New Indian Environmental Norms: How advanced DeSO\textsubscript{x} solutions guarantee a sustainable power generation

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Doosan Lentjes
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- Solutions for Desulphurization Processes
- Requirements of the Indian Market
- Unique Features of the Different Technologies
  - Tailor-made solutions for the different processes:
    - Wet Lime / Limestone FGD
    - Circoclean® FGD / FGC
    - Seawater FGD

Case Study:
Gheco One, Thailand
Contract award: 2009
Project:
Delivery of key SW FGD technology
Main fuels: Coal
Plant output: 1 x 700 MW<sub>e</sub>
Flue gas flow (wet): 2,158,000 Nm<sup>3</sup>/h
## Emission Norm India for Thermal Projects installed

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>SO₂</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 500 MW:</td>
<td>600 mg/Nm³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 500 MW:</td>
<td>200 mg/Nm³</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NOₓ</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 mg/Nm³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 mg/Nm³</td>
<td></td>
<td></td>
<td>100 mg/Nm³</td>
</tr>
<tr>
<td><strong>PM²</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 mg/Nm³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 mg/Nm³</td>
<td></td>
<td></td>
<td>30 mg/Nm³</td>
</tr>
<tr>
<td><strong>Hg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 500 MW:</td>
<td>0.03 mg/Nm³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.03 mg/Nm³</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Solutions for Desulphurization Processes: Doosan Lentjes’ APC Products –

- **Wet Lime / Limestone FGD**
  - 205 absorbers installed (110 absorbers in China) (DHI: additional 19 absorbers, 10.7 GWₑ installed)
  - 71 GWₑ total capacity
  - Maximum absorber size: 1,000 MWₑ

- **Seawater FGD**
  - 14 absorbers installed (7 absorbers in cooperation with DHI)
  - 8 GWₑ total capacity
  - Maximum absorber size: 700 MWₑ

- **Circoclean® FGD / FGC**
  - 88 reactors installed (18 reactors in China, 26 in the USA, 2 in cooperation with DHI)
  - 13 GWₑ total capacity
  - Maximum reactor size: 305 MWₑ

**Case Study: Rugeley, United Kingdom**

Contract award: 2006
Project: Flue gas desulphurisation plant retrofit
Main fuel: Coal
Plant output: 1 x 500 MWₑ
Max. flue gas flow rate (wet): 2,103,000 Nm³/h
Our Products and Services

Boiler Business Group

Lentjes Business Unit
- CFB
- Waste-to-Energy
- Air Pollution Control

Boiler Business Unit
- Boiler

Babcock Business Unit
- Service

Future Energy Business Unit

Doosan Lentjes is the global center of competence for CFB, WtE and APC in DHI and has its own R&D center for these technologies

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Our Product Lines — CFB, WtE and APC

**CFB**
- Circulating Fluidised Bed
- Top tier level CFB OEM technology
- References: 113 units (22 GWth, max. 280 MWel)

**WtE**
- Waste-to-Energy
- Top tier WtE OEM technology
- References: 77 units (9 mill t/a, max. 35 t/h)
- Chute-to-stack or full turnkey supply solutions

**APC**
- Air Pollution Control
- Various APC OEM technologies
- References:
  - Wet FGD: 205 units (71 GWel, max. 1,000 MWel)
  - Seawater FGD: 14 units (8 GWel, max. 700 MWel)
  - Circoclean® FGD / FGC: 88 units (13 GWel, max. 305 MWel)
  - SCR DeNOx
  - Fabric Filters and ESP

Today’s Focus

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EEC 2016: DeSOx Technologies to meet new Indian Environmental norms

### FGD Technology – Origin

<table>
<thead>
<tr>
<th>Year</th>
<th>Company Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Acquisition by Doosan</td>
</tr>
<tr>
<td>2007</td>
<td>AE&amp;E Lentjes GmbH</td>
</tr>
<tr>
<td>2004</td>
<td>Lentjes GmbH</td>
</tr>
<tr>
<td>2004</td>
<td>Lurgi Lentjes AG</td>
</tr>
<tr>
<td>2002</td>
<td>Lurgi Energie und Entsorgung GmbH</td>
</tr>
<tr>
<td>1998</td>
<td>Lurgi Lentjes Bischoff GmbH</td>
</tr>
<tr>
<td>1996</td>
<td>Lentjes Bischoff GmbH</td>
</tr>
<tr>
<td>1984</td>
<td>Acquisition by Lentjes</td>
</tr>
<tr>
<td>1910</td>
<td>Foundation</td>
</tr>
</tbody>
</table>

- **Dry FGD**: Doosan Lentjes GmbH
- **Wet FGD**: Gottfried Bischoff GmbH & Co. KG
## Comparison of FGD processes

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Circoclean® FGD/ FGC</th>
<th>Seawater FGD</th>
<th>Wet Limestone FGD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suitable for high sulphur</td>
<td>mg/Nm³</td>
<td>Not economic</td>
<td>Only with additional additives or fresh seawater</td>
<td>yes</td>
</tr>
<tr>
<td>SO₂ removal efficiency</td>
<td>%</td>
<td>&gt;99</td>
<td>&gt;99</td>
<td>&gt;99</td>
</tr>
<tr>
<td>SO₃ removal efficiency</td>
<td>%</td>
<td>&gt;99</td>
<td>approx. 50%</td>
<td>approx. 50%</td>
</tr>
<tr>
<td>Absorbents</td>
<td>-</td>
<td>lime</td>
<td>seawater</td>
<td>limestone/lime</td>
</tr>
<tr>
<td>Investment cost</td>
<td>%</td>
<td>70-80</td>
<td>70-80</td>
<td>100</td>
</tr>
<tr>
<td>Power consumption</td>
<td>% in PP capacity</td>
<td>1-1.5</td>
<td>0.8-1.5</td>
<td>1-2</td>
</tr>
<tr>
<td>Maintenance</td>
<td>%</td>
<td>80</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Absorbents costs</td>
<td>%</td>
<td>200</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>By- product</td>
<td>-</td>
<td>dry calcium sulfite/calcium sulfate mixture</td>
<td>sulfate ions (dissolved in seawater)</td>
<td></td>
</tr>
<tr>
<td>By- product costs</td>
<td>-</td>
<td>high disposal costs</td>
<td>none</td>
<td>saleable (low price)</td>
</tr>
</tbody>
</table>

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Basic Flow Sheet

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Doosan Lentjes
Modules

Raw gas

Additive

L/LS Supply by truck and/or train

Mill

L/LS Slurry Preparation

Absorber

Stack, Wet Stack, or Cooling Tower

Gas-Gas-Heater

Gypsum

Dewatering

1. Stage HC

Gypsum

Dewatering

2. Stage VBF

Product

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Why to prefer our proven Wet Limestone FGD technology?

- New-build and retrofit
- Size: up to 1,000 MWₑ and even more
- Application for a wide range of fuels: coal, lignite, heavy fuel oil
- Suitable for:
  - High sulphur applications
  - Large scale power plants

Case Study: Taichung, Taiwan

Contract award: 1993
Project: Provision of a limestone FGD plant on a turnkey basis
Main fuel: Coal
Plant output (unit 1-4):
- 4 x 550 MWₑ
Max. flue gas flow:
- 2,150,000 Nm³/h

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Overall Reactions

Limestone

$$\text{SO}_2(g) + \text{CaCO}_3 + 2\text{H}_2\text{O} + \frac{1}{2} \text{O}_2 \rightarrow \text{CaSO}_4 \cdot 2\text{H}_2\text{O} + \text{CO}_2(g)$$

Lime

$$\text{SO}_2(g) + \text{CaO} + 2\text{H}_2\text{O} + \frac{1}{2} \text{O}_2 \rightarrow \text{CaSO}_4 \cdot 2\text{H}_2\text{O}$$

Additive: Lime / limestone suspension

Oxi-air

Product: Gypsum

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## Requirements of the Indian Market

<table>
<thead>
<tr>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>► Reliable and proven FGD technology ensured by reference plants</td>
</tr>
<tr>
<td>► Optimized design regarding Capex and Opex</td>
</tr>
<tr>
<td>► Minimized water consumption, limited waste water</td>
</tr>
<tr>
<td>► Small and optimized plant footprint especially for retrofit projects</td>
</tr>
<tr>
<td>► Short erection period, short shut down periods</td>
</tr>
<tr>
<td>► Regarding retrofit projects: relining of chimney and installation of booster fan</td>
</tr>
</tbody>
</table>
Key Project Data Rugeley

<table>
<thead>
<tr>
<th>Customer</th>
<th>International Power plc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of power station</td>
<td>Rugeley, Staffordshire, UK</td>
</tr>
<tr>
<td>Award date</td>
<td>2006</td>
</tr>
<tr>
<td>Gross power generation (per unit)</td>
<td>500 MWₑ</td>
</tr>
<tr>
<td>Number of units</td>
<td>2</td>
</tr>
<tr>
<td>Maximum flue gas flow rate (wet)</td>
<td>2,103,000 m³/h (STP)</td>
</tr>
<tr>
<td>Maximum S content in coal</td>
<td>1%</td>
</tr>
<tr>
<td>Maximum SO₂ inlet concentration</td>
<td>2,076 mg/m³</td>
</tr>
<tr>
<td>Guaranteed emissions (acc 6% O₂, dry)</td>
<td></td>
</tr>
<tr>
<td>So₂ remocal efficiency</td>
<td>94%</td>
</tr>
<tr>
<td>Particulate matter</td>
<td>25 mg/m³ (STP)</td>
</tr>
<tr>
<td>Waste water</td>
<td>10.5 m³/h</td>
</tr>
</tbody>
</table>
EEC 2016: DeSOx Technologies to meet new Indian Environmental Norms – DL Reference Plant in Rugeley
Precise and Accurate Design Calculation: Doosan Lentjes Software Tool

<table>
<thead>
<tr>
<th>Consideration of all chemical and physical processes and interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>► Validated by all performance data documented in the extensive database for all Doosan Lentjes reference plants</td>
</tr>
<tr>
<td>► Precise calculation of plant dimensions regarding correlation of Capex and Opex</td>
</tr>
<tr>
<td>► Consideration of all key design parameters:</td>
</tr>
<tr>
<td>• Limestone reactivity</td>
</tr>
<tr>
<td>• Limestone particle size distribution</td>
</tr>
<tr>
<td>• Organic acid dosage</td>
</tr>
<tr>
<td>• Position of spray level in operation</td>
</tr>
<tr>
<td>• Absorber height</td>
</tr>
<tr>
<td>• Temperature of suspension</td>
</tr>
<tr>
<td>• Chloride concentration</td>
</tr>
<tr>
<td>• Absorbent droplet size</td>
</tr>
<tr>
<td>• Effect of $\text{SO}_2$ and $\text{CO}_2$ concentration on mass transfer</td>
</tr>
<tr>
<td>• …</td>
</tr>
</tbody>
</table>
Optimized Design regarding Capex and Opex

Cost Relationships and influential variables

Influential variables:
- Erection Costs
- Equipment Costs

Influential variables:
- Costs for Power Cons.
- Maintenance Costs

FGD Design

Investment Costs  Operational Costs  Total Lifetime Costs
Optimized Design regarding Capex and Opex

Reduction of $L$  
$\rightarrow$ Reduction of Opex

Reduction of $H$  
$\rightarrow$ Reduction of Capex

Optimal design range:  
Integral consideration of $L$ and $H$

$\rightarrow$ Reduction total lifetime costs
Minimized Water Consumption

| ► | Minimizing of water evaporation by installing highly efficient gas gas heater and minimizing raw gas temperature before absorber |
| ► | Use of cooling water (SW) as process water |
| ► | FGD plant operation with no waste water by injection of residual water before ESP |
| ► | Installation of a waste water evaporator – highly expensive |
| ► | For power plants located in coastal areas the installation of SW FGD plants, where no additive or fresh water is used, has advantages. |
| ► | For FGD plants with a capacity of up to 350 MW the installation of the dry Circolclean® FGD plants has a lower water consumption |
## Use of Cooling Water (SW) as Process Water

### Challenges by use of seawater as process water

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial grade gypsum is produced in all plants.</td>
<td></td>
</tr>
<tr>
<td>The chlorine content in the absorber is higher than in the case of using fresh water: 40,000 ppm instead of 20,000 ppm.</td>
<td></td>
</tr>
<tr>
<td>Wearing of balls for the wet ball mill is higher.</td>
<td></td>
</tr>
<tr>
<td>Amount of bleed waste water is higher.</td>
<td></td>
</tr>
<tr>
<td>Chlorine content has a negative impact on removal efficiency</td>
<td>(higher L/G to reach the same removal efficiency means higher power consumption).</td>
</tr>
<tr>
<td>For saturation of oxidation air and for gypsum washing</td>
<td></td>
</tr>
<tr>
<td>material selection (absorber, mill, process water system) has to be suitable for the high chlorine content.</td>
<td></td>
</tr>
<tr>
<td>Desalinated water is required for gypsum washing.</td>
<td>(range: 2-5% of total water consumption)</td>
</tr>
</tbody>
</table>

I. Doosan Lentjes WLST-FGD plant in Rostock (510 MW<sub>e</sub>) with seawater used as process water.
II. Power Station Almeria, 550 MWe, Spain, Mediterranean Sea
III. Power Station Iskenderun, 2 x 606 MWe, Turkey, Mediterranean Sea
Spray Tower Design

- Mist Eliminators
- Spraying Zone
- Sump equipped with Impulse Suspending System
Sump Design

Special advantages only available with Doosan Lentjes’ Sump System

- Suspends the solids without moving parts within the absorber
- Two different zones for oxidation and crystallization
- Better utilization of consumables
- Higher quality of gypsum
- Trouble-free restart of IS-system after FGD shut-down
- No need to operate Impulse Suspension System during shutdown

Doosan Lentjes
Aspects Regarding the Choice of Fan for Wet FGD Systems

■ Combined ID Fan
  • State of the art solution for new-build power plants
  • References available
  • Simpler control loop for flue gas flow
  • Reduced danger of flue gas pressure oscillation, smooth operation
  • Investment cost saving

■ Booster Fan dedicated to FGD
  • Preferred for retrofit projects
  • No adaption of existing ID fan means reduced tie-in period
  • Better efficiency during bypass-operation
Aspects Regarding the Choice of Type of Chimney

Chimney Design and Material Selection

- Common stand-alone chimney with one or more flues possible
- Wet stack may also be built on top of absorber
- Existing chimney may be used as FGD by-pass
- In case existing chimney will be modified and reused, stand-still period has to be considered

Material selection for flue:

- Carbon steel with flake lining
- Carbon steel with rubber lining
- FRP
- Acid resistant bricks
- Alloy material
Customer Benefits

- A simple solution to remove SO₂, HCl and HF
- SO₂ removal efficiency up to 99%
- Almost stoichiometric absorbent consumption
- Spray tower absorber not susceptible to clogging due to patented Impulse Suspension System
- Individual spray levels can be switched off during low load or low sulphur fuel operation to reduce power consumption
- Variety of corrosion resistant materials available for absorber design
- A high-quality gypsum is created as a by-product which has manifold uses

Case Study: Dolna Odra, Poland
Contract award: 1999
Project: Provision of a flue gas cleaning plant for boilers 7+8
Main fuel: Coal
Plant output: 1 x 220 MWₑ
Max. flue gas flow (wet): 1,926,000 Nm³/h
Doosan Lentjes’ Capabilities at a Glance

- More than 40 years of experience with FGD technology
- Three different FGD technologies available
- Worldwide proven technology is own IP of Doosan Lentjes
- High number of references for all FGD technologies
- Experience with seawater as process water (WLST FGD)
- Continuous intensive R&D in own laboratory
- In-house CFB modelling
## Wet Lime / Limestone FGD Plant References

<table>
<thead>
<tr>
<th>Location</th>
<th>Customer</th>
<th>Capacity</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiddler’s Ferry, UK</td>
<td>Scottish and Southern Energy</td>
<td>3 x 500 MW&lt;sub&gt;e&lt;/sub&gt;</td>
<td>Hard coal</td>
</tr>
<tr>
<td>Ferrybridge, UK</td>
<td>Scottish and Southern Energy</td>
<td>2 x 500 MW&lt;sub&gt;e&lt;/sub&gt;</td>
<td>Hard coal</td>
</tr>
<tr>
<td>Rugeley, UK</td>
<td>International Power plc</td>
<td>2 x 500 MW&lt;sub&gt;e&lt;/sub&gt;</td>
<td>Hard coal</td>
</tr>
</tbody>
</table>
## Wet Lime / Limestone FGD Plant References

<table>
<thead>
<tr>
<th>Location</th>
<th>Customer</th>
<th>Capacity</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oroszlány, Hungary</td>
<td>Vertes Power Plant Limited</td>
<td>1 x 240 MW&lt;sub&gt;e&lt;/sub&gt;</td>
<td>Lignite</td>
</tr>
<tr>
<td>Lippendorf, Germany</td>
<td>Vattenfall / EnBW</td>
<td>2 x 933 MW&lt;sub&gt;e&lt;/sub&gt;, 4 absorbers</td>
<td>Lignite</td>
</tr>
<tr>
<td>Cayirhan, Turkey</td>
<td>TEAS</td>
<td>2 x 150 MW&lt;sub&gt;e&lt;/sub&gt;</td>
<td>Lignite (extreme high sulphur)</td>
</tr>
</tbody>
</table>

**EEC 2016: DeSOx Technologies to meet new Indian Environmental norms**
Why to prefer our proven Circoclean® technology?

- New-build and retrofit
- Power stations and waste-to-energy plants
- Size: up to 350 MWₑ and even more
- Wide range of fuels: coal, lignite, heavy fuel oil, municipal and industrial waste
- SO₂, SO₃, HCl, HF removal efficiency up to 99% and more
- Usage of hydrated lime as additive
- Hydration of burnt lime on site possible
- Usage of limestone in fuel, calcined in upstream CFB boiler
- Removal of PCDD, PCDF and heavy metals with optional activated carbon injection

Case Study: Cochrane, Chile
Contract award: 2014
Project: Engineering, manufacture and supply of dry FGD system
Main fuel: Hard coal
Plant output: 2 x 250 MWₑ
Flue gas flow (wet): 2 x 857,000 Nm³/h
Overall Reactions

**Main reactions, significant for the flue gas desulphurisation in the fluidised bed**

\[
\begin{align*}
\text{Ca(OH)}_2 + \text{SO}_2 & \rightarrow \text{CaSO}_3 \cdot \frac{1}{2} \text{H}_2\text{O} + \frac{1}{2} \text{H}_2\text{O} \\
2 \text{CaSO}_3 \cdot \frac{1}{2} \text{H}_2\text{O} + \text{O}_2 & \rightarrow 2 \text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O} \\
\text{Ca(OH)}_2 + \text{SO}_3 & \rightarrow \text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O} + \frac{1}{2} \text{H}_2\text{O}
\end{align*}
\]

**Additional reactions with chlorides and fluorides**

\[
\begin{align*}
\text{Ca(OH)}_2 + 2 \text{HCl} & \rightarrow \text{CaCl}_2 \cdot 2 \text{H}_2\text{O} \\
\text{Ca(OH)}_2 + 2 \text{HF} & \rightarrow \text{CaF}_2 \cdot 2 \text{H}_2\text{O}
\end{align*}
\]

In case of usage of activated carbon adsorption of:
- PCDD, PCDF and Heavy Metals

**Parallel reaction with CO\textsubscript{2}, forming limestone**

\[
\begin{align*}
\text{Ca(OH)}_2 + \text{CO}_2 & \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} \\
\text{CaO} \text{ hydrated in a dry hydrating plant on site} & \rightarrow \text{Ca(OH)}_2
\end{align*}
\]
Circoclean® FGD / FGC Plant Design

- Circoclean® Reactor (1)
- Filter (2)
- Venturi Nozzle (3)
Multiple Venturi Nozzle (Flow > 400,000 Nm$^3$/h)

Inlet View

Outlet View
Customer Benefits

- Moderate process water consumption
- Small power consumption
- Small foot print
- No waste water – dry particles only
- High SO₃ removal
- No flue gas re-heating
- Reactor made of carbon steel
- Easy adoption to higher SOₓ removal
- Attractive investment costs

Case Study:
Iaşi, Romania
Contract award: 2014
Project: Delivery of key Circoclean® FGD technology
Main fuel: Lignite
Plant output: 1 x 50 MWₑ
Flue gas flow (wet): 623,500 Nm³/h

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Low Pressure Pulse Jet Fabric Filter downstream Circoclean® FGD / FGC Reactor

Customer Benefits

- Far less than 10 mg/m³
- Independent from boiler load
- DeSOₓ – effect in ash layer on filter bag
- Furnace sorption injection or CFB installation possible
- Relatively low investment costs
- Higher life time of filter bags
Typical Layout

- Product Silo (1)
- Sorbent (Lime) Silo (2)
- Absorber (3)
- Fabric Filter (4)
- Absorber Inlet (5)
- Electrical Building (6)
## Key Project Data Cochrane

<table>
<thead>
<tr>
<th>Customer</th>
<th>AES/ Empresa Eléctrica Cochrane (EEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of power plant</td>
<td>Mejillones, Chile</td>
</tr>
<tr>
<td>Award date</td>
<td>2014</td>
</tr>
<tr>
<td>Main fuels</td>
<td>hard coal</td>
</tr>
<tr>
<td>Gross power generation</td>
<td>$2 \times 250 \text{ MW}_e$</td>
</tr>
<tr>
<td>Flue gas flow rate</td>
<td>$2 \times 857,000 \text{ m}^3/\text{h (STP, wet)}$</td>
</tr>
<tr>
<td>DeSO$_x$ - technology</td>
<td>Circoclean® FGD</td>
</tr>
<tr>
<td>Number of lines</td>
<td>2</td>
</tr>
<tr>
<td>SO$_2$ inlet concentration</td>
<td>$1865 \text{ mg/ Nm}^3 \text{ dry @ 6% O}_2$</td>
</tr>
<tr>
<td>Dust inlet concentration</td>
<td>$21,100 \text{ mg/ Nm}^3 \text{ dry @ 6% O}_2$</td>
</tr>
<tr>
<td>Guaranteed emissions</td>
<td></td>
</tr>
<tr>
<td>SO$_2$</td>
<td>$200 \text{ mg/ Nm}^3 \text{ dry @ 6% O}_2$</td>
</tr>
<tr>
<td>SO$_2$ removal efficiency</td>
<td>88.6%</td>
</tr>
<tr>
<td>Dust</td>
<td>$30 \text{ g/ Nm}^3 \text{ dry @ 6% O}_2$</td>
</tr>
<tr>
<td>Dust removal efficiency</td>
<td>99.85%</td>
</tr>
<tr>
<td>Location</td>
<td>Moneypoint, Ireland</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Customer</td>
<td>Electricity Supply Board (ESB)</td>
</tr>
<tr>
<td>Capacity</td>
<td>3 x 305 MW_e</td>
</tr>
<tr>
<td>Fuel</td>
<td>Hard coal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Plžen, Czech Republic</th>
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</thead>
<tbody>
<tr>
<td>Customer</td>
<td>Plzeňská Teplárenská a.s.</td>
</tr>
<tr>
<td>Capacity</td>
<td>3 x 35 MW_e – 1 reactor</td>
</tr>
<tr>
<td>Fuel</td>
<td>Lignite</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Usti nad Labem, Czech Republic</th>
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</thead>
<tbody>
<tr>
<td>Customer</td>
<td>SETUZA Cinergetika U/L, a.s.</td>
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<tr>
<td>Capacity</td>
<td>1 x 65 MW_e</td>
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<tr>
<td>Fuel</td>
<td>Lignite</td>
</tr>
<tr>
<td>Location</td>
<td>Antwerp, Belgium</td>
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<tr>
<td>--------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Customer</td>
<td>Indaver N.V.</td>
</tr>
<tr>
<td>Capacity</td>
<td>3 x 105,000 Nm³ / h</td>
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<tr>
<td>Fuel</td>
<td>Municipal and industrial waste</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Allington</th>
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</thead>
<tbody>
<tr>
<td>Customer</td>
<td>Kent Enviropower</td>
</tr>
<tr>
<td>Capacity</td>
<td>3 x 100,000 Nm³ / h</td>
</tr>
<tr>
<td>Fuel</td>
<td>Municipal waste</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Frankfurt am Main, Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer</td>
<td>AVA Nordweststadt</td>
</tr>
<tr>
<td>Capacity</td>
<td>4 x 114,000 Nm³ / h</td>
</tr>
<tr>
<td>Fuel</td>
<td>Municipal waste</td>
</tr>
</tbody>
</table>
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SWFGD - Background
Typical Flow Sheet – Example: Open Spray Tower
EEC 2016: DeSOx Technologies to meet new Indian Environmental norms
Types of SWFGD Absorbers

- **Influencing factors on product selection**
  - SO₂ raw gas content
  - Required SO₂ removal efficiency
  - Seawater quality, e.g.:
    - Temperature
    - pH value
    - Alkalinity
  - Focus on:
    - Capex
    - Opex
    - Hybrid solution
Field Study at Gheco One Power Plant
Validation at full size Power Plants

- Verification of models and experimental results

SO\textsubscript{2} removal in absorber
- Flue gas grid measurements under different operating conditions

pH increase and oxidation in aeration basin
- Seawater measurements under different operating conditions

Flow optimization
- Pressure drop measurements under different operating conditions

Absorber Type: Open Spray Tower

- No. of spray levels: 4
- No. of oxidation air blowers: 2+1 standby
- Maximum SO\textsubscript{2} concentration (Raw Gas): \(~2700\) mg/Nm\textsuperscript{3}

Gheco One, Thailand
1 x 660 MW\textsubscript{e}, coal

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Field Study at Gheco One Power Plant

Flue Gas Grid Measurements

- Measuring grids
  - Raw gas upstream GGH (25 measuring points)
  - Clean gas upstream GGH (24 measuring points)
  - Clean gas downstream GGH (20 measuring points)

- Measured values
  - SO₂-concentration
  - O₂-concentration
  - CO₂-concentration
  - H₂O-concentration
  - Flue gas temperature
  - Static pressure
  - Flue gas velocity

- A different number of spray pumps (4, 3, 2) were in operation
  - 6 test runs were executed
Field Study at Gheco One Power Plant
Flue Gas Grid Measurements

- Results (selected data)
  - Coal with less sulphur content than planned is fired
  - SO$_2$ removal efficiency of $\geq 99\%$ can be reached
  - SO$_2$ removal efficiency between $\geq 93.5\%$ and $\geq 99\%$ were measured depending on number of operated spray banks and height of operated spray bank
  - The emission limits were upheld under all operating conditions
  - Homogeneous distribution of SO$_2$ at stack
  - Result of flow optimization
  - The expected calculated values were reached
  - Validation of experimental and modelled results successful
  - New operation concept
  - Customer benefits: Reduction of power consumption under current operating conditions

---

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Field Study at Gheco One Power Plant

Seawater Measurements

- Measurements in aeration basin in parallel to flue gas grid measurements
- Measured values at 12 measuring points (selected values)
  - pH Value
  - Alkalinity
  - Dissolved Oxygen [DO]
  - $SO_3^{2-}$ concentration
    - Chemical Oxygen Demand [COD] increase
  - Salinity
  - Conductivity
  - Temperature
  - Seawater Velocity

- Different number of oxidation air blowers (1, 2) were in operation
  - Influence on performance of aeration

- Different number of absorber spray pumps (2, 3, 4) were in operation
  - Influence on seawater inlet quality to aeration basin

- 12 test runs

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Field Study at Gheco One Power Plant

Seawater Measurements

- **Results (selected data)**
  - Correlation between pH value and SO₂ removal efficiency (basin Inlet pH value)
  - Higher SO₂ removal efficiency → Lower aeration basin inlet pH value
  - All emission limits are kept under all operating conditions
  - pH-value and DO increase faster, when more air is brought into aeration system
  - The expected calculated values were reached
  - Validation of experimental and modelled results successful
  - New operation concept
  - Customer benefits: Reduction of power consumption under current operating conditions
Why to prefer proven SWFGD technology?

- **Cost effective solution for plants in coastal regions:**
  - Seawater is used as an absorbent
  - Seawater typically taken from the power plants cooling circuit

- **Size:** up to 1,000 MWₑ and higher

- **Application for a wide range of different fuels:**
  - coal
  - lignite
  - heavy fuel oil

- **Applicable for a wide range of SO₂ raw gas concentrations**

- **High level of removal efficiency, ≥ 99% possible**

- **No by-product and no additional absorbents necessary**

- **Low operating and capital costs**
<table>
<thead>
<tr>
<th>Location</th>
<th>Customer</th>
</tr>
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<tbody>
<tr>
<td>Vinh Tan</td>
<td>Vietnam National Coal – Mineral Industries Holding Corp. Ltd.</td>
</tr>
<tr>
<td>Rabigh, KSA</td>
<td>Doosan Heavy Industries &amp; Construction</td>
</tr>
<tr>
<td>Gheco One, Thailand</td>
<td>Doosan Heavy Industries &amp; Construction</td>
</tr>
<tr>
<td>Capacity</td>
<td></td>
</tr>
<tr>
<td>2 x 620 MWₑ</td>
<td></td>
</tr>
<tr>
<td>4 x 700 MWₑ</td>
<td></td>
</tr>
<tr>
<td>1 x 700 MWₑ</td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td></td>
</tr>
<tr>
<td>Hard coal</td>
<td></td>
</tr>
<tr>
<td>HFO</td>
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## SWFGD Plant References

<table>
<thead>
<tr>
<th>Location</th>
<th>Qatalum, Qatar</th>
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<tbody>
<tr>
<td>Customer</td>
<td>SNC Lavalin</td>
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<tr>
<td>Capacity</td>
<td>4 units</td>
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<tr>
<td>Fuel</td>
<td>Aluminium smelter gas</td>
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<table>
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<th>Madinat Yanbu, KSA</th>
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<tr>
<td>Customer</td>
<td>Enel Power</td>
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<tr>
<td>Capacity</td>
<td>1 x 130 MW&lt;sub&gt;e&lt;/sub&gt;</td>
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<td>Fuel</td>
<td>HFO</td>
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<tbody>
<tr>
<td>Customer</td>
<td>Siemens</td>
</tr>
<tr>
<td>Capacity</td>
<td>2 x 660 MW&lt;sub&gt;e&lt;/sub&gt;</td>
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<tr>
<td>Fuel</td>
<td>Hard coal</td>
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Questions?

Thank you धन्यवाद! Danke

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F +49 (0) 2102 166 2492
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anette.ziemann-noethe@doosan.com

Doosan Lentjes
Excellence in Power
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Backup

- Save flue gas desulphurization processes reduce SO$_2$ emissions to a minimum according to new Indian environmental norms
- Provision of complete clean gas packages from boiler to stack (SO$_x$, NO$_x$, PM, Hg)
- Clean and efficient power generation from coal and biomass support a sustainable long-term growth of the Indian economy
- Reliable waste-to-energy solutions help India reduce its waste volumes (>90%) while recovering valuable energy

Indian’s Powerful German Engineering and Technology Partner - for Protection of the Environment