Modernization and Optimization of Flue Gas Cleaning Plants

Solutions for Air Pollution Control Upgrades following BAT revision in 2017

Speakers:
Dr. Stefan Binkowski (Department Manager Flue Gas Cleaning Process)
Dr. Axel Thielmann (Department Manager Proposals Flue Gas Cleaning)
# Employment Record Dr. Stefan Binkowski

<table>
<thead>
<tr>
<th>Year</th>
<th>Position</th>
<th>Department/Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 - present</td>
<td>Steinmüller Engineering GmbH, Gummersbach, Germany</td>
<td>Engineering and Supplies for Power Plants Department Manager Flue Gas Cleaning Process</td>
</tr>
<tr>
<td>2009 - 2013</td>
<td>Steinmüller Engineering GmbH, Gummersbach, Germany</td>
<td>Engineering and Supplies for Power Plants Head of Flue Gas Desulphurization Department</td>
</tr>
<tr>
<td>2005 - 2009</td>
<td>Steinmüller Engineering GmbH, Gummersbach, Germany</td>
<td>Engineering and Supplies for Power Plants Process Engineer Flue Gas Cleaning</td>
</tr>
<tr>
<td>2001 - 2005</td>
<td>Universität Dortmund, Germany</td>
<td>Lehrstuhl Umwelttechnik, Fachbereich Chemietechnik, Dr.-Ing. (PhD)</td>
</tr>
<tr>
<td>Year</td>
<td>Institution</td>
<td>Location</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>2015 - present</td>
<td>Steinmüller Engineering GmbH, Gummersbach, Germany</td>
<td>Deutschland</td>
</tr>
<tr>
<td>2013 - 2014</td>
<td>Steinmüller Engineering GmbH, Gummersbach, Germany</td>
<td>Deutschland</td>
</tr>
<tr>
<td>2009 - 2012</td>
<td>Siemens AG, Erlangen, Germany</td>
<td>Deutschland</td>
</tr>
<tr>
<td>2006 - 2008</td>
<td>Siemens AG, Berlin, Germany</td>
<td>Deutschland</td>
</tr>
<tr>
<td>2001 - 2005</td>
<td>Max-Planck-Institute for Chemistry, Mainz, Germany</td>
<td>Deutschland</td>
</tr>
<tr>
<td>1997 - 2000</td>
<td>ETH Zürich, Switzerland</td>
<td>Switzerland</td>
</tr>
</tbody>
</table>
Industrial Emissions Directive – Rationale

**Best**
most effective in achieving a high general level of protection of the environment as a whole

**Available**
developed on a scale to be implemented in the relevant industrial sector, under economically and technically viable conditions, advantages balanced against costs

**Techniques**
the technology used and the way the installation is designed, built, maintained, operated and decommissioned

**BAT:** Best Available Techniques
**BREF:** BAT REFerence Document
BREF 2017: Emission Limit Values (ELVs) under discussion for existing Large Combustion Plants (LCPs) ≥ 300 MWth

<table>
<thead>
<tr>
<th></th>
<th>Current IED</th>
<th>BAT Yearly(^1)</th>
<th>BAT Daily(^1)</th>
<th>BREF 2017(^2)</th>
<th>China 2020(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO(_x) [mg/Nm(^3)]</td>
<td>200</td>
<td>65-175</td>
<td>85-220</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>PM [mg/Nm(^3)]</td>
<td>20</td>
<td>2-10</td>
<td>2-10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>SO(_2) [mg/Nm(^3)]</td>
<td>200</td>
<td>10-180</td>
<td>25-220</td>
<td>130</td>
<td>35</td>
</tr>
<tr>
<td>HF, HCl [mg/Nm(^3)]</td>
<td>---</td>
<td>1-5</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Hg [µg/Nm(^3)]</td>
<td>---</td>
<td>1-3 (hard coal)</td>
<td>1-7 (lignite)</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

1: Rolf Becks, Umweltbundesamt (German “Environmental Protection Agency”), during the 11\(^{\text{th}}\) “VGB-Fachkonferenz REA-, SCR- und Entstaubungsanlagen in Großkraftwerken” 25./26. November 2015
2: expected new ELVs in the European Union
3: ELVs required in the 13\(^{\text{th}}\) Five Year Plan 2015-2020
Potentially all Power Plants in the EU (≥ 300 MWth, > 90% solid fuels) will require Air Pollution Control Equipment Upgrades due to the BREF 2017

Source: Emission data reported for 2012 under the European Pollutant Release and Transfer Register (E-PRTR)
## Content

1. Introduction – Revision of LCP BREF
2. DeNOx – Our Post-Combustion Solutions
3. Electrostatic Precipitators – ESPs
4. Flue Gas Desulphurization – FGDs
5. Summary
DeNOx – Steinmüller Product Range

**Primary Measures:**
- Replacement or modifications of burners to Low-NOx-Burners
- Installation of Over-Fire-Air ports
- Optimization of air supply / air ratio
- Adaptation of coal mills

**Secondary Measures:**
- SCR retrofits and upgrades
- SNCR systems
- Adaptation of heating surfaces following SCR retrofits
DeNOx – Shell Wesseling

Reference project key data

- Location Wesseling (near to Cologne) / Germany
- Refinery with fuel oil fired Boiler (unit 6)
- Boiler capacity: 200 MW\text{therm.}
- Flue gas volume flow: 192,000 Nm$^3$\text{wet}/h
- Flue gas temperature: 325 °C
  (downstream of air preheater)
- NOx Emission after boiler: 570 mg/Nm$^3$
- Firing of HFO / Cracker residue (HHVR) / off-gas
DeNOx – Shell Wesseling

Shell Wesseling requirements:

- NOx less than 140 mg/Nm³ @ 3 % O₂,dry
- NH₃ slip less than 1 mg/Nm³ @ 3 % O₂,dry

Steinmüller scope:

- Engineering and Supply of new low NOx burners
- Engineering and Supply of SCR DeNOx
  (consortium with Balcke Dürr for erection)
- Engineering of boiler heating surface modifications
  (as sub-supplier to Balcke Dürr)
DeNOx – Shell Wesseling - Steinmüller Scope

- SCR casing
- Soot blowers
- NH₃-Injection
- Duct upstream catalyst
- Static mixer
DeNOx – Shell Wesseling - Modification of Pressure Part of Boiler 6

Technical Data:

Steam data 200 t/h
Max. operation pressure 132.4 bar
Test pressure (1.2 x 132.4 bar) 159 bar
Superheated steam temperature 525 °C
Year of construction 1978

Heating surfaces:

ECO I: 564 m²
ECO II: 542 m²
Natural circulation system: 1243 m²
Superheater sling tube 173 m²
Pre-Superheater 1 1187 m²
Pre-Superheater 2 522 m²
Final Superheater 249 m²
Total: 4480 m²
DeNOx – Shell Wesseling - Customer Benefits

- Integrated design (modification of heating surface and temperature window for SCR) for all load cases
- LowNOx burner design + SCR allows:
  - Cost benefit analysis of primary and secondary measures
    → Lower investment and operational costs
  - Reduction of interfaces
    → Easier contracting and handling of guarantees
- Construction and erection in existing plant with limited space
- Burners for special applications (HFO, HHVR, off-gas)
<table>
<thead>
<tr>
<th></th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction – Revision of LCP BREF</td>
</tr>
<tr>
<td>2</td>
<td>DeNOx – Our post-combustion solutions</td>
</tr>
<tr>
<td>3</td>
<td>Electrostatic Precipitators – ESPs</td>
</tr>
<tr>
<td>4</td>
<td>Flue Gas Desulphurization – FGDs</td>
</tr>
<tr>
<td>5</td>
<td>Summary</td>
</tr>
</tbody>
</table>
ESPs – Upgrade Possibilities

Measures I

- Additional ESP field OR higher ESP casing
- Adapted ESP lane width
  - Reduced flue gas velocity and hence higher dust removal efficiency
- Deployment of modern 3-phase high voltage aggregates
- Adapted high voltage control
ESP – Upgrade Possibilities

Measures II
- Primary removal of coarse particles in the inlet hood
- Homogenization of flue gas velocity distribution

Before

After
ESPs – Example: CET Govora

- Power plant CET Govora, 7 Units of 380 MWth
  - Flue gas volume flow: 1.024.000 m³/h
  - Dust load (raw gas): 70.000 mg/Nm³ @ 6% O₂
  - Clean gas before retrofit: > 200 mg/Nm³ @ 6% O₂
  - Clean gas after retrofit: < 50 mg/Nm³ @ 6% O₂
  - Pressure loss improvement: - 30 Pa (0.3 mbar)

- Revamp of 2 existing ESP casings
  - Including Engineering and Supply of steel components
  - Reduce dust emission < 50 mg/Nm³
  - New ESP-design (roof) whilst maintaining original footprint and creating a reduction in pressure loss
  - Reduction of dust emission from 280 mg/Nm³ to below 30 mg/Nm³
ESPs – Example: CET Govora - Implementation
ESP s – Customer Benefits

- Reduction of dust emissions < 10 mg/Nm³
- Upgrade possible whilst maintaining original footprint and weight (SE low weight ESP-roof)
- Reduction in pressure loss (adapted ESP lane width & ESP hoods)
- Power savings (modern high voltage aggregates & control)
- Robust design
Content

1. Introduction – Revision of LCP BREF
2. DeNOx – Our post-combustion solutions
3. Electrostatic Precipitators – ESPs
4. Flue Gas Desulphurization – FGDs
5. Summary
FGD – Upgrade Possibilities

• Optimizing gas flow distribution and gas-liquid contact
  • Nozzle type and nozzle arrangement
  • Wall rings
  • Tray
  • CFD analysis
• Optimizing FGD operation
  • Limestone quality, injection point
  • Oxidation air system
  • Liquid level
  • Number of operated pumps
  • pH value
• Combination of above mentioned measures
Steinmüller Engineering “tray basket elements”

- Material: poly propylene with reinforcement
- Standardized modular basket design
- Easily combined to cover the whole cross section
- Project specific variation of hole size and arrangement
- Convenient working platform when covered with planking
- Different absorber shapes can be covered
FGD – General Functional Principle of the Tray

Spray nozzles

Tray basket element

Flue gas flow
FGD – General Functional Principle of the Tray

- Pressure loss across the entire cross-section causes a homogenous flue gas distribution above the tray.
- Relative low pH-value causes enhanced Limestone dissolution on the tray.
- High SO$_2$ content in the gas phase causes high SO$_2$ absorption rate on the tray.
- Intensive phase mixing favors the separation of the finest particles (fine dust, SO$_3$).

Flue gas flow inlet (asymmetric)

Surface of bubble layer

Tray
FGD – Flue Gas Velocity Distribution

- Nearly homogeneous flue gas flow in the absorption zone by implementation of a tray
- More effective $\text{SO}_2$ separation by the spray layers
FGD – Tray Basket Elements

Steinmüller Engineering “tray basket elements”

• Establish a bubbling layer → liquid contact layer
• Enlarged contact surface
• Increase removal efficiency of \( \text{SO}_2, \text{SO}_3, \text{Dust} \)
• Influence on the removal efficiency comparable to one spray level
• More equal gas distribution
• Increase limestone utilization
• Reduce residual limestone in gypsum
• Increase oxidation of sulfite
• Reduce mercury re-emission
## FGD – Tray Revamp: References

<table>
<thead>
<tr>
<th>Location</th>
<th>Fuel</th>
<th>Volume flow [Nm³/h]</th>
<th>Original removal rate</th>
<th>Removal rate after Revamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Völklingen (HKV)</td>
<td>Hard Coal</td>
<td>800.000</td>
<td>88 %</td>
<td>94 %</td>
</tr>
<tr>
<td>Völklingen (MKV)</td>
<td>Hard Coal</td>
<td>600.000</td>
<td>87 %</td>
<td>94 %</td>
</tr>
<tr>
<td>Deuben</td>
<td>Lignite</td>
<td>625.000</td>
<td>95 %</td>
<td>98 %</td>
</tr>
<tr>
<td>Novaky</td>
<td>Lignite</td>
<td>1.250.000</td>
<td>96 %</td>
<td>98 %</td>
</tr>
<tr>
<td>Herten</td>
<td>Waste</td>
<td>60.000</td>
<td>90 %</td>
<td>96 %</td>
</tr>
</tbody>
</table>
**FGD – Tray Revamp: Example Deuben**

- **SO₂ content in raw gas:**
  7.600 mg/Nm² → 8.200 mg/Nm³ (6% O₂)

- **SO₂ content in raw gas:**
  380 mg/Nm³ → < 230 mg/Nm³

- **Max. flue gas flow:**
  625,000 Nm³/h (wet)

- **No additives (e.g. adipic acid)**

Combine first and second spray level to create space for tray installation
FGD – Tray Revamp: Example Deuben

- Install Tray modules at support of former 1st level
- Installation time: 231 hours
FGD – Tray Revamp: Installation
## FGD – Tray Revamp: Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Influences</th>
<th>With Tray</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂ / SO₃ separation rate</td>
<td>Increase of the separation rate</td>
</tr>
<tr>
<td>Pressure loss</td>
<td>Increase of the pressure loss 0 - 6 mbar</td>
</tr>
</tbody>
</table>
| Power consumption at constant separation rate (i.e. 5 spray levels without a tray vs. 4 spray levels with tray) | Recirculation pumps: less power consumption  
Booster fan: more power consumption                  |
| Limestone utilization factor                         | Slight increase by about 1 %, i.e. slight decrease of limestone consumption|
| Flue gas velocity distribution                       | Homogeneous flue gas distribution after the tray                          |
| Dust separation                                      | Reducing of the residual dust content                                     |
| Oxidation of Sulfite and Mercury                     | Increase oxidation of sulfite (less deposits), increase oxidation of mercury (less re-emission) |
FGD – Tray Revamp: Pressure Loss

• New coal quality; SO₂ increase: 10,000 mg/Nm³ → 14,500 mg/Nm³ (6% O₂)
• New emission limit value: < 400 mg/Nm³ → < 200 mg/Nm³
• Constant pressure loss:
• Maximum flue gas flow:
• No additives (e.g. adipic acid)

• Installation of tray level increases pressure loss
• Full compensation of pressure loss by:
  • Reduction of the spray levels
    (also save power for 1 recycle pump)
  • Use of other nozzle types
  • Modification of mist eliminator

Guarantee: No additional pressure loss for overall system!
FGD – Tray Revamp: Customer Benefits

Steinmüller Engineering offers customized FGD upgrades for:

- Lower emission limit values for SO₂, SO₃, Dust (IED 75/2010 & BREF)
- Changing fuel range (e.g. higher S-content of coals)
- Cost savings I (e.g. pump power)
- Cost savings II (lower maintenance expenditures, shorter outage times)
- Complete system from one source
  - Less interfaces
  - SE has the process know-how and the contacts to sub-supplier → best interaction
FGD – Tray Revamp: Savings on OPEX Example

- Cost savings by less power consumption (savings recirculation pumps minus booster fan upgrade):
  - 300,000 – 500,000 €/a
- Cost savings by less limestone consumption:
  - 50,000 – 90,000 €/a
- Cost savings by scaffolding in the lower part of the absorbers:
  - ca. 50,000 €/revision

- Total operational cost savings for two absorbers (2x 1,7 Mio. m³/h)
  ➔ approx. 500,000 €/a
Content

1. Introduction – Revision of LCP BREF
2. DeNOx – Our post-combustion solutions
3. Electrostatic Precipitators – ESPs
4. Flue Gas Desulphurization – FGDs
5. Summary
Summary

Our Solutions for Air Pollution Control Upgrades

• Meeting of emission limit requirements in answer to IED & BREF
• Balancing (CAPEX & OPEX) between primary and secondary APC upgrades
• Integrated plant solutions
• Reducing interfaces
• Best combination of qualified equipment sub-suppliers
• Cost savings
• Additional SCR experience through IHI (e.g. mercury oxidation)

We will find the best solution for your plant together!
Thank you for your attention