Retrofit of 2 FGD Systems for Boilers in Plock/Poland

Kolkata, Raipur, Hyderabad

Dr. Frank Delle

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1. Introduction Steinmüller Babcock Environment

2. The Plock Retrofit Project

3. The FGD-System in Plock

4. Facts and Figures

5. Basic Retrofit considerations for India
1. Introduction

- SBE – The Company
- Portfolio
Where do we come from?
Portfolio of SBE Gas Cleaning Division

Scope:
- EPC Turnkey
- Retrofits
- Revamping
- Engineering
- Studies

990 worldwide references:  730/Europe  170/Asia  80 N.-America  10/others
2. The Plock Retrofit Project

- The Client
- Existing plant
- Task & scope of work, setup
- Project time schedule
Plock FGD-Retrofit Project – The Client

- largest petrochemical company in Poland
- operating refineries in eastern Europe and
- gasoline distribution networks

- approx. 22,000 employees
- approx. 30 billion US$ revenue
Plock FGD-Retrofit Project – The Plant

7 oil fired boilers & 1 gas fired boiler with a total capacity of 2,150 MWth,
- 3 boilers of 230 MWth capacity each (K1 – K3)
- 4 boilers of 290 MWth capacity each (K4 – K7)
- 1 boiler of 300 MWth capacity (K8, gas fired)

6 steam turbines with a total capacity of 345 MWel,
- 5 back pressure extraction turbines of 55 MWel capacity each
- 1 condensing turbine with bleeding of 70 MWel capacity

3 district heat stations with a total thermal capacity of 340 MWth
for heating of refinery and residential areas in Plock

Source: PKN Orlen
www.steinmueller-babcock.com

Source: Google Earth
New installed flue gas cleaning systems

Typical arrangement (LCP)

- New SCR DeNOx
- New Desulfurisation (Steinmüller Babcock)
- New wet stack
- New wet stack
- New Electrostatic Precipitator
- New radial ID-fans

Turbine  Boiler  SCR-DeNOx  ESP  ID-fan  Stack
Plock FGD-Retrofit Project – The Plant

Existing Power Plant incl. ESP’s:

K8  K7  K6  K5  K4  K3  K2  K1

- flue gas collecting and distribution
- Two absorbers with wet stack
- Lime system
- gypsum dewatering and silo
Plock FGD-Retrofit Project – The Services

Executed as Consortium:

SBE as technology provider
- Process Design
- Absorbers
- Gypsum Dewatering
- Booster Fans
- Duct system

Orlen Projekt as local partner
- Water systems
- Lime system
- Piping
- Civil
- Erection

Basic Engineering
Detail Engineering
Project Management
Quality / HSE-Management
Procurement
Construction
Commissioning
Operational Support
After Sales Service
Plock FGD-Retrofit Project – The Milestones

Time schedule was handled very flexibly according to the requirements of the power plant operation!

6 m: to start of site activities
26 m: 1st boiler connected
31 m: PAC unit 2
3. The FGD-System in Plock

- Design data, technical requirements
- Guarantee Data
- Selected functional units of the FGD plant
- Consumables and utilities
- Design Optimisations by CFD
FGD - open spray tower

- Absorber: Single stage scrubber
- Absorbent: Limestone powder (CaCO₃)
- Product: Saleable gypsum
- Dewatering: Gypsum hydro cyclone stations
  - Vacuum belt filter
  - Eurosilo gypsum storage

- Waste water discharge: Waste water hydrocyclone station
- Waste water treatment plant: Chemical and biological treatment

State-of-the-art FGD-process
Guarantees at stack are fulfilled
Prepared for future lower emission limits
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design 1 absorber</th>
<th>Design FGD plant</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flue gas volume flow</td>
<td>1.980.000</td>
<td>2.640.000</td>
<td>Nm³/h wet</td>
</tr>
<tr>
<td>Flue gas mass flow</td>
<td>2.607.304</td>
<td>3.470.480</td>
<td>kg/h</td>
</tr>
<tr>
<td>H₂O</td>
<td>8,4</td>
<td>8,8</td>
<td>vol.-% wet</td>
</tr>
<tr>
<td>SO₂</td>
<td>4.850</td>
<td>4.850</td>
<td>mg/Nm³ dry, 3 vol.-%O₂</td>
</tr>
<tr>
<td>SO₃</td>
<td>135</td>
<td>135</td>
<td>mg/Nm³ dry, 3 vol.-%O₂</td>
</tr>
<tr>
<td>HCl</td>
<td>11</td>
<td>11</td>
<td>mg/Nm³ dry, 3 vol.-%O₂</td>
</tr>
<tr>
<td>HF</td>
<td>0,4</td>
<td>0,4</td>
<td>mg/Nm³ dry, 3 vol.-%O₂</td>
</tr>
<tr>
<td>Dust</td>
<td>25</td>
<td>20</td>
<td>mg/Nm³ dry, 3 vol.-%O₂</td>
</tr>
<tr>
<td>Flue gas temperature</td>
<td>170-190</td>
<td>170-190</td>
<td>°C</td>
</tr>
<tr>
<td>Flue gas pressure</td>
<td>-0,5</td>
<td>-0,5</td>
<td>mbarg</td>
</tr>
</tbody>
</table>
## Guarantee data: (extract)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂ clean gas concentration</td>
<td>≤ 100</td>
<td>mg/Nm³ dry, 3 vol.-%O₂</td>
<td>Hourly average value</td>
</tr>
<tr>
<td>SO₂ reduction efficiency</td>
<td>≥ 97,94</td>
<td>%</td>
<td>At max. SO₂ inlet concentration of 4.850 mg/Nm³ dry, 3 vol.-%O₂</td>
</tr>
<tr>
<td>Dust clean gas concentration</td>
<td>≤ 18</td>
<td>mg/Nm³ dry, 3 vol.-%O₂</td>
<td>At max. inlet dust concentration of 25 mg/Nm³ dry, 3 vol.-%O₂</td>
</tr>
<tr>
<td>Sound pressure level</td>
<td>≤ 85</td>
<td>dB(A)</td>
<td>In 1m distance</td>
</tr>
<tr>
<td>Availability of the FGD plant</td>
<td>≥ 98,6</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>NOₓ clean gas concentration</td>
<td></td>
<td>Not higher than at battery limit to FGD</td>
<td></td>
</tr>
<tr>
<td>NH₃ clean gas concentration</td>
<td></td>
<td>Not higher than at battery limit to FGD</td>
<td></td>
</tr>
<tr>
<td>SO₃ reduction efficiency</td>
<td>≥ 40</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Droplet content in clean gas</td>
<td>≤ 50</td>
<td>mg/Nm³ dry, 3 vol.-%O₂</td>
<td>For water droplets &gt; 10µm</td>
</tr>
</tbody>
</table>
## Guarantee data: gypsum quality (extract)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGD post-processing product</td>
<td>Calcium sulphate dihydrate CaSO₄ x 2H₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purity</td>
<td>≥ 95</td>
<td>wt-%</td>
<td>CaSO₄ x 2H₂O in dry mass</td>
</tr>
<tr>
<td>Moisture content</td>
<td>≤ 10</td>
<td>wt-%</td>
<td></td>
</tr>
<tr>
<td>Chlorine content</td>
<td>≤ 0,01</td>
<td>wt-%</td>
<td></td>
</tr>
<tr>
<td>Colour</td>
<td>≥ 60 (White)</td>
<td>Ry L<em>a</em>b</td>
<td>with the whiteness of limestone powder not worse than 75% Ry L<em>a</em>b</td>
</tr>
<tr>
<td>Content of CaCO₃ x MgCO₃</td>
<td>≤ 1,6</td>
<td>wt-%</td>
<td></td>
</tr>
<tr>
<td>Particulate size (granularity)</td>
<td>50 wt-% ≥ 32µm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Also guaranteed: Waste water flow and quality
FGD - process flow chart

- **Flue gas path with booster fans**
- **Absorber**
- **Oxidation air supply**
- **Limestone unloading and storage**
- **Emptying system**
- **Reclaim water**
- **Process water supply**
- **Gypsum dewatering and storage (Eurosilo)**
- **Waste water discharge**
- **Waste water treatment plant**

www.steinmueller-babcock.com
FGD functional units: Flue gas path
Overview

Σ: 30 flue gas dampers, each equipped with seal air!
FGD functional units: Booster fans
Arrangement overview

Booster fans 1+2

Booster fans 3+4

www.steinmueller-babcock.com
**FGD functional units: Booster fans**

**Technical data**

<table>
<thead>
<tr>
<th>Design 1 booster fan</th>
<th>Design 1 absorber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flue gas volume flow, total</td>
<td>1.200.000</td>
</tr>
<tr>
<td>Flue gas volume flow, per booster fan</td>
<td>1.200.000</td>
</tr>
<tr>
<td>Pressure increase</td>
<td>21,7</td>
</tr>
<tr>
<td>Shaft power per fan</td>
<td>1.575</td>
</tr>
<tr>
<td>Fan efficiency</td>
<td>77,5</td>
</tr>
<tr>
<td>Installed motor power per fan</td>
<td>2.800</td>
</tr>
</tbody>
</table>

**Axial fan:**
- single stage
- speed control
- hydr. blade pitch control
- prepared for possible retrofit of HDS system
FGD functional units: Absorber

Dimensions

**Mist eliminator**
- 2 stages

**4 spray levels**
- Co-current/counter current flow

**Recirculation flow**
- 4 x approx. 11,000 m³/h

**Agitators**
- with oxidation air supply

- Height 39,1 m
- $v_{\text{Gas}} \approx 4 \text{ m/s}$
- $\phi 15,0 \text{ m}$
- Volume of sump: approx. 3000 m³
- $\phi 19,0 \text{ m}$

www.steinmueller-babcock.com
FGD functional units: Absorber
Spray banks

4 spray banks
with each 2 main
headers DN800
per absorber
FGD functional units: Absorber
Arrangement of spray nozzles

Edge zone
Double full cone nozzle 90°

Header zone
Double hollow cone nozzle 120°

Central zone
Double hollow cone nozzle 120°
higher flow / lower flow

Header/Support zone
Double hollow cone nozzle 90°
lower flow / higher flow

Flue gas inlet
FGD functional units: Absorber
Arrangement of spray banks
FGD functional units: Gypsum dewatering

Process flow diagram

Absorber 2
- Gypsum slurry pumps 2
- Gypsum slurry
  144 m³/h
  15 % solids
- Gypsum hydrocyclones 2
  Solid content
  50 %
  Gypsum slurry
  Vacuum belt filter 2
  Gypsum
- Overflow collecting tank
- Solid content
  2-5 %

Absorber 1
- Gypsum slurry pumps 2
- Gypsum slurry
  max 202 m³/h
  15 % solids
- Gypsum hydrocyclones 1
  Solid content
  50 %
  Gypsum slurry
  Vacuum belt filter 1
  Gypsum
- Overflow collecting tank
- Gypsum
  max 31,3 t/h
  < 10 % moisture

Gypsum silo
FGD functional units: Gypsum dewatering
Arrangement and technical data

Gypsum hydro cyclones
- Number of cyclones: 12
- Flow: 14,4 m³/h per cyclone

Vacuum belt filter
- Capacity: 20,1 t/h dry
- Filtration area: 24,7 m²
- Width of belt: 1900 mm
- Effective filter length: 13 m
- Belt speed: 0,5 … 5,1 m/min
- Required process water flow: 13 m³/h
FGD functional units: Gypsum storage
Arrangement and technical data

Gypsum storage silo
- Feed capacity: 35 t/h
- Discharge capacity: 200 t/h
- Volume: 5800 m³
- Height: 50 m
- Diameter: 26 m

Source: ESI Eurosilo B.V.
## FGD Utility consumers

<table>
<thead>
<tr>
<th>Medium</th>
<th>Unit</th>
<th>Consumption</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance point</td>
<td></td>
<td>FGD Plant</td>
<td>one Absorber BP1 / BP11</td>
</tr>
<tr>
<td>Power</td>
<td>MWh/h</td>
<td>11,6</td>
<td>8,7</td>
</tr>
<tr>
<td>Limestone</td>
<td>t/h</td>
<td>17,1</td>
<td>12,1 Pureness 95% CaCO₃</td>
</tr>
<tr>
<td>Oxidation air</td>
<td>Nm³/h</td>
<td>15800</td>
<td>10900</td>
</tr>
<tr>
<td>Process water</td>
<td>m³/h</td>
<td>244</td>
<td>182</td>
</tr>
<tr>
<td>Waste water</td>
<td>m³/h</td>
<td>10</td>
<td>7,7 max. 12 m³/h possible</td>
</tr>
<tr>
<td>Gypsum</td>
<td>t/h</td>
<td>31,3</td>
<td>22,2 Residual moisture 10%</td>
</tr>
<tr>
<td>Cooling water, dem.</td>
<td>m³/h</td>
<td>33</td>
<td>16,5 Cooling FC booster fan</td>
</tr>
<tr>
<td>Cooling water</td>
<td>m³/h</td>
<td>85</td>
<td>Limestone unloading</td>
</tr>
<tr>
<td>Instrument air</td>
<td>m³/h</td>
<td>57</td>
<td>Average consumption</td>
</tr>
<tr>
<td>Service air</td>
<td>m³/h</td>
<td>40</td>
<td>Average consumption</td>
</tr>
</tbody>
</table>
Computational Fluid Dynamics (CFD)
Raw gas inlet duct
Computational Fluid Dynamics (CFD): Unsteady calculations
Computational Fluid Dynamics (CFD): Absorber

demister

spray banks

gas/liquid contact zone

absorber sump

clean gas outlet

flue gas inlet
4. Facts and Figures
Plock: Facts and Figures
Space Requirements

- Absorber with pumps: 25 mx 30m
- Stack: d=26m flexible
- Gypsum dewatering storage: access by truck or train
- Lime system: access by truck or train
- Emptying tank: flexible
- No space for wet stack: flexible
Flue Gas Duct System:

Flue gases from 8 boilers to be fed in 2 absorbers with unlimited flexibility for combinations

- 30 flue gas dampers
- 4 booster fans
- Total duct weight approx. 2,000 t
Absorbers:

- Height approx. 40 m = f (SO2 removal requirements, no of spray levels)
- Diameter approx. 15 m = f (flue gas flow)
- Material: carbon steel with flake lining
- Weight approx. 500 t (each)
Plock: Facts and Figures

Electrical Power Consumption: \(11.6\ \text{MWel}\)
with all 8 boilers (2,150 MWth) in operation

- 6.2 MW (53%) circulation pumps \(= f (\text{SO}_2\ \text{removal requirements})\)
- 3.4 MW (30%) booster fans \(= f (\text{flue gas flow, ducting, SO}_2\ \text{removal requirements})\)
- 0.7 MW (6%) oxidation air supply \(= f (\text{SO}_2\ \text{removal requirements})\)
Lime consumption: 17.1 t/h
@ maximum plant load

= f (SO₂ load), stoechiometric ratio close to 1

= f (lime quality) i.e. purity (usually > 90%), reactivity
Lime consumption (95% CaCO₃): 17.1 t/h

Gypsum production (CaSO₄·2H₂O): 31.3 t/h

=> stoechiometric ratio approx. 1.0x
PKN Orlen in Plock is a petrochemical plant with extremely high safety standards!

Strict site safety regulations had to be followed and have been followed successfully during erection:

No mayor accidents occurred
Other specific execution experiences:

• Polish language (esp. during erection and commissioning)

• Repeatedly the client requested changes in the tight time schedule due to delays in client’s scope

• High SO3- and Vanadium contents (HFO firing) had to be considered regarding corrosion, removal and WWT

• Strict site safety regulations
Successful Execution

• in time according tight time schedule
• in budget
• all guaranteed values have been achieved

SBE was selected
„Best Supplier of PKN Group 2014“
(out of 8,000 suppliers from the whole group)
5. Cost Influences for Retrofit projects (in India)

- Project Definition, Interfaces to existing plants
- Space & other Requirements
- Schedule requirements
- Cost relevant requirements
- Local partner
Cost influences on retrofit projects (in India)

Project Definition

Tendering Concept:

✓ **Procurement Concept:** EPC – lotwise – components

✓ „Make in India“ Concept with high local portion: JV's and Licencees of foreign Technology Providers (like concept of SBE with Indure Ltd./India)

- local engineering (in cooperation with technology provider)
- sourcing: mix of local supply – low cost imports – „crucial“ technological equipment
Cost influences on retrofit projects (in India)

Project Definition

**Plant Concept:**

- Most economical **concept for consumables** (i.e. lime or lime stone, grinding by supplier or within plant)

- Most economical **concept for gypsum** (produce saleable gypsum or mixing with ash for landfilling)

- Wet **stack** with plume or dry stack (minimising water consumption)

- Definition of **availability / redundancy concept**

- General **quality requirements** (i.e. automatisation concept, equipment specifications, insulation specifications, etc.): best available technology – economic state of the art – adopted to existing overall plant
Existing layout and available space:

- Sufficient space for new installations - especially absorber - close to boiler and stack? => minimise flue gas ducts and other transport installations (piping/conveying)

- Sufficient space for storage and prefabrication on site or close to site?

Time Schedule:

- To be adopted to maintenance scheme of operating plant
- Availability of qualified operator personnel during commissioning phase
- Optimisation during commercial operation to shorten commissioning
Cost influences on retrofit projects (in India)
Existing Plant

Design Data:
✓ Requested design data close to actual operation without large safety margins (Realistic definition of minimum design requirements avoids over-engineering)

Operation of the existing plant:
✓ Reliable (!) measurements of operation data for defining the design load case minimises risk margins for equipment design
✓ Design and operation data of existing equipment (i.e. fans) to identify unused operation margins

Condition of hardware of existing plants (revamping projects):
✓ Detailed information about the condition, expected lifetime, corrosion status of installations, which might be destined for further operation
SBE’s approach to the Indian FGD market

Licence concept SBE with Indure Ltd. / New Delhi

- EPC done by Indure Ltd.
- Engineering based on SBE Know How
- Basic Engineering Checked by SBE
- SBE available for all kind of support during execution
- SBE provides supervision for erection and commissioning
Indure : EPC Capabilities

Major references for “Balance of Plant” packages on EPC basis

✔ Complete BoP with civil for 1x250 MW Suratgarh TPS of RRVUNL
✔ BoP (Mechanical) package for 1x63 MW Renki project of SV Power
✔ BoP package for 2x250 MW Panipat TPS of HPGCL
✔ BoP package for 2x210 MW Paricha TPS of UPRVUNL
✔ BoP packages for 2x250 MW Bhavnagar Lignite Project (under execution)
✔ Complete BoP with civil for 2x250 MW Chhabra TPS of RRVUNL (under execution)
✔ Complete BoP package including civil for 2x525 MW Angul Project of Monnet Power (under execution)
✔ Coal Handling Plant for 2x660 MW Solapur Super Thermal Power Project of NTPC (under execution)
✔ DM Plant for Fujairah Cement, Dibba, UAE for Sinoma Energy Conservation Limited, China
WE MAKE THE WORLD A CLEANER PLACE

Let’s work it out together.

Steinmüller Babcock Environment