Topsoe’s Emission Management Solution--DeNOx

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Haldor Topsoe Company in brief

• Established in 1940 by Dr. Haldor Topsøe.
• Market leader in heterogeneous catalysis and surface science for 75 years.
• More than 2,800 employees in 11 countries across five continents.
• 2015 revenue of approximately USD 1 billion
• Headquarters in Denmark.
• Production in Denmark, and Houston, Texas, USA.
• New plants in Tianjin, China, and Joinville, Brazil, in 2015.
• Spends more than 10% of revenue on R&D.
Headquartered in Denmark, our 2,800 employees work with customers all over the globe

Locations:
Bahrain
Beijing
Buenos Aires
Cape Town
Copenhagen
Edmonton
Houston
Joinville
Kuala Lumpur
Los Angeles
Moscow
New Delhi
Rio de Janeiro
Tianjin

- Headquarters
- Production
- Engineering
- Sales & Service
We provide a full range of products and services for a broad range of business.

**Chemical Processing**
- Ammonia
- Syngas
- Methanol
- Hydrogen
- SNG
- Sulfuric acid
- Dimethyl ether
- Formaldehyde
- Gasoline synthesis

**Hydroprocessing**
- Naphtha
- Kerosene
- Diesel
- VGO
- Resid

**Emissions Management**
- Sulfur removal
- NOx & CO removal
- VOC abatement
- Particulate filtration

**Services**
- Process design, Engineering, & licensing
- High-performance catalysts
- Proprietary equipment
- Business & technical services
Haldor Topsoe Solution
For Environment Protection

- Technology to transform sulfur pollutants into sulfuric acid
- Catalysts to clean the vehicle exhaust
- Technology to remove nitrogen oxides
- Technology to treat volatile organic compounds
Topsoe’s Environmental Solution

• **SCR DeNOx** for removal of NOx: **DNX® catalysts**
  Stationary sources: Power plants, turbines, engines, waste incineration, chemical processes etc.

• **Automotive DeNOx**
  Trucks, buses, generators, etc.

• **Sulfuric acid: VK catalysts**
  $\text{SO}_2$ to $\text{SO}_3$ conversion

• **Treatment of sulfurous waste gases: WSA**
  Refineries, gasification, coke, viscose, metallurgy, etc.

• **Flue gas desulfurization: SNOX™**
  Combined removal of SOx, NOx and particulates from combustion of high sulfur fuels

• **VOC removal: CK catalysts**
  Catalytic oxidation of solvents, etc.

• **Catalytic filters**
  Combined removal of particulates, NOx, CO, and VOCs
**Wet gas Sulfuric Acid**
A process for cleaning sulfur containing streams under production of concentrated sulfuric acid

Lean $\text{H}_2\text{S}$ gas
Rich $\text{H}_2\text{S}$ gas
SRU tail gas
SWS gas
$\text{SO}_2$
$\text{SO}_3$
Spent $\text{H}_2\text{SO}_4$

**WSA**

→ **Cleaned gas**
→ **HP Steam**
→ **$\text{H}_2\text{SO}_4$**
Catalytic combustion process

General

\[ \text{VOC} + \text{O}_2 = \text{CO}_2 + \text{H}_2\text{O} \]
DeNOx Technology
What is NOx?

- NOx is oxides of nitrogen, NO and NO₂

- NOx is formed by:
  - Natural sources like lightning
  - Biogenic sources like nitrogen fixing plants and microorganisms
  - Man made from combustions processes

- NOx emissions cause adverse effects on health, property, and the environment:
  - Smog, PM, acid rain causing deforestation and destruction of water life, ground-level ozone
    - NO₂ + O₂ + hν → NO + O₃
    - 4 NO + 3 O₂ + 2 H₂O → 4 HNO₃

- Emission of NOx is regulated in many regions of the world
  - Maximum NOx emission vary local environmental requirements
NOx formation by combustion

Fuel NOx
• Formed by oxidation of nitrogen containing compounds in the fuel

  Governed by:
• Temperature
• Oxygen level
• Residence time

Predominate in fossil fuels as oil and coal

\[
\text{N}_2 + \text{O}_2 \rightarrow 2 \text{NO}
\]

\[
2 \text{NO} + \text{O}_2 \rightarrow 2 \text{NO}_2
\]

Thermal NOx
• Formed by oxidation of atmospheric nitrogen from the combustion air:

Predominate in gas firing
Why clean the flue gas - DeNOx

- Normally driven by legislation
- Fines or taxes as function of the amount of NOx emission

BUT ..... 

- Turn the picture around?
  - Look at the benefit of DeNOx and use it as a green image!
A green image sells

- "Green" and "Environment" safe technology is desired today
- Many companies around the world have a green strategy and use it actively in their marketing

NOx reduction is green image
Range of NOx reduction options

Operating Considerations
- Combustion modifications
- Excess air maintenance
- Flue gas recirculation
  - Up to 30% reduction
- Burner operation & maintenance
- Fuel conditioning

Technology Considerations
- Low NOx burners
  - Up to 40% reduction
- Selective Non-Catalytic Reduction, SNCR
  - Up to 30-60% reduction
- Selective Catalyst Reduction, SCR
  - Up to 98-99% reduction

......Best Available Technology
**SCR – What it does**

Inject NH₃, mix with NOx, pass through a catalyst = DeNOx

- A reducing agent, most commonly ammonia (NH₃), is injected and mixed into the process gas stream, sometimes using mixing plates.
- The mixed gas then passes through the catalyst layers where the NH₃ reacts with NOx on the catalyst surface and in the pores to form N₂ and H₂O vapor.
- Temperature is typically 350-400°C (160-550°C).
- Catalyst is based on vanadium pentoxide.
SCR DeNOx reactions

\[
4 \text{NO} + 4 \text{NH}_3 + \text{O}_2 \rightarrow 4 \text{N}_2 + 6 \text{H}_2\text{O}
\]
\[
\text{NO} + \text{NO}_2 + 2 \text{NH}_3 \rightarrow 2 \text{N}_2 + 3 \text{H}_2\text{O}
\]

\[
\text{NH}_3 (g) \quad \text{NOx} (g) \quad \text{N}_2 (g) + \text{H}_2\text{O}(g)
\]

**Adsorption on surface**

**Chemical reaction**

**SCR catalyst**

Vanadium pentoxide, V$_2$O$_5$
Tungsten trioxide, WO$_3$
Titanium dioxide carrier, TiO$_2$
General SCR layout

Main components:
- Ammonia storage
- Ammonia evaporation
- Ammonia injection
- SCR reactor and catalyst
- Control system
SCR of NOx by NH\textsubscript{3}
Proven technology for effective NOx removal

Operating temperature: 180 – 450 °C
Topsøe DNX® catalyst - product range

• Channel size
  • 2.7 – 9 mm

• Wall thickness
  • 0.3 – 1.0 mm

• Chemical compositions
  • 10 different to adapt to specific operating conditions
Advantages of Topsoe DNX Catalyst & Technology

Topsoe Operating Experience:

- Gas flows up to 2.7 million Nm³/h.
- SOx contents up to 5% (vol.).
- Temperatures between 225 and 475°C.
- Pressures up to 4 bar.
- Dust contents up to 50 g/Nm³
Combining competences
Haldor Topsoe

- Oxidation
  - HT CK Series
  - Dioxins & Furans
  - CO
  - VOCs
  - HC

- SCR
  - HT DNX Series
  - NH₃
  - NOx

- Filtration
  - Fabric Filters & Filter Bags
  - Dust/PM
**CataFlex™ catalyzed filter technology**

*CataFlex™ catalytic filter bags*

- Each bag consists of up to three fabric layers, impregnated individually
- Combined removal of NOx, ammonia, CO, VOCs, and dust
- No poisoning of catalyst
- Temperature from 180°C up to 260°C
- High filtration efficiency, less than 2 mg/Nm³
- 6 - 12 m length
- Can replace existing bags in any baghouse
TopFrax™ high temperature filter technology

TopFrax™ catalytic ceramic filters

• The filter candles consist of a ceramic fiber based filter impregnated with a catalyst in the filter wall (20 mm thickness)
• Combined removal of NOx, ammonia, CO, VOCs, and dust
• No poisoning of catalyst
• Up to 350-400°C (filter up to 900°C)
• High filtration efficiency, less than 2 mg/Nm³
• 1-3 m length
Schematic illustration of the catalytic filter bag

1. layer
- Membrane
- VOC
- NO\textsubscript{x}
- NH\textsubscript{3}
- CO
- Catalyst

2. layer
- Dust
- VOC
- NO\textsubscript{x}
- NH\textsubscript{3}
- CO
- Catalyst

3. layer
- Dust
- VOC
- NO\textsubscript{x}
- NH\textsubscript{3}
- CO
- Catalyst

Dust
VOC
NO\textsubscript{x}
NH\textsubscript{3}
CO
Concluding remarks

Some key messages:

• NOx is major problem globally, causing great damages to the environment, the health, and to property
• NOx emissions are becoming regulated in still more areas and limits are continually being tightened
• SCR is considered BAT, Best Available Technology, for most applications
• Costs for reducing NOx is far less than the damage costs
• New catalytic technologies become available, enabling e.g.
  • Combined removal of several air pollutants as NOx, CO, dust
  • Application of SCR DeNOx also in difficult areas as waste incineration and cement production
Let’s Make India Clean & Green