Basics of flue gas cleaning

ENTRAIN | AEE INTEC | Harald Schrammel, Christian Ramerstorfer
CONTENT

- Particle removal (dust precipitation)
  - (Multi-)cyclone
  - Electrostatic precipitator (ESP)
  - Baghouse filter
- Flue gas condensation
- Nitrogen oxides reduction (De-NOx)
  - Selective non catalytic reduction (SNCR)
  - Selective catalytic reduction (SCR)
CYCLONE/MULTI-CYCLONE

Cyclone

- Centrifugal separator
- Coarse fly ash precipitation (particles > 5 µm)
- Wide operation window (temperature up to > 1000 °C)
- Usually designed as multi-cyclone
- Dust load downstream < 150 mg/Nm³ possible

State of the art for industrial biomass combustion plants


source: multi-cyclone from Scheuch at Holzwärme Grindelwald (CH) in Focus Technik, Ausgabe 1, 2011, Schmid energy solutions
ELECTROSTATIC PRECIPITATOR (ESP) OVERVIEW

- Electrostatic particle separation
  - Suitable for very small particles (≥ 1 µm)

- Dry (dESP) or wet (wESP) operation possible
  - dESP state of the art for plants which have to meet dust emissions < 50 mg/Nm³
  - wESP for application downstream flue gas condensation unit

- About 120 °C minimum operation temperature

- Safety measures regarding high voltage operation (in the range of 20 to 100 kV) have to be considered

Source: Evan Mason - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=20315619
**ELECTROSTATIC PRECIPITATOR EXAMPLES**

➢ ESP at the biomass district heating plant (4 MW) in Maria Gugging (Lower Austria)

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1. GAS DISTRIBUTION SYSTEM
2. IONISING ELECTRODES
3. COLLECTING ELECTRODES
4. RAPPING MECHANISMS
5. HIGH-VOLTAGE UNIT
6. DUST DISCHARGE SYSTEM
7. TRACE HEATING
8. MAINTENANCE OPENINGS

source: Scheuch Electrostatic Precipitators (product folder)

EXAMPLE FLUE GAS CLEANING SYSTEM WITH MULTI CYCLONE AND ESP

Man hole (maintenance access)

Electrostatic precipitator

Multi-cyclone

Flue gas ventilator

Rotary valve

De-ashing system

➢ separated ash fractions for cyclone/ESP
**BAGHOUSE FILTER**

- Fabric filter (adhesion separator)
- Almost 100% dust removal efficiency (independent of particle size)
- Dust load cleaned gas $< 5 \text{ mg/Nm}^3$
- About 180 °C minimum operation temperature
- Dust removal from filter bags into de-ashing system by frequent back-pulsing with compressed air (impuls cleaning system)
- Beyond state of the art (applied for waste wood comb.)
FLUE GAS CONDENSATION (SCRUBBERS)

- Primarily heat recovery (sensible and latent heat - feasibility mainly depends on moisture content of the fuel and return flow temperature from the district heating grid)
- Additional positive effect on dust emissions precipitation of fly ash upstream is recommended (dESP) in order to reduce problems regarding condenser corrosion and condensate composition
- Dust load gas outlet < 50 mg/Nm$^3$ (without ESP upstream)
- Almost 100% coarse fly ash removal (particle size > 1 µm)
- Stainless steel heat exchanger (condenser)
- Periodic cleaning of the heat exchanger with process water/option for scrubber (quench)
EXAMPLE FLUE GAS CLEANING SYSTEM WITH ESP AND FLUE GAS CONDENSATION

➢ Plant with 5 MW heat output (incl. condensation)

source: flue gas cleaning system from Scheuch at Holzwärme Grindelwald (CH), in Focus Technik, Ausgabe 1, 2011, Schmid energy solutions
## Overview Dust Precipitation Technologies

<table>
<thead>
<tr>
<th></th>
<th>Cyclones</th>
<th>ESP (dry)</th>
<th>Baghouse filter</th>
<th>Flue gas condensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size</td>
<td>&gt; 5 µm</td>
<td>≥ 1 µm</td>
<td>all</td>
<td>≥ 1 µm</td>
</tr>
<tr>
<td>Dust content cleaned gas [mg/Nm³, 11% O₂]</td>
<td>120 - 200</td>
<td>5 - 50</td>
<td>1 - 5</td>
<td>25 - 50</td>
</tr>
<tr>
<td>Operation temperature min (max) [°C]</td>
<td>(&gt; 1000)</td>
<td>120 - 130 (300)</td>
<td>180 - 220 (280)</td>
<td>(40 - 60)</td>
</tr>
<tr>
<td>Pressure loss [mbar]</td>
<td>6 - 15</td>
<td>1.5 - 3</td>
<td>10 - 20</td>
<td></td>
</tr>
<tr>
<td>Options</td>
<td>multi-cyclone</td>
<td>wet ESP</td>
<td>dry sorption (HCl, SOx, Hg, dioxins)</td>
<td>scrubber (quench)</td>
</tr>
</tbody>
</table>
FUEL NITROGEN - NOX IN THE FLUE GAS
DENOX TECHNOLOGIES

explanations: NOx calculated as NO\textsubscript{2} (d.b., 11 vol-% O\textsubscript{2})
source: I. Obernberger, THE PRESENT STATE AND FUTURE DEVELOPMENT OF INDUSTRIAL BIOMASS COMBUSTION FOR HEAT AND POWER GENERATION, Figure 24

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**Primary measures**
- low-NO\textsubscript{x} comb. with air staging

**Secondary measures**
- SNCR process
- SCR process
SELECTIVE NON CATALYTIC REDUCTION (SNCR)

- Injection of Ammonia (NH₃) or Urea (CO(NH₂)₂) into the secondary combustion zone
- Reaction of nitrogen oxides (with injected reducing agent) to N₂ directly in the flue gas; by-products: H₂O (and CO₂)
- Temperature range 850°C to 950°C
- Reduction efficiencies of 60 to 70 %
- NOx downstream < 100 mg/Nm³
- Non-reacted Ammonia is emitted (ammonia slip < 10 mg/Nm³)
- Cost effective solution

source: CODEL International Ltd
SELECTIVE CATALYTIC REDUCTION (SCR)

- (similar to NOx reduction technology applied for Diesel engines in cars)
- Reduction of NOx with Ammonia using a catalyst material
- Temperature range 170°C to 450°C
- Reduction efficiencies of 80 to 95 %
- NOx downstream lower than with SNCR
- Ammonia slip in the range of 1 to 5 mg/Nm³
- Issues with catalyst deactivation for biomass combustion (due to potassium and other alkali compounds in the flue gas)
SUMMARY

- Flue gas cleaning is an important plant component
  - Authority, operating permit
  - Public acceptance
- It requires special attention and profound planning
  - Evaluation of local legal emission limits
  - Selection of suitable technology
  - Consider space demand and costs
THANK YOU!

Harald Schrammel, Christian Ramerstorfer
AEE INTEC
Feldgasse 19, A-8200 Gleisdorf

www.interreg-central.eu/entrain
h.schrammel@aei.at, c.ramerstorfer@aei.at
+43 3112 5886-232, +43 3112 5886-262

@ENTRAIN_project
@AEE_INTEC