RODENHUIZE POWER PLANT
ADVANCED AND MAX GREEN CONFIGURATION

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Product Manager Power Plant Refurbishment
PRESENTATION OVERVIEW

• The Max Green Project
• Biomass handling (unloading, storage, milling pneumatic transport)
• Firing system retrofit
• Flue gas treatment
• Process key figures
• Conclusion
THE MAX GREEN PROJECT

• The Max Green Project
  - conversion of Unit 4 of the Rodenhuize Power Station from coal firing to pure biomass combustion
  - power generation 200MWe
THE MAX GREEN PROJECT

• Why clean wood pellets?
  - Large potential supply → availability on the market
  - Relatively high energy density – 16 to 19 MJ/kg
  - Low ash content and low moisture content

Clean wood pellets very attractive for conversion of PF boiler

• Biomass sourcing as early as possible
  - Secure the biomass supply on long term
  - Freeze the set of inputs for the boiler design
THE MAX GREEN PROJECT

- Pre 2005:
  - Coal: Main fuel, 720 MWth
  - HFO: Start-up & secondary fuel
  - BFG: Up to 360MWth
THE MAX GREEN PROJECT

- **2005: “Light Green”**
  - Start co-firing of wood pellets with pulverized coal
  - Only burner row 2
THE MAX GREEN PROJECT

- **2005: “Light Green”**
  - Start co-firing of wood pellets with pulverized coal
  - Only burner row 2

- **2008: “Advanced Green”**
  - Wood pellets replace coal on the 2nd & 3rd burner row
  - HFO firing abandoned → NG
THE MAX GREEN PROJECT

• 1/2009 – 8/2010: Transition phase to MG
  - Coal abandoned
  - Only biomass firing @ rows 2+3, sometimes NG or BFG

• 2011: “Max Green”
  - All 3 burner levels on pulverized wood (100% biomass)
  - No boosting of other fuels (except Backup for BFG)
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BIOMASS HANDLING

1. Unloading
2. De-dusting & Pre-treatment
3. Covered conveyors
4. Hammer mills 5 t/h each
5. Pneumatic transport to burners
6. Dosing bin
7. Day tank 3 x 2000 m³
8. Dosing bin
9. Covered conveyors
10. Boiler

Day tank 2000 m³

Design and optimisation of cofiring configurations – DEBCO final conference

Unloading

ELECTRABEL RODENHUIZE

DOPLAC SILO'S PELLETS

De-dusting & Pre-treatment

Boiler

3

Hammer mills 5 t/h each

Pneumatic transport to burners

Dosing bin

5

Day tank 3 x 2000 m³

Dosing bin

Covered conveyors

Boiler

10/12/2012 10
BIOMASS HANDLING

• Fire & Explosion risks mitigation

1. building up of explosive atmosphere has to be avoided
   • dedusting systems
   • filters
   • intensive house keeping program

2. if this is not reachable, ignition source must be prevented
   • ferro separation
   • anti static material, avoidance of hot surfaces, earthing and equipotential connections
   • use of ATEX equipments
   • CO and hot spots detection

3. if despite all an explosion arises, the consequences must be mitigated
   • reduction of the blast by mean of explosion panels, explosion bottles
BIOMASS HANDLING - PELLETS

- Pellets are supplied by ships 50 000 tons
- Ship unloading via grab crane
- New Pellet storage (108000 ton)
BIOMASS HANDLING - PELLETS

- Transport to milling plant by belt conveyors
BIOMASS HANDLING - PELLETS

- Cleaning tower

Ferro separator to remove metals
Oversize screening
Filter to avoid that dust escapes to the environment
BIOMASS HANDLING - PELLETS

- Corner tower with dedusting
BIOMASS HANDLING - PELLETS

• Weight (moisture) measurement
BIOMASS HANDLING - PELLETS
BIOMASS HANDLING - PELLETS

• Onsite storage of pellets in 3 day-silos of 2000 m³
BIOMASS HANDLING - PELLETS

- Onsite storage of pellets in 3 day-silos of 2000 m³
BIOMASS HANDLING – MILLING

- Pellets milled to dust by hammer mills
- Cleaning step
  - Ferro separation
  - Windsifter
- Separate milling installation per burner row consisting of 4 mills
- 1 hammer serves 2 burners
BIOMASS HANDLING - WOODDUST

- **Pneumatic transport system**
  - One blower – one transport – one burner
  - 2000 Nm³/h transport air – 7t/h per line
  - Dust air ratio max. 3.5 kg dust/kg transport air
  - P = 250mbar
BIOMASS HANDLING - WOODY DUST

- Pneumatic transport system

To row 1  To row 3  To row 2

To boiler
**Biomass Handling - Wood Dust**

- Wood dust injection in PA/Crcoal pipe before the burners

![Diagram of wood dust injection](image)

- Wood dust injection pieces (protected by ceramic tiles) into coal pipes ~2 m upstream burner entrance

![Image of biomass handling system](image)
BIOMASS HANDLING - WOODDUST

CFD simulation PA flow towards the burners

- Check good distribution of wood pellets in burner
- Check absence of sedimentation risk
- Check areas subject to high erosion
- Calculate wood particles outlet speed

Pressure loss:
- Combustion air: 9 mbar
- Biomass air: 17.8 mbar

Average outlet velocity: 17.2 m/s

Source: Babcock Borsig Steinmüller GmbH
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FIRING SYSTEM RETROFIT

- **Wooddust ≠ coal dust**
  - Coarser particle size distribution
  - Higher volatile content, moisture content
  - Different chemical composition (O2,...)
  → different combustion behaviour

- **Boiler’s ability to burn 3 fuels**
  - Natural Gas up to 200 MWth (start-up and transition fuel)
  - Biomass up to 560 MWth (main fuel)
  - Biomass burning without support fuel by self sustaining wooddust flame
  - Blast Furnace Gas up to 560 MWth (back-up for Knippegroen, no cofiring with biomass)
FIRING SYSTEM RETROFIT - BURNERS

- **Erosion protection**
  - Ceramic tiles on the first section of the primary air (Hexagon shaped)
  - Inner side of the SA pipe (in contact with wooddust) protected by using hard facing by welding.

- **Flame guarding by UV and IR detection**

Source: Babcock Borsig Steinmüller GmbH
FIRING SYSTEM RETROFIT - BURNERS

- Air staging on burner-level to reduce NOx formation as with coal firing
- Front fired pulverized fuel burners allowing the reuse of the boiler pressure parts
- Result of CDF simulations on burner level
  - Modification of the section passages on the primary and secondary air to obtain the desired air velocity.
  - Flame stabilizer ring at burner nose
  - No swirl in PA section, adjusted swirl for the SA section

Source: Babcock Borsig Steinmüller GmbH
FIRING SYSTEM RETROFIT — BURNERS MODIFICATIONS

- Adjustable combustion air swirl
- Stabilizer ring on PA at burner nose
- Increase passage section of secondary air

Diagram:
- Primary air + wood dust
- Secondary air I
- Secondary air II
- Core air
FIRING SYSTEM RETROFIT - FURNACE

- CFD simulations on furnace level/
  - Relocation of the 5th row BFG burners on the 2nd row to reduce furnace exit temperature
  - Low temperature re-circulated flue gas (low Oxygen content) to cool down the BFG burners
    - CFD → Air entrances disturb the combustion process and lead to flame instability and too high NOx or CO emissions
  - Combustion air injection at the bottom of the boiler
    - avoid concentration of CO in the hopper (the lowest part of the furnace chamber) to avoid CO corrosion
FIRING SYSTEM RETROFIT - FURNACE

• **Review of the air supply control system**
  - Primary/secondary air balancing and temperature set point in function of the fuel(s) fired (NG, woooddust or NG + woooddust)
  - Primary air control takes into account the higher pressure drop when wood dust is injected in the primary air pipe ("blocking" of PA due to wood dust)
  - \( \text{O}_2 \) control: modifying air excess complement on every burner
  - Primary Air control: 1 fan per biomass level
  - Secondary air control: per burner (K1, K2, K3 settings)

• **OFA**
  - Further NOx reduction through air staging
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- Process key figures
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FLUE GAS TREATMENT

• **MAX Green**: More stringent emission limits imposed

<table>
<thead>
<tr>
<th>Emission limits</th>
<th>Past (coal)</th>
<th>Actual (wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{x} (mg/Nm\textsuperscript{3} @ 6%O\textsubscript{2})</td>
<td>1100</td>
<td>90</td>
</tr>
<tr>
<td>SO\textsubscript{x} (mg/Nm\textsuperscript{3} @ 6%O\textsubscript{2})</td>
<td>2000</td>
<td>75</td>
</tr>
<tr>
<td>CO (mg/Nm\textsuperscript{3} @ 6%O\textsubscript{2})</td>
<td>250</td>
<td>150</td>
</tr>
<tr>
<td>Dust (mg/Nm\textsuperscript{3} @ 6%O\textsubscript{2})</td>
<td>165</td>
<td>15</td>
</tr>
</tbody>
</table>

• **DeSOx**
  - Not required thanks to the very low sulphur content in the fuel fired
FLUE GAS TREATMENT - DENOX

• **NOx formation**
  - Fuel NOx (general 70%)  →  Fuel type
  - Thermal NOx  →  Boiler type
  - Boiler concept: decrease NOx formation by decreasing
    - **Flame & combustion chamber temperature**
    - **Residence time**
    - **Air excess**
    - **Fuel particle size / milling process**

• **NOx emission level**
  - Abatement measures on boiler level
    - **Low Nox burners,**
    - **OFA**
  - Project objective: 70mg/Nm³ @ 6%O2 (20mg margin)  →  additional reduction measures required
NOx abatement
- SNCR not effective in combination with PF technology
- High dust tail-end SCR has been selected

NEW SCR in flue gas line
- First time this technology is applied for 100% wood
- Specific design of the catalyst to take into account specificity of wood pellets firing (higher concentration of volatile poisonous, less fly ash in FG, less SO2 in FG, lower FG temperature, operation with BFG, etc.)
- Principles:
  - Ammonia injection in the flue gas
  - $\text{NO}_x$ to $\text{N}_2$ by Selective Catalytic Reactor
  - 3 active layers + 1 spare layer
  - Catalyst reactivity requires close follow-up
FLUE GAS TREATMENT - DENOX

- NEW SCR in fluegas line
  - Sootblowers to keep the reactor clean
FLUEGAS TREATMENT - ESP

- **Dust abatement**
  - Existing ESP design based on coal combustion
  - Combustion of wood release less dust than coal (6 to 8 times less) → oversized
  - ESP retrofit sufficient to achieve 10 mg / Nm³ @ 11% O₂

- **ESP Retrofit**
  - Replacement of the electrodes
  - Replacement of the collecting plates and hammer
  - Electrical renovation (transformers, control system, etc.)
  - Optimization of the flue gas flow repartition by installation of perforated plates
FLUE GAS TREATMENT - EMISSIONS

- Results
Presentation overview

• Max Green Project description
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• Flue gas treatment
• **Process key figures**
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## PROCESS KEY FIGURES

<table>
<thead>
<tr>
<th></th>
<th>Pure coal (MCR)</th>
<th>Pure biomass (Max Rate)</th>
<th>Pure biomass (NCR)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross electrical output [MW]</strong></td>
<td>279</td>
<td>242.1</td>
<td>216.5</td>
</tr>
<tr>
<td><strong>Net electrical output [MW]</strong></td>
<td>Unknown</td>
<td>223.3</td>
<td>200.0</td>
</tr>
<tr>
<td><strong>De-rating of gross electrical output [%]</strong></td>
<td>Reference</td>
<td>-13%</td>
<td>-28%</td>
</tr>
<tr>
<td><strong>Steam production [t/h]</strong></td>
<td>808</td>
<td>697</td>
<td>600</td>
</tr>
<tr>
<td><strong>Pressure/ temperature [bara, °C]</strong></td>
<td>124.5 / 540.0</td>
<td>124.3 / 536.9</td>
<td>124.1 / 538.0</td>
</tr>
</tbody>
</table>
# PROCESS KEY FIGURES

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</tr>
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<tbody>
<tr>
<td><strong>Fuel LHV [kJ/kg]</strong></td>
<td>20500</td>
<td>17740</td>
<td>17740</td>
</tr>
<tr>
<td><strong>Fuel input [t/h]</strong></td>
<td>126.7</td>
<td>123.4</td>
<td>113.5</td>
</tr>
<tr>
<td><strong>Thermal input [MW]</strong></td>
<td>721.6</td>
<td>608.2</td>
<td>559.3</td>
</tr>
<tr>
<td><strong>Net electrical output [MW]</strong></td>
<td>223.3</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td><strong>Thermal input per burner [MW]/number of burners in operation</strong></td>
<td>30.1 / 24</td>
<td>27.6 / 22</td>
<td>28.0 / 20</td>
</tr>
<tr>
<td><strong>Site Heat Rate (thermal input vs net electrical output) kJ/kWh</strong></td>
<td>Unknown</td>
<td>9804</td>
<td>10067</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36.7%</td>
<td>35.8%</td>
</tr>
<tr>
<td><strong>Emission at boiler outlet (NOₓ) [mg/Nm³ @ 6% O₂]</strong></td>
<td>&lt;1300</td>
<td>198.1</td>
<td>192.8</td>
</tr>
<tr>
<td><strong>Emission at chimney (NOₓ, CO, dust) [mg/Nm³ @ 6% O₂]</strong></td>
<td>&lt;1300, &lt;125, -</td>
<td>74.7, 27.6, 3.3</td>
<td>72.3, 30.0, 3.6</td>
</tr>
</tbody>
</table>
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Conclusion

• Electrabel GDF-SUEZ satisfaction met

• 9 months of reliable operation
  - biomass handling
  - once trough injection (one blower /one injection line / one burner)
  - flue gas treatment
  are the most advanced good practice within the GDF-SUEZ group

• Net electrical output above 200 Mwe

• Areas for improvement for better efficiency and NOx emissions
  - Reduction of the global air excess, better use of OFA’s
  - Improvement of the primary air control
Final result is .....
Thank you for your attention
The Max Green Project

- Unit 4
- Boiler retrofit
- Installation of a Selective Catalytic Reduction of Nox
- ElectroStatic Precipitator retrofit
- Auxiliary boiler installation
The Max Green Project

- Condenser revamping
- Auxiliary circuits modifications
- 3rd biomass milling installation
- Retrofit of I&C
- Modification of EL systems

Unit 4
... handle it safely

- Biomass handling releases dust -> do it safely!

Biomass in pellets or in pulverized forms represent a risk of fire and explosion.