Advanced Technology to control PM, Nox, VOCs in a cost effective Manner…..

Presented by:
SACHIN PANWAR
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- Catalytic Filtration technology
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Why Clean the Flue Gas?

**CAPITAL BREATHE UNEASY**

Tops global cities with worst air pollution

<table>
<thead>
<tr>
<th>Country</th>
<th>2014</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>169</td>
<td>139</td>
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<tr>
<td>India</td>
<td>155</td>
<td>123</td>
</tr>
<tr>
<td>Pakistan</td>
<td>148</td>
<td>125</td>
</tr>
<tr>
<td>Nepal</td>
<td>139</td>
<td>38</td>
</tr>
<tr>
<td>China</td>
<td>118</td>
<td>121</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>69</td>
<td>58</td>
</tr>
</tbody>
</table>

**Ranking based on 9 parameters:**
Health impact, air pollution, water & sanitation, water resources, agriculture, fisheries, forests, biodiversity & habitat, climate change & energy

**On list of 178 countries, India ranks as low as 174 on air pollution, 127 on health impact**

**5 CLEANEST COUNTRIES:**
Switzerland, Luxembourg, Australia, Singapore and Czech Republic
Major Contributing Factors
For Air Pollution
Daily cycle of pollutant concentration
Why VOCs, NOx, SOx, PM are threat?

• Forms ground level ozone (or smog)
• Triggers asthma attacks and cancer
• Contributes to acid rains
Haldor Topsoe in brief

- Established in 1940 by Dr. Haldor Topsøe.
- Private 100% family-owned company.
- Market leader in heterogeneous catalysis and surface science for over 70 years.
- Around 2,800 employees in 11 countries across 5 continents.
- Headquarters in Lyngby, Denmark.
- 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

*H* Headquarters

*P* Production

*E* Engineering

*S* 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

Process design, Engineering, & licensing + High-performance catalysts + Proprietary equipment + Business & technical services
Catalytic Process - Fundamental steps

1. Step
Gas phase transport and pore diffusion of educts

2. Step
Adsorption of educts

3. Step
Surface reaction

4. Step
Desorption of products

5. Step
Gas phase transport and pore diffusion of products

Reactant + Products → Products
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
**Wet gas Sulfuric Acid**
A process for cleaning sulfur containing streams under production of concentrated sulfuric acid

Lean H$_2$S gas
Rich H$_2$S gas
SRU tail gas
SWS gas
SO$_2$
SO$_3$
Spent H$_2$SO$_4$

[Diagram]

WSA

Cleaned gas
HP Steam
H$_2$SO$_4$
WSA process lay-out, H$_2$S gas

Reaction:
H$_2$S (g) → H$_2$SO$_4$ (liq)

Superheated steam

Combustion air

BFW

Steam Drum

H$_2$S gas

Combustor

Reaction:
H$_2$S + 1½O$_2$ → SO$_2$ + H$_2$O

H$_2$SO$_4$ (g)

Reaction:
SO$_2$ + ½O$_2$ → SO$_3$

Reaction:
SO$_3$ + H$_2$O → H$_2$SO$_4$ (g)

Stack gas

Air

Blower

WSA Condenser

Acid cooler

Product acid

CW
Topsoe Vanadium SCR for Indian automotive market

- Very good low temperature conversion
- **Full-body**, unlike coated SCR
- Best in class **dynamic response** to transient conditions
- Best in class sulfur tolerance, due to **high porosity substrate**
- **Low deactivation** over time
- Lowest weight
- Zone coated ASC, if needed
- Available in diameters 7.5” - 17”
- **Proven technology** for Euro IV/V/VI and Tier4i/f

- Proprietary substrate, **no dependency on substrate manufacturers**
- Local engine test and production planned
- Mechanical durability, simple canning
Catalytic combustion process

General

\[ \text{VOC} + \text{O}_2 = \text{CO}_2 + \text{H}_2\text{O} \]
Oxidation catalyst portfolio
> 500 references

<table>
<thead>
<tr>
<th>Type</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK-302/322</td>
<td>Hydrocarbons, hydrocarbons with oxygen and nitrogen. Silicon and bromine resistant</td>
</tr>
<tr>
<td>CKM-2x</td>
<td></td>
</tr>
<tr>
<td>CKM-3x, DNOC</td>
<td>Aromatics, CO, hydrogen, ammonia, short-chained alkanes</td>
</tr>
<tr>
<td>CK-304</td>
<td></td>
</tr>
<tr>
<td>CKM-3x</td>
<td>Halogenated hydrocarbons</td>
</tr>
<tr>
<td>DNOC</td>
<td></td>
</tr>
<tr>
<td>CK-305</td>
<td></td>
</tr>
<tr>
<td>CK-395</td>
<td></td>
</tr>
<tr>
<td>CK-306</td>
<td>Halogenated hydrocarbons, CO</td>
</tr>
<tr>
<td>CK-307</td>
<td>All hydrocarbons, CO, sulphur compounds (&lt;200 ppm)</td>
</tr>
<tr>
<td>CK-428</td>
<td>Sulphur compounds (&gt;200 ppm), ammonia</td>
</tr>
</tbody>
</table>
SCR DeNOx Technology
Chemical Reaction

- $6 \text{NO} + 4 \text{NH}_3 \rightarrow 5 \text{N}_2 + 6 \text{H}_2\text{O}$
- $6 \text{NO}_2 + 8 \text{NH}_3 \rightarrow 7 \text{N}_2 + 12 \text{H}_2\text{O}$

$\text{O}_2$ makes the reaction faster
Me=Vanadium or Tungsten

Mechanism:
- Adsorptions mechanism
- Elay-Rideal mechanism
- Langmuir-Hinshelwood mechanism
Reaction mechanism

(1) \( \text{NH}_3 + \text{V}^{5+} + \text{OH} \leftrightarrow \text{V-ONH}_4 \)

(2) \( \text{V-ONH}_4 + \text{V} = \text{O} \leftrightarrow \text{V-ONH}_3 \cdot \text{V}^{4+} \cdot \text{OH} \)

(3) \( \text{NO} + \text{V-ONH}_3 \cdot \text{V}^{4+} \cdot \text{OH} \rightarrow \text{N}_2 + \text{H}_2 \text{O} + \text{V}^{5+} + \text{OH} \)

(4) \( 2\text{V}^{4+} + \text{OH} \leftrightarrow \text{H}_2 \text{O} + \text{V}^{3+} + \text{V} = \text{O} \)

(5) \( \text{O}_2 + 2\text{V}^{3+} \rightarrow 2\text{V} = \text{O} \)

(6) \( \text{H}_2 \text{O} + \text{V}^{5+} + \text{OH} \leftrightarrow \text{V}^{5+} \cdot \text{OH}_3 \cdot \text{O} \)
DeNOx reaction mechanism

1. Diffusion of the reactants to the catalyst surface
2. Adsorption of NH₃ on an active site
3. Reaction of NH₃ with NOx
4. Diffusion of products back to the flue gas
5. Reoxidation of vanadium site
DeNOx technology
General system layout
• Ammonia storage
• Ammonia evaporation
• Ammonia injection
• Flow stratification
• Soot blowers
• SCR reactor and catalyst
• Control system
Topsoe DNX catalyst characteristics

- Corrugated honeycomb
- Open geometry
- Titania based and impregnated with vanadium and tungsten
- High strength – fibre reinforced
- Very porous structure
- High poisoning resistance
- Low SO$_2$ oxidation
- Thermal shock resistant
- Temperature range: 180°C – 555°C
DeNOx catalyst - product range

Channes size
- 2.5-10.0 mm

Wall thickness
- 0.4, 0.8 and 1.0 mm

Chemical compositions
- 10 different to optimise activity/SO₂ oxidation
Catalyst Modules

- Modular Design
- 0.25, 0.50, 0.75, 1.00 meter catalyst height
- 2 x 4 cassette standard design
SCR process - Reactor
DNX catalyst features
Easy loading
Advantages of Topsoe DNX Catalyst & Technology

Topsoe Operating Experience:
- Gas flows up to 2.7 million Nm$^3$/h.
- SOx contents up to 5% (vol.).
- Temperatures between 180 and 475°C.
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Parameter</th>
<th>Outlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>NOx, ppm</td>
<td>&lt;25</td>
</tr>
<tr>
<td>2.</td>
<td>NH3 slip, mg/Nm$^3$ @ 6% O2 dry</td>
<td>&lt;10</td>
</tr>
<tr>
<td>3.</td>
<td>NH3 reagent consumption, Kg/hr</td>
<td>Low</td>
</tr>
<tr>
<td>4.</td>
<td>Pressure Drop, mmH20 (4 $^\circ$C)</td>
<td>20</td>
</tr>
</tbody>
</table>
Topsoe DeNOx Technology has around ≈1200 references worldwide in different sectors.

Reference

149 Coal fired boilers
108 Oil and gas fired boilers
23 Biomass fired boilers
 2 Petcoke fired boilers
107 Stationary diesel engines
31 Marine diesel engines
53 Gas engines
342 Gas turbines
203 Refinery/Petrochemical
37 Waste incineration
97 Other
Combining competences
Haldor Topsoe

- SCR
  - HT DNX Series
- Oxidation
  - HT CK Series
- Filtration
  - Fabric Filters & Filter Bags

- NH₃
- NOₓ
- Dioxins & Furans
- CO
- VOCs
- Dust/PM
- HC
Technology

EnviroTex™ Catalytic filter bags

• Each bag consist of three fabric layers (bags) which individually are impregnated

• High filtration efficiency

• Filter bag up to 464 F (240 deg. C)

• VOC, ammonia removal, and DeNOx at low temperature

• No poisoning of catalyst

Design T: 410-464 F (210-260 C)
Dimension: app. 20-40 feet (6-12m) length
Catalytic filter bag
Catalytic Filter Bag
Catalytic filter bag

Catalyst

Fibers
Technology

TopFrax™ Catalytic ceramic filters

• Each filter consist of a ceramic fiber based filter impregnated with a catalyst in the filter wall (20 mm thick)

• High filtration efficiency (<2 mg/Nm³)

• Up to 662 F (350 deg. C) with present catalyst (filter up to 900 deg. C)

• DeNOx, ammonia and VOC removal.

• No poisoning of catalyst

Design T: 410-752 F (210-400 C)
Dimension: 1-3m length
**NO\textsubscript{x} and NH\textsubscript{3} removal (SCR)**

\[
4 \text{NO} + 4 \text{NH}_3 + \text{O}_2 \rightarrow 4 \text{N}_2 + 6 \text{H}_2\text{O}
\]
$\text{NO}_x$ and $\text{NH}_3$ removal (SCR)
Removal of VOC’s / Organic HAP

VOC = Volatile Organic Compound: CO, Toluene, Benzene, Formaldehyde etc.
HAP = Hazardous Air Pollutant
Removal of VOC’s / Organic HAP

![Graph showing the conversion of Methanol and Toluene vs Temperature](image-url)

- **Methanol**
- **Toluene**

Conversion, %

Temperature, °C
**Furan/dioxin removal**

Off-gas

Dioxin

O₂

Furan

O₂

Dioxin

O₂

Particulate matter (dust)

Catalytic filter bag

Clean gas

H₂O

N₂

CO₂

H₂O

N₂

HCl

Gasflow
**CataFlex™ Catalytic filter bag principle**

Dust is collected on the surface. Pollutants are removed by a catalytic process. Cleaned gas passes through a filter element.

- **Raw gas side:**
  - HAP*
  - CO₂
  - NH₃
  - N₂
  - NOₓ
  - O₂
  - CO
  - Dust

- **Clean gas side:**
  - CO₂
  - N₂
  - O₂
  - H₂O

* Organic HAP includes formaldehyde, benzene, toluene, styrene (m-, p-, o-) xylene, acetaldehyde and naphthalene.
TopFrax™ Ceramic filter principle

Raw gas side

- HAP*
- CO₂
- NH₃
- N₂
- NO₂
- O₂
- CO
- Dust

Clean gas side

- CO₂
- N₂
- O₂
- H₂O

Dust is collected on the surface

Pollutants removal by catalytic process

Cleaned gas pass filter element

Hollow candle made of porous high temperature resistant material with embedded catalyst

Raw gas with dust and pollutants

* Organic HAP includes formaldehyde, benzene, toluene, styrene (m-, p-, o-) xylene, acetaldehyde and naphthalene.
Schematic illustration of the catalytic filter bag

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

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

3. layer
- Catalyst
- VOC
- NO\textsubscript{x}
- NH\textsubscript{3}
- CO
- Dust
Application of catalytic filtration Technology

- Cement kilns
- Power plants
- Waste incinerators
- Chemical industry
- Biomass
- Glass plants
- Metal production (sintering)
- Roasting (Corn, cacao, coffee)
- Carbon black
  Etc...
## Overview - Legislation within Cement Manufacturing

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>USA</th>
<th>Germany</th>
<th>China (Common)</th>
<th>World (Financing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>THC (TOC)</td>
<td>3.6</td>
<td>10*</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>SO₂</td>
<td>94</td>
<td>50*</td>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>NOₓ</td>
<td>360</td>
<td>200</td>
<td>400</td>
<td>600</td>
</tr>
<tr>
<td>NH₃</td>
<td>-</td>
<td>30</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Hg</td>
<td>0.005</td>
<td>0.03</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Dust</td>
<td>1.8</td>
<td>10</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

*) Exceptions for raw materials possible

* Cement plants co-processing waste in common regions. The key region limits are stricter.
Catalytic Filtration Solutions

- New cost efficient solution for removing gas emission along with particulate matter
- Making the plants staying in compliance with even the stringent regulations
- Saves up to 80% on CAPEX compared to existing solutions used today
- Saves operational cost (OPEX) compared to existing solution used today
- Saves foot print of the total installation compared to existing solution used today
- Targeting Waste to Energy, Boilers, Cement Plants, Glass Plants
- ...and similar industries with a flue gas containing hazardous compounds and dust
- Removal of (separately or combined at the same time):
  - NOx
  - HAP (hazardous air pollutants)
  - VOC (volatile organic compounds)
  - CO
  - Dioxin and Furans
  - NH₃
  - Dust and particulate matter (PM)
Let’s Make India Clean & Green
Questions?

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