De-NOx – Concept to commissioning
DEC Envirosystems in technical collaboration with Beijing National Power Group of P.R of China is providing comprehensive De-NOx solutions which includes Ammonia Storage, Ammonia Vaporizer & Dilution Units, Urea pyrolysis and SNCR/SCR/Hybrid systems. BNPG is a research based Catalyst manufacturer and has supplied Catalyst to around 70 Projects of De-NOx meeting very specific requirements of the Clients in addition to having provided EPC/Engineering De-NOx solutions to over 20 Projects.

BNPG has developed Catalysts to meet the varying conditions & temperature of flue gases including conditions causing poisoning / fouling of the Catalyst. It has, based on extensive research, developed Catalyst which carries out de-nitrification & mercury removal simultaneously.
Ammonia Storage and Dilution Systems

Ammonia is used in the following forms for SNCR / SCR Systems
• Ammonia Water (of 10-20% w/w) for SNCR / SCR
• Urea Solution (40% w/w) for SNCR / SCR
• Liq. Ammonia / Vapor (5% v/v) for SCR

DEC Envirosystems in association with BNPG can provide the following facilities:
• PESO approved unloading & storage facility for Ammonia
• Ammonia Dilution units for the production of Ammonia Water of concentrations 10-20%
• Urea storage and solution preparation units
• Liq. Ammonia Vaporisation Units
SNCR De-NOx System

- Compressed air
- Ammonia water
- Demineralized Water
- Pump
- Static mixer
- Metering and distribution module
- Injection system
- Boiler
- Reagent storage tank
- Storage and supply system
SCR De-NOx Systems
Catalyst Manufacturing base

Beijing National Power Group Co. Ltd. has three Catalyst manufacturing facilities in P.R China having annual capacity of 30000 M³ having supplied Catalyst to over 70 Projects for De-NOx.

BNPG has founded the BNP United Laboratory for research and development of de-nitration, de-sulphurisation, Biomass Boiler and Waste Incineration technologies for Industrial applications.

The Catalysts / environmental Products meet the requirements of Thermal Power Plants and the quality meets the advanced international levels with high NOx removal efficiency, high anti fouling rate, low resistance and high mechanical strength.
Catalyst Product advantages include:

- Has high de-nitration efficiency over wide operation temperature range
- Good thermal stability, strong resistance to oxidation of SO$_2$ and can be used for de-nitration and Mercury removal simultaneously
- It has large circulation area in the section of folded plate structure and small pressure drop
- Strong resistance to ash fouling and is suitable for dirty coal-fired flue gas
- Has strong mechanical performance, good abrasion resistance and long service life
- It can achieve high de-nitration efficiency even with flue gas temperature fluctuation
Product Test Indicators include:

- Catalyst type & shape
- Specific surface area, pore volume, pore size and pore size distribution
- Chemical composition
- Trace elements in Catalyst
- Adhesion strength and wear resistance
- NOx reduction efficiency
- SO2/SO3 conversion rate
- Ammonia slip
- Pressure drop
Performance Test of De-nitration Catalyst:

The BNP United Laboratory is accredited with Qualification Certificate by Certifications and Accreditation Administration of the People’s Republic of China (CNCA) and National CMA Accreditation Measurement Certificate (Ref No: 150020003337).

Catalyst types:

- The traditional $V_2O_5$-$WO_3$/TiO$_2$ catalyst has been in use for a long time because of its high catalytic activity, thermal stability and economic viability.
- Several modified SCR catalysts have been made by adding a series of metal oxides to address specific duty conditions.
- BNPG being a research based Catalyst manufacturer has successfully made formulations to address Client specific requirements considering the following:
  - Flue gas temperature
  - Flue gas composition and presence of fouling & poisoning agents
  - Flow pattern
  - Nature of Ash – abrasiveness etc.
The Catalysts being manufactured by BNPG broadly falls under:

Medium Temperature SCR Plate type De-nitration Catalyst

BNPG’s research has led to the successful development of the medium temperature SCR Plate type de-nitration Catalyst which is suitable for medium to high temperature (310 – 420 deg. C) and low to high temperature (250 – 450 deg. C).

Advantages of medium – high temperature (HDGD-DLY-ZMH1) and low to medium temperature (HDGD-DLY-ZML1) SCR Plate-type de-nitration Catalyst include:

• Can handle wide de-nitration temperature range, good activity and high de-nitration efficiency
• Very good resistance to alkali, alkali earth metals, Arsenic etc in flue gas.
• Has good thermal stability and strong anti-oxidation property for SO₂.
• Very suitable for high ash coal – fired flue gas with corners & low velocity areas with plugging greatly reduced.
• It has strong mechanical properties, good abrasion resistance and long service life.
High Temperature SCR Plate type de-nitration Catalyst

BNPG has developed SCR plate type de-nitration Catalyst which is suitable for high temperature (420 – 650 deg. C) flue gas thereby providing solutions for high temperature flue gas de-nitration.

Advantages of High Temperature SCR Plate Type De-nitration Catalyst (HDGD-DLY-ZHI) include:

- It is applicable for de-nitration system of waste incineration and engines etc.
- Works well between 420 – 650 deg. C
- Has high adhesion strength with 0.263% of peeling rate as tested
- It has good wear resistance of 26.45 mg /100U
- Large specific surface area, high activity, low pressure drop and low operation cost
- It has good resistance to Sulphur poisoning, water presence and Hydrogen chloride poisoning.
- Catalyst can be modified to meet the flue gas parameters provided by the Customer to obtain the optimal results.
Low Temperature SCR Plate type De-nitration Catalyst

BNPG has developed SCR Plate type Catalyst which is suitable for low temperature flue gas.

Advantages of Low Temperature SCR Plate type De-nitration Catalyst (HDGD-DLY-ZL1) include:

• Applicable for de-nitration system of Coke oven, Cement kiln, Glass furnaces, Sintering Plants etc.
• Works at a temperature range of 140 – 280 deg. C
• It has high adhesion strength and good wear resistance.
• Has large specific surface area, high activity and low pressure drop with low operation cost

BNPG can suitably customize the Catalyst according to the flue gas parameters.
Catalysts for De-nitration and Mercury removal

Coal-fired Power Plants are considered as one of the most important pollution sources of Mercury emissions in China. The average mercury content of Coal in China is 0.2 mg/kg, which is significantly higher than the world’s average of 0.13 mg/kg.

To meet the criteria of 0.03 mg/M³ of Mercury limit, BNPG has developed Catalyst which can take care of de-nitration and Mercury removal simultaneously.

The SCR reactors have been widely used to reduce NOₓ emissions. The traditional V₂O₅-WO₃/TiO₂ SCR catalyst has a synergistic catalytic effect on oxidation of Hg⁰. Through SCR system, catalytic conversion of Hg⁰ to its oxidized form followed by the capture of the oxidized Mercury in the wet flue-gas desulfurization (FGD) has been considered as an effective traditional way to remove Hg⁰ from coal-fired Power Plants.
CeO₂ modified SCR catalyst has now been found to be most effective. The highest catalytic oxidation efficiency reached 95.11% at the optimal space velocity, temperature and flue gas parameters. In addition, the CeO₂ doping does not affect the de-nitration efficiency of the SCR catalyst. The main reactions of joint de-nitration and Mercury removal is:

\[
\begin{align*}
4\text{NH}_3 + 4 \text{NO} + \text{O}_2 & \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O} \\
8\text{NH}_3 + 6\text{NO}_2 & \rightarrow 7\text{N}_2 + 12\text{H}_2\text{O} \text{ (NOx removal)} \\
\text{Hg}^0 & \rightarrow \text{Hg}^{2+} \\
2\text{Hg} + 4\text{HCl} + \text{O}_2 & \rightarrow 2\text{HgCl}_2 + 2\text{H}_2\text{O} \text{ (Hg removal)}
\end{align*}
\]

Advantages of simultaneous de-nitration and Mercury removal Catalyst (HDGD-DLY-ZHg1) include:

- It applies to the Industries of Thermal power, Steel, Chemical industry, Waste incineration, Cement etc
- High De-NOx efficiency and Hg oxidation efficiency
- Can effectively suppress SO₂ oxidation rate and reduce occurrence of side effects in de-nitration process
- Has high adhesion strength and good wear resistance
- It has large specific surface area, high activity, low pressure drop and low operation cost
Effect & solutions for high Ash content in flue gas on SCR Catalyst:

The effect and solutions to mitigate the presence of high ash content on the performance of the De-NOx catalyst for SCR is explained as under.

Ash concentration is one of the factors that affect the performance and service life of the de-NOx catalyst.

Ash in the flue gas is in the following forms:

- The small particles of ash in the flue gas are usually deposited in the pores of the Catalyst. It can obstruct NOx, NH₃, and O₂ to reach the active surface of the catalyst, and leads to the passivation of the de-NOx catalyst. Plugging of the catalyst in the De-NOx process also makes the flue gas flow velocity in the catalyst channel to increase, leading to catalyst wear and the De-NOx system resistance increases quickly affecting the performance of the De-NOx system and operation of the Boiler.

- Large particle ash in the flue gas (popcorn fly ash) forms bridge between the catalyst boards & plugs the catalyst channel.

The degree of the catalyst wear is related to the concentration of the fly ash, the particle size of the fly ash, the angle of incidence of the fly ash, the flue gas flow rate, catalyst running time and the hardness of the catalyst itself.
Other components of the flue gas

The alkali metal in the fly ash causes catalyst poisoning

Usually the fly ash contains a certain amount of alkali metal (Na⁺, K⁺). When the fly ash along with the flue gas enters into the SCR system, the alkali metals are always attached to the catalyst surface & the alkali metal and catalyst active ingredients come into contact. As the alkalinity of Sodium and other soluble alkali metal salts are stronger than NH₃, alkali metal and catalyst active ingredients react first and lead to catalyst poisoning. In the damp environment, the impact of alkali metal on the catalyst is more serious.

CaO in the fly ash causes catalyst poisoning.

The reasons for CaO which causes SCR catalyst poisoning are:

• CaO causes micro pore clogging
• Alkalinity of CaO causes decrease in the acidity of the catalyst
• The formation of CaSO₄ decreases the Catalyst's activity. The CaO deposited on the surface of the catalyst reacts with SO₃ in the flue gas to form CaSO₄. CaSO₄ is the main reason for the decrease of the catalyst activity by clogging the catalyst pores. The volume of CaSO₄ gradually expands to mask the reactive sites, clog the surface of the catalyst and prevents the diffusion of NH₃ and NO onto the catalyst surface and internal structure thereby leading to the poisoning of the catalyst and reducing the de-NOx efficiency.
In view of the above situation, BNPG takes the following measures while designing & manufacturing of the De-NOx Plate-type catalyst.

• Stainless steel mesh is used as the substrate of the Plate-type De-NOx catalyst, the plate-type De-NOx catalyst will have vibrations when the flue gas passes through, which achieves automatic ash-cleaning. In addition, based on the flue gas conditions, BNPG prevents catalyst blockage by adjusting the catalyst pitch:

  For Soot concentration > 60 gm / Nm³, 7.2mm pitch is selected and for Soot Concentration 30 ~ 60 gm / Nm³, 7.0 mm pitch is selected

• Based on the content of the alkali metal and calcium oxide content in the flue gas, BNPG adjusts the catalyst formulation, in order to take care of catalyst poisoning.

• To meet the varying ash content, BNPG optimizes the production process – which enhances the adhesion properties of catalyst on the steel mesh, improve the density of the catalyst and enhance its wear resistance achieving catalyst wear rate < 130mg/100U & peel rate of less than 1% ensuring the Product has strong wear resistance

• On the top of the catalyst module, filter ash net is installed. The filter ash net can be a good way to intercept the large particles in ash.
• The soot blowers are installed above each of the catalyst layers in the SCR system, in order to remove the ash in the flue gas that may plug or clog the catalyst surface and channel, keeping the flue gas passage to the Catalyst channel clear and reduce the large particle ash in the flue gas which plugs the De-NOx catalyst thereby reducing the de-NOx system resistance.
The undermentioned installations are a testimony to the effectiveness & quality of BNPG's Catalysts & design of SCR systems.

- Guodian Yangzonghai Power Generation Co., Ltd. (2 × 300MW) flue gas De-NOx Project

  Project is for No. 3 & 4 Unit (2×300MW PC Boiler) of Guodian Yangzonghai Power Generation Co., Ltd. The following are the main parameters of this Project.

  - The dust concentration of the De-NOx system is 65.6 g/Nm³, and the maximum is 75 g/Nm³.
  - The design temperature of De-NOx is 308-420 deg. C.
  - The De-NOx process adopts SCR method, and the number of denitrifying layers is set to "2+1".
  - The design De-NOx efficiency is not less than 85% with Nox in outlet being less than 100 mg/NM³
  - The conversion rate of SO₂/SO₃ is less than 1% and Ammonia escape rate is less than 3ppm.
  - The De-NOx reactor is arranged between the Boiler Economizer and the air Preheater.
  - The reducing agent is prepared by hydrolysis of Urea.
  - The catalyst pitch is 7mm, and the opening ratio is 89%. The total amount of catalyst in two boilers is 1066 M³ and the catalyst type is Plate-type.

The Project has been running since October 2014, and all the indexes meet the design requirements.
**Tiefa Coal Industry Group Co., Ltd. Thermal Power Plant flue gas deNOx renovation Project**

Four units of CFBC Boilers of capacity 130 TPH steam.

The following are the main parameters of the Project.

- De-NOx system design meets the following two conditions:
  - Inlet of 400mg/Nm³ (Standard, dry basis, 6% O2), corresponding to outlet of 80mg / Nm³ (Standard, dry basis, 6% O2).
  - Inlet of 360mg/Nm³ (Standard, dry basis, 6% O2), corresponding to the outlet 50mg / Nm³ (Standard, dry basis, 6% O2).
- The dust concentration of the system is **84.2 gm / Nm³**.
- Design temperature range is 320-420 °C.
- De-NOx process is SCR and the number of Catalyst layers is three.
- Design De-NOx efficiency is not less than 86.2%.
- SO2 / SO3 conversion rate is less than 1% and Ammonia escape rate is less than 3ppm.
- The de-nitration reactor is arranged between the Boiler economizer and the air Preheater.
- The reducing agent is NH₃ from Urea Pyrolysis.
- The catalyst pitch is 7.2 mm and the opening ratio is 89%. For three sets of Boilers, the catalyst quantity is 159m³. The catalyst type is Plate-type.
- The Project has been in operation since September 2015, and all the performance indexes meet the design requirements.
2 × 2000 TPH steam (PC Boiler) Unit of Shanxi Huaguang Power Generation Co., Ltd.

(Environmental Ultra-low emission renovation) Project

The dust concentration of the De-NOx system is 70gm/Nm³.
Design temperature of De-NOx is 270-420°C.
The De-NOx process adopts SCR method, and the number of Catalyst layers is three.
The design De-NOx efficiency is not less than 90% and the NOx level at the outlet is 50 mg/Nm3 with the inlet NOx of 500 mg/Nm3.
The conversion rate of SO2/SO3 is less than 1% and the Ammonia escape rate is less than 3ppm.
The De-NOx reactor is arranged between the Boiler Economizer and the Air Preheater.
The reducing agent is Liq. Ammonia.
The catalyst pitch is more than 7mm, and the opening ratio is 90%. The total amount of catalyst for the two Boilers is 1886 M3. The catalyst type is Plate-type.
The Project has been running since April 2016, and all the performance indexes meet the design requirements.
Shanxi Pingshuo Coal Gangue Power Generation Co. Ltd

The Project is of Shanxi Pingshuo Gangue Power Generation Limited Liability Company having 2 × 300MW Units, for the direct air-cooled circulating fluidized bed units. The unit uses CFB low nitrogen combustion technology. The following are the main parameters of this Project.

• The dust concentration of the De-NOx system is 50g/Nm³.
• Design temperature is 310-400°C.
• The De-NOx process adopts SCR+SNCR system, and the number of de-nitrifying layer is one.
• The design NOx efficiency is not less than 75%. The NOx level at the outlet is less than 50 mg/Nm³.
• The conversion rate of SO₂/SO₃ is less than 1% and Ammonia escape rate is less than 3ppm.
• The De-NOx reactor is arranged between the Boiler Economizer and the Air Preheater.
• The reducing agent is Ammonia water.
• The catalyst pitch is more than 7mm, and the opening ratio is 90%. The total amount of catalyst for the two Boilers is 304 M³ and the catalyst type is Plate-type.
• The Project has been running since September 2015, and all the performance indexes meet the design requirements.
It is to be highlighted that BNPG has also developed the super wear-resistant catalyst.

Shenyang Xinbo Industrial Technology Co., Ltd.: De-NOx for Alumina roasting furnace

The dust concentration of the De-NOx system is 300g/Nm³.

- Design temperature of De-NOx is 320-420°C.
- The De-NOx process adopts SCR method, and the number of denitrifying layers is “2+1”.
- The design De-NOx efficiency is not less than 66.7% with Nox in outlet being less than 100mg/NM3.
- The conversion rate of $SO_2/SO_3$ is less than 1%. Ammonia escape rate is less than 3ppm.
- The De-NOx reactor is arranged between the Boiler Economizer and the air Preheater.
- The reducing agent is Liq. Ammonia.
- The catalyst pitch is more than 7mm, and the opening ratio is 90%. The total amount of catalyst in one Boiler is 38 M³ and the catalyst type is Plate-type.

The Project has been running since April 2017, and all the performance indexes meet the design requirements.