SCR technology for NOx control
CCPP, power generation with highest overall efficiency at lowest emissions limits

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- General
- Products of ANDRITZ air pollution control
- Best Available Techniques (BREF document)
- Emission Limits for CCPP in Europe
- Performance data for Mellach power plant
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ANDRITZ has supplied secondary NOx emission control equipment for various types of firing and fuels (coal, oil, gas, biomass, waste, off gases etc.)

ANDRITZ`s first reference for Selective Catalytic Reduction (SCR) of NOx was started up in the year 1986 at the coal fired power plant Mellach/ Austria.

The strict Austrian emission limit for NOx leads to first integration of SCR for CCPP in Leopoldau, Linz Süd and Donaustadt Unit 03.

ANDRITZ was awarded contracts for 2 x SCR at CCPP GaoAnTun in Beijing/China in 2012.

SCR for Mellach CCPP Unit 10 & 20 was taken over in 2012.
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# Products of ANDRITZ air pollution control

Wide product range for removal of SOx, dust, Hg, heavy metals, NOx, …

<table>
<thead>
<tr>
<th></th>
<th>Wet method</th>
<th>Dry method</th>
<th>DeNOx</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POWER STATIONS</strong></td>
<td>Wet limestone FGD</td>
<td>Dry Sorption Turbo CDS / TurboSorp</td>
<td>SCR (high dust application)</td>
</tr>
<tr>
<td></td>
<td>FGD plus Mercury removal</td>
<td>Mercury removal</td>
<td><strong>SCR for combined cycle power plants (CCPP)</strong></td>
</tr>
<tr>
<td></td>
<td>Sea Water FGD</td>
<td>Dust removal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CO2 absorption</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INDUSTRY</strong></td>
<td>Wet FGC (calcium and NaOH based)</td>
<td>Dry Sorption TurboSorp</td>
<td>SCR (low dust / clean gas application)</td>
</tr>
<tr>
<td>incl. EfW and biomass</td>
<td>Multistage scrubber Combined systems</td>
<td></td>
<td></td>
</tr>
</tbody>
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### BAT (Best Available Technique) for CCPP emission limits

<table>
<thead>
<tr>
<th>Plant Type (new large combustion plants, LCP)</th>
<th>Emission level associated with BAT (mg/m³n)</th>
<th>O₂ level (%)</th>
<th>BAT options to reach this level</th>
</tr>
</thead>
<tbody>
<tr>
<td>New CCPP without supplementary firing</td>
<td>NOx 20-50, CO 5-100</td>
<td>15</td>
<td>Dry low NOx premix burners or SCR</td>
</tr>
<tr>
<td>New CCPP with supplementary firing</td>
<td>NOx 20-50, CO 30-100</td>
<td>Plant spec.</td>
<td>Dry low NOx premix burners and low NOx burners for the boiler part or SCR or SNCR</td>
</tr>
</tbody>
</table>
Dry Low NOx burner (DLN)

**DLN basic characteristic:** mixing of combustion air and fuel before combustion

- ⇒ homogeneous temperature distribution
- ⇒ lower flame temperature
- ⇒ lower NOX emissions

**CCPP Mellach:**
- Siemens SGT5-4000F(6) with annular combustion chamber
- 24 HR3-burners (PMP)
  - 2-stage hybrid-burner
  - premix-pilotgas (PMP): mixing of pilotgas and air in axial swirler => NOx-reduction
  - premix-gas: mixing of premix-gas and air in diagonal swirler => NOx-reduction

[Figure: Siemens AG]
Dry Low NOx burner (DLN)

**Premix- Gas Nozzle**

**Pilot- Gas Nozzle**
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Emission limits for CCPP in Europe

<table>
<thead>
<tr>
<th>Plant</th>
<th>Emission limit (mg/m³ n,dry)</th>
<th>O₂ level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOₓ</td>
<td>NH₃</td>
</tr>
<tr>
<td>EU-directive LCP</td>
<td>50 *</td>
<td>-</td>
</tr>
<tr>
<td>Austrian Law (LRV-K)</td>
<td>35</td>
<td>10 (at 0 % O₂)</td>
</tr>
<tr>
<td>Permit for CCPP Mellach</td>
<td>20 ***</td>
<td>10 (at 0 % O₂)</td>
</tr>
</tbody>
</table>

*) valid for power output at ISO conditions > 50 MW thermal, the emission limits apply for loads higher than 70 % resp.:

- NOₓ < 75 mg/Nm³ (efficiency of the gas turbine determined under ISO base load conditions) in the following cases:
  - Gas turbines used in a combined heat and power generation with an overall efficiency higher than 75 %;
  - Gas turbines used in combined cycle plants having an overall annual average electrical efficiency higher than 55 %.

**) at 100 % load

***) from minimum load to 100 % load
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### Performance data for Mellach power plant

<table>
<thead>
<tr>
<th>Data</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net electrical power output Unit 10</td>
<td>MWel</td>
<td>421</td>
</tr>
<tr>
<td>Net electrical power output Unit 20</td>
<td>MWel</td>
<td>417</td>
</tr>
<tr>
<td>Max. total district heating output</td>
<td>MWth</td>
<td>400</td>
</tr>
<tr>
<td>Net efficiency Unit 10 (river water cooling)</td>
<td>%</td>
<td>59.6</td>
</tr>
<tr>
<td>Net efficiency Unit 20 (cooling tower)</td>
<td>%</td>
<td>58.7</td>
</tr>
<tr>
<td>Fuel conversion efficiency (400 MW district heating)</td>
<td>%</td>
<td>81</td>
</tr>
</tbody>
</table>
Input/output of CCPP Mellach

- Synergies: existing infrastructure
- River water
- Electricity lines
- District heat
- Consumables
- Cooling system
- Cooling tower
- Fuel gas

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## Performance data for Mellach power plant

### Key Data

**UNIT:** 2 x SCR for CCPP Mellach/AUSTRIA  
**CUSTOMER:** VERBUND Thermal Power  
**Start-Up:** 2011/12

**TECHNOLOGY/SUPPLY:**  
2 x SCR integrated into HRSG

**Fuel:** natural gas

**Capacity:** total 838 MWel

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flue Gas Flow:</strong></td>
<td>2 x 2,110,000 m³/h (std&lt;sub&gt;wet&lt;/sub&gt;)</td>
</tr>
<tr>
<td><strong>NO&lt;sub&gt;x&lt;/sub&gt; inlet:</strong></td>
<td>61.6 mg/m³ (std&lt;sub&gt;dry&lt;/sub&gt;, 15% O&lt;sub&gt;2&lt;/sub&gt;)</td>
</tr>
<tr>
<td><strong>NO&lt;sub&gt;x&lt;/sub&gt; outlet:</strong></td>
<td>&lt;20 mg/m³ (std&lt;sub&gt;dry&lt;/sub&gt;, 15% O&lt;sub&gt;2&lt;/sub&gt;)</td>
</tr>
<tr>
<td><strong>NH&lt;sub&gt;3&lt;/sub&gt;- slip:</strong></td>
<td>&lt;10 mg/m³ (std&lt;sub&gt;dry&lt;/sub&gt;, 0% O&lt;sub&gt;2&lt;/sub&gt;)</td>
</tr>
<tr>
<td><strong>Reducer:</strong></td>
<td>Anhydrous ammonia</td>
</tr>
</tbody>
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SCR for Mellach Power Plant

- With the following reactions on the catalyst surface
  
  - $4 \text{NO} + 4 \text{NH}_3 + \text{O}_2 \rightarrow 4 \text{N}_2 + 6 \text{H}_2\text{O}$
  - $2 \text{NO}_2 + 4 \text{NH}_3 + \text{O}_2 \rightarrow 3 \text{N}_2 + 6 \text{H}_2\text{O}$

- Decomposition of dioxins and furans (PCDD, PCDF)

- Side reaction
  
  - $2 \text{SO}_2 + \text{O}_2 \rightarrow 2 \text{SO}_3$
SCR for Mellach Power Plant

**AIG design:**
- Low flue gas pressure loss (< 0.3 mbar)
- 32 adjustable AIG sections to meet the required NH₃/NOx molar ratio upstream catalyst
- Number of nozzles optimized according to distance between AIG and catalyst via CFD

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Ammonia distribution upstream catalyst for two control zones (worst cases) acc. CFD study:

<table>
<thead>
<tr>
<th>Description</th>
<th>Load</th>
<th>Location</th>
<th>Result</th>
<th>Minimum requirement acc. catalyst supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃ concentration deviation (Case 2A: control zone A1)</td>
<td>100%</td>
<td>1st catalyst layer inflow cross sectional area</td>
<td>100% of the values within a range of -6.9% / +6.8% (CoV = 2.8%)</td>
<td>80% of the values within a range of +/-10% and the remaining 20% of the values within a range of +/-20%</td>
</tr>
<tr>
<td>NH₃ concentration deviation (Case 2B: control zone A5)</td>
<td>100%</td>
<td>1st catalyst layer inflow cross sectional area</td>
<td>100% of the values within a range of -4.9% / +8.1% (CoV = 2.1%)</td>
<td>80% of the values within a range of +/-10% and the remaining 20% of the values within a range of +/-20%</td>
</tr>
</tbody>
</table>

CoV = coefficient of variation = standard deviation / mean value
SCR for Mellach Power Plant

AIG design:
- Co-current injection of ammonia
- Duct dimension 21,9 x 11,6 m
- 32 adjustable AIG sections of approx. 8 m² each
- Distance from AIG to catalyst inlet > 2,5 m

Standard deviation of NH₃-concentration versus distance between AIG and catalyst (based on CFD study)
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AIG tuning flaps:

- Upper header of AIG
- Lower header of AIG
- Mixture gas fans

Source: Fotostudio Pachernegg, Graz
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Catalyst design:
- Operation flue gas temperature from 300 to 350 °C
- GT operation with natural gas only
- Performance lifetime 24000 operational hours
- Catalyst pitch is 3 mm (50 x 50 cells per element)
- Catalyst length 285 mm
- Catalyst pressure loss < 3,4 mbar
- 132 (12 x 11) modules installed on steel frame, supported on top of HRSG
- 6 modules (12 x 6) are stapled on each other and screwed, then intermediate supporting frame is installed for further 12 x 5 modules
- Space between modules and HRSG duct is sealed by insulation pads, all modules are screwed together
- Space is kept free upstream for additional 50% catalyst
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AIG erection (8 pieces per unit):
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Catalyst module installation:

Insulation pad
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Catalyst module erection (132 modules per Unit):
DeNOx System for HRSG

Catalyst modules installed:

- Net measuring point
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Ammonia dosing station:
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Commissioning of unit 10 & 20:

- NOx downstream GT far below design figure (design 61 mg/m³ NOx, dry, 15 vol% O₂)

- CO downstream GT at base load at 2 mg/m³ far below emission limit (35 mg/m³)

- NO₂/NOx ratio measured approx. 20% at 100 % GT load

- AIG with 32 adjustable fields, NOx profile can be adjusted accurately

- Ammonia flow control valve was changed to smaller dimension due to much lower ammonia mass flow than actually designed
SCR for Mellach Power Plant

Commissioning of unit 10:

Standard deviation 1.5 mg/nm³ NOx

Standard deviation 0.7 mg/nm³ NOx
First year operating experience with SCR CCPP Mellach

- NOx-value stable below 20 mg/Nm³
  - at 100 % load
  - over entire ambient temperature range

- NOx-value can be kept below 20 mg/Nm³ down to approx. 50 % load (min. load)

- pressure drop: approx. 3.2 mbar at 100% load (=> power output reduction due to pressure drop approx. 0.3 MWel / 0.1 %)
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Selected SCR References

PS Leopoldau (Austria)
Capacity: 170 MWel
Fuel: Natural gas
Flue gas volume: 1,400,000 Nm³/h
NOx content: 170 mg/Nm³
Removal efficiency: 80 %
Start-up: 1988

PS Donaustadt (Austria)
Capacity: 350 MWel/ 250 MW district heating
Fuel: Natural gas
Flue gas volume: 1,940,000 Nm³/h
NOx content: 68 mg/Nm³
Removal efficiency: 50 %
Start-up: 2001
Selected SCR References

CCPP Mellach (Austria)

- Capacity: 838 MWel
- Fuel: Natural gas
- Flue gas volume: 2 x 2,110,000 Nm³/h
- NOx content: 61.6 mg/Nm³
- Removal efficiency: 67%
- Start-up: 2012

PS GaoAnTun (China)

- Capacity: 836 MWel
- Fuel: Natural gas
- Flue gas volume: 2 x 2,055,000 Nm³/h
- NOx content: 51.3 mg/Nm³
- Removal efficiency: 85%
- Start-up: 2013 / 2014
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SCR technology for NOx control—perfect APC solution for HRSG’s, Summary:

- Due to the strict NOx emission limit of 20 mg/m³n and the NOx raw gas guarantee given from GT supplier it was necessary to implement a SCR system in Mellach power station.

- NOx raw gas concentration from GT are much lower than guaranteed values from SIEMENS, SCR system in Mellach is oversized but still necessary.

- Latest AIG and catalyst design leads to lowest pressure loss of SCR system (<3.2 mbar at full load), this results in a loss of power output of not more than approx. 0.3 MW_{el}.

- Distance between AIG and catalyst can be reduced from 3 m down to 2.5 m for further CAPEX reduction.

- CCPP can meet lowest emission limits (CO < 2mg/m³n and NOx < 20 mg/m³n) and efficiency is still kept high, helping to cut down CO₂ emission (60 % less CO₂ emission compared to coal fired power plant).
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