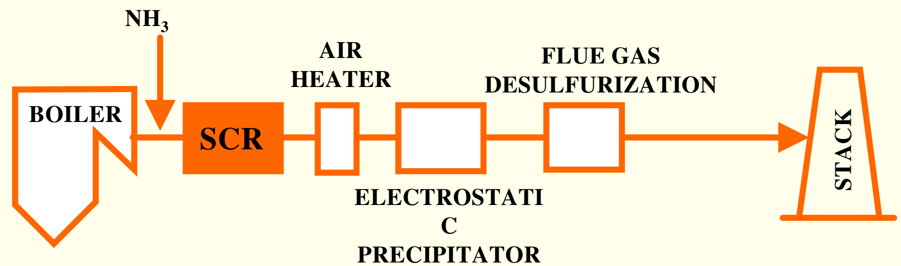
… of ammonia in flue gas (Herrin, 1999)



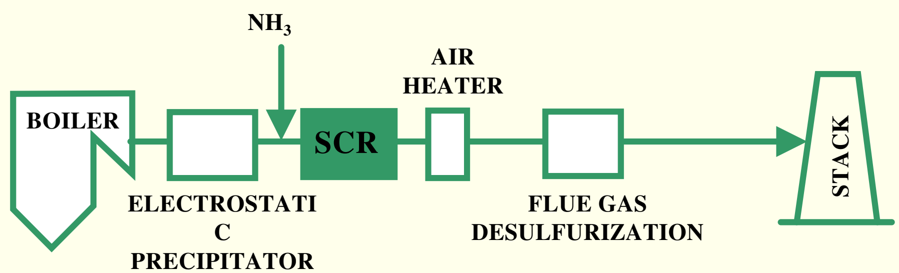
NOx reduction and ammonia slip as a function of reagent normalised stoichiometric ratio (Soud and Fukasawa

SCR CONFIGURATIONS

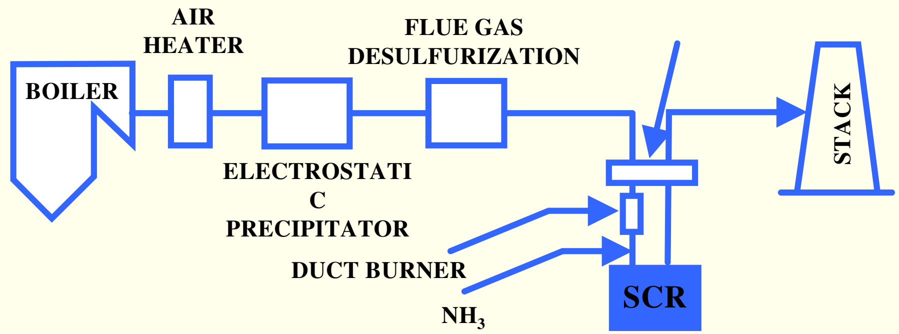
HOT-SIDE, HIGH DUST SCR



HOT-SIDE, LOW DUST SCR



COLD-SIDE SCR, TAIL END



SCR DESIGN