

NO_x – Theory (Types of...)

NO_x - Nitric Oxide (NO)
Nitrogen Dioxide (NO₂)

Thermal NO_x – High temperature oxidation of N₂ (from air) in furnaces at >2200F.

- Controlled by reducing flame temperatures in the furnace, flue gas recirculation (FGR).

Fuel NO_x – Nitrogen bearing fuels (coal, oil etc.)

- Controlled by pretreatment of fuels and treatment of flue gas.

Flue Gas Treatment

Converting NO_x to N_2



SNCR – Selective Non-Catalytic Reduction.

High Temperature – 1700 F

<1600 – Requires enhancers such as H_2

>2000 – $\text{NH}_3 + \text{O}_2 \rightarrow \text{NO}_x$

SCR - Selective Catalytic Reduction.

Temperatures – 600 F to 750 F

(Depends upon Catalyst)

SNCR – Drawbacks.

- The high temperature range required.
- Large amount of space required to adapt injection nozzles and to accommodate enough residence time to complete the reduction chemical reaction at the high temperatures.
- The undesirable excess ammonia reagent "slip" which takes place due to incomplete chemical reaction.



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Ammonia Reagents

Anhydrous Ammonia

99.5-99.7% pure NH_3

Aqueous Ammonia

NH_3 diluted with water <30 %

More volume to vaporize.

Ammonia Injection Grid

Ammonia reagent is vaporized and injected into the flue gas stream for reaction.

Factors affecting ammonia distribution:

- Ammonia dispersion from one injection point to another.
Achieved by increasing injection points per unit area
- Ammonia concentration with respect to localized NO_x concentration.
Achieved by adjusting ammonia flow through different injection points.
- Use of Static Mixers downstream of AIG for uniform NO_x/NH_3 distribution.

SCR Systems.

Main reaction at Catalyst

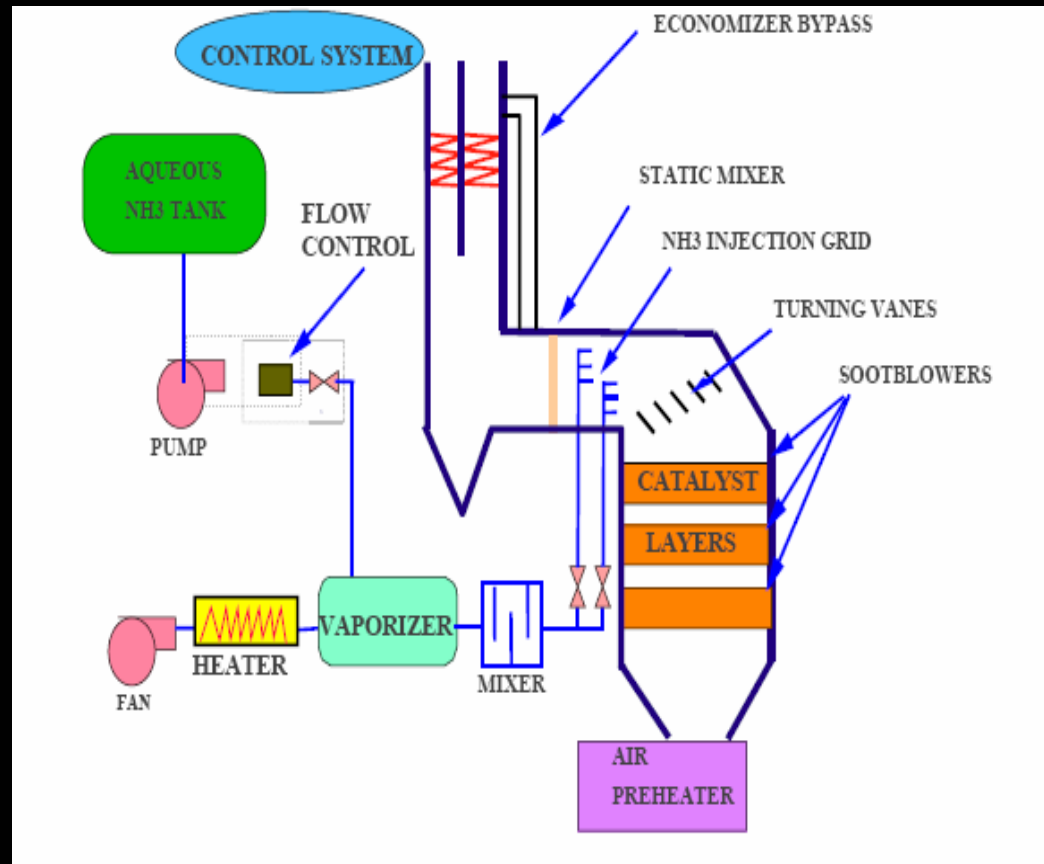


Secondary reaction

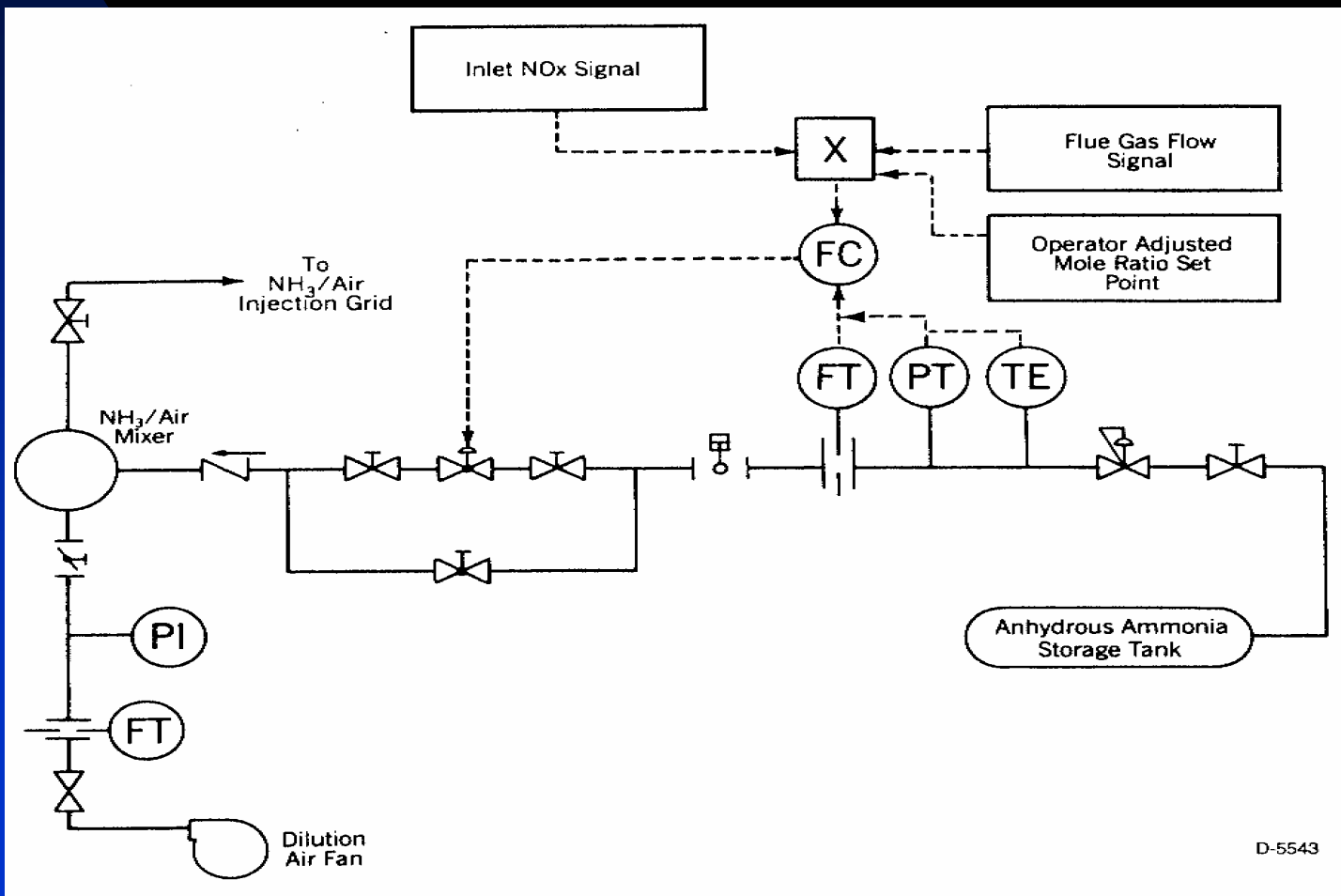


The DeNO_x reaction is preferred over SO₂ oxidation on the catalyst.

Typical SCR System



Typical Ammonia Flow Control



CATALYST

- Homogeneous honeycomb type.
- Titania-Vanadia base metals
- Performance depends upon surface area velocity and Ammonia/ NO_x distribution.
- Sizing factors – NO_x reduction, flue gas flow, ammonia slip, gas velocity, gas constituents and required life.



Catalyst Deactivation and poisoning

- High dust and Ash → accumulation → Plugging.
- Moisture.
- $T > 800\text{F}$ can cause sintering.
- At low temperatures ammonia can react with SO_3 to form sulfates which deposit on the catalyst.

Temperature Control

Most Important factor in SCR systems.

Depending upon the catalyst

Higher temperatures - SO_3 formation rates may increase.

Lower Temperatures - Limited NO_x reduction, Ammonia passes through unreacted (ammonia slip)

Ammonia Slip

Flow of unreacted ammonia through the catalyst.

Cause: Non uniform mixing of ammonia with the gas. Some areas may have higher concentrations than required.

Absorption of ammonia onto ash or other dust particles.

Effects: Less ammonia left for NO_x reduction.

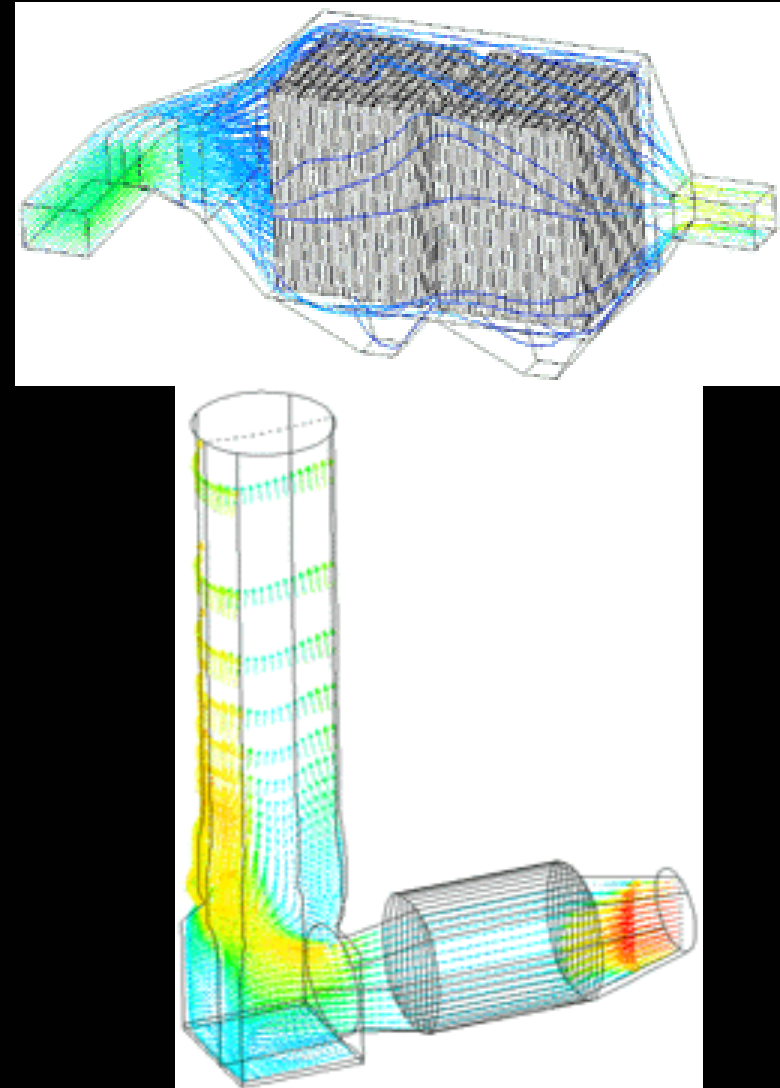
Ammonia may react with SO_3 to form ammonium bisulfate which might condense and lead to plugging.

Important Parameters

- Flow characteristics and flue gas composition.
- Localized NO_x in flue gas.
- Temperature control depending upon catalyst requirements.
- Residence time for reaction.
- Ammonia Injection and amount of ammonia needed.
- Distribution of ammonia in flue gas, depending upon localized NO_x
- Uniformity of ammonia/flue gas at catalyst, so that all of the catalyst is consumed.

Flow Modeling

- Flue gas flow dynamics before and after AIG.
- Ammonia distribution in the system.
- Mixing of ammonia with flue gas.
- Uniformity of the mixture before it enters the catalyst.
- Temperature and pressure distribution.



Our Scope

- Ammonia Storage.
- Ammonia Vaporization Skid.
- Ammonia-Air mixing.
- Ammonia/Air injection into Flue gas.
- CFD Modeling.



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Ammonia Storage





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Ammonia Vaporization



**Feed-Back
Vaporizers
above...**



**Feed Out
Vaporizers
to right...**



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Ammonia Air Mixing Skid



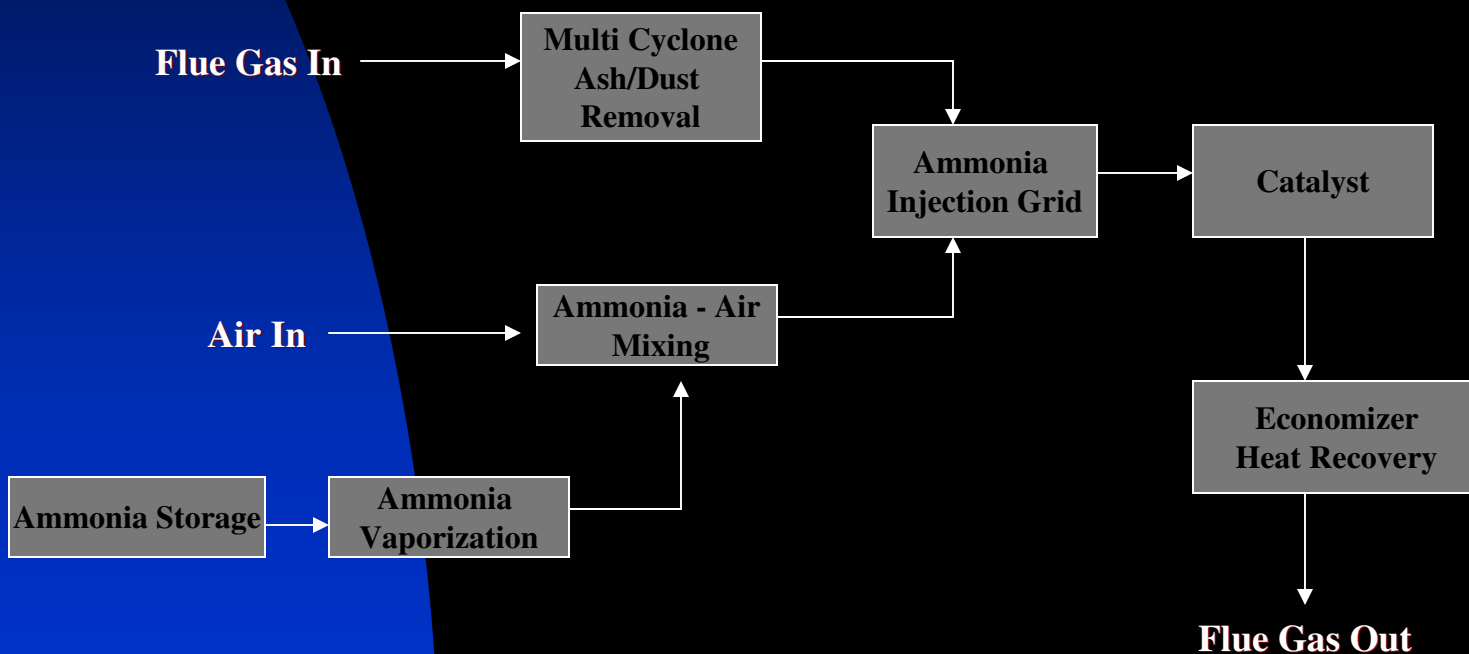


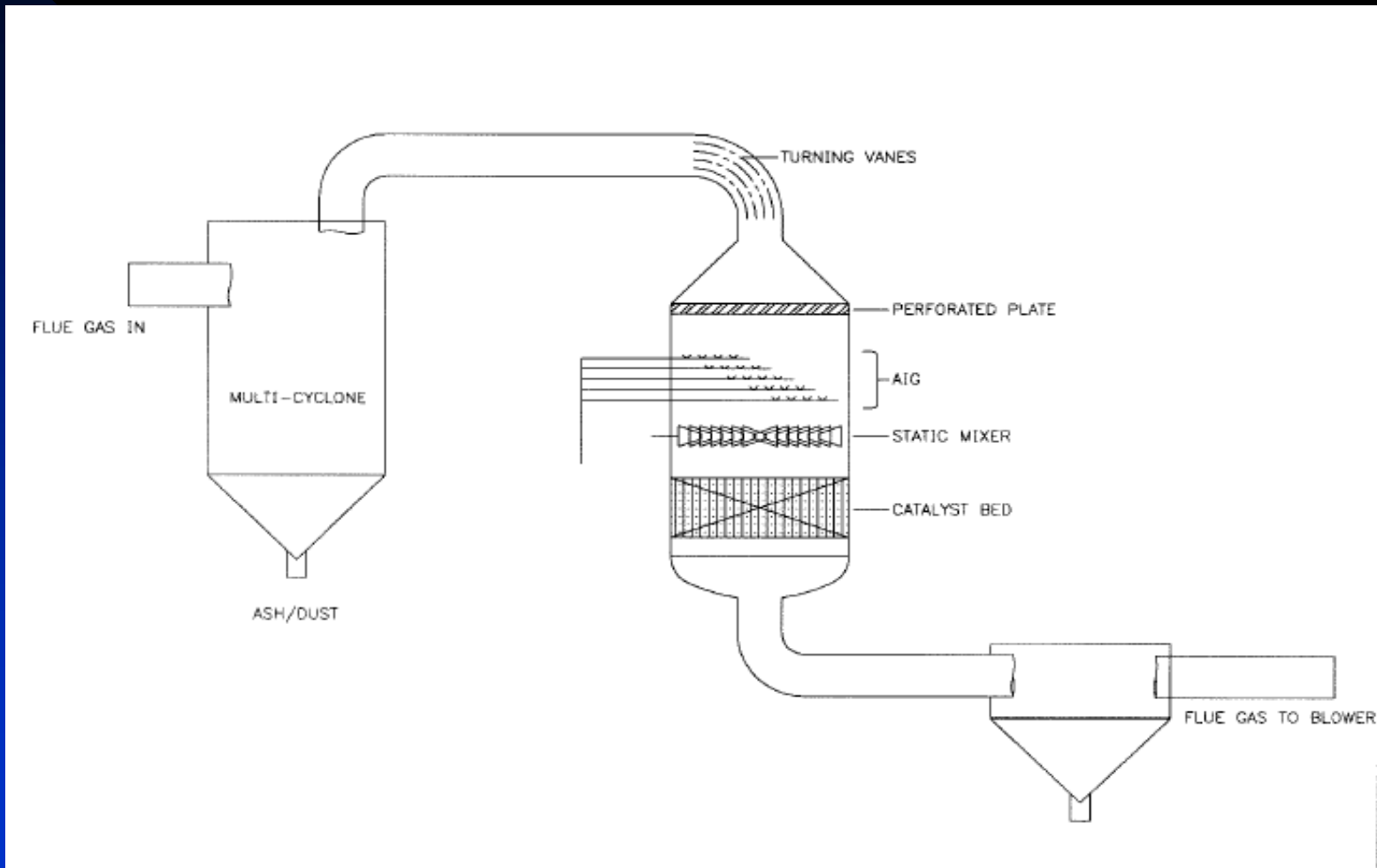
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Ammonia Air Mixing Skid



Proposed SCR Configuration





References

- 1) "Steam its generation and use", Babcock & Wilcox. Ed. 40.
- 2) Pritchard et.al., "Optimizing SCR catalyst design and performance for coal-fired boilers". EPA/EPRI joint symposium. 16-19, May 1995.
- 3) Johnson et.al., " Improved SCR control to reduce ammonia slip". ADA-ES Publication No. 99004.
- 4) www.fluent.com