Recent developments in particulate control

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Introduction: Emission Limit Values (ELV) in 2012

- UK (old)
- Germany
- UK (new build)
- China (mainland, from 2012)
- USA (some states)
- China (urban, from 2012)
- Isogo power plant

Particulate matter (mg/m³)
Introduction: Times are changing...

Different coals

Biomass firing

Cyclic operation

Emission reduction technologies

Space restrictions
Introduction: Times are changing...

- Wet flue gas desulphurisation (wet FGD)
- Further reduce fly ash from particulate control by ~60%
- Power plant in China
  - Dry ESP outlet 23.4 mg/m³
  - Wet FGD outlet: 6.2 mg/m³
Electrostatic precipitator (ESP)

- ~80-90% of fleet
- 130-180°C (cold side)
- Operation:
  - Charging
  - Migrating
  - Accumulating
  - Rapping

Low resistivity particulates:
- Does not migrate/accumulate

High resistivity particulates:
- Results in sparking

Power Supply
- ~45-85kV
ESP: Maintenance & Upgrade

- **Discharge electrodes**
  - Upgrade to rigid pipe design

- **Plate electrodes:**
  - Wider plate spacing (23-30 cm to 41-46 cm)
  - Increase plate width and height (aspect ratio of 0.8)

- **Rappers:**
  - Upgrade and add more
  - Minimise air leakage
Traditional methods (physical models, tests)
- Time consuming
- Expensive

Computational fluid dynamics (CFD)
- Quick
- Lower cost

SteagEnergy Services, Iskenderun power plant, 2012
- ESP outlet emissions from 65 mg/m³ to 55 mg/m³
ESP: Power supply and control

- Conventional T-R sets superseded by modern switched mode power supplies (SMPS)
- Basic on/off control superseded by sophisticated microprocessor based controls (MBC)
- Waigaoqiao power station: Outlet emissions from 25 to 12 mg/m³ and auxiliary load from 871 to 266 kW
ESP: Rebuilding & adding fields

Rebuild of Aiysis coal fired power plant (China):
- 265 mg/m³ reduced to 31.5 mg/m³

Statistical analysis:
- 86% of existing ESP upgraded to meet 30 mg/m³ ELV
ESP: Flue gas conditioning (FGC)

- Low sulphur coal = high fly ash resistivity
- FGC chemicals: Sulphur trioxide and ammonia

- 2012: Guangdong Pinghai power station, SO$_3$ FGC system:
  - Moderate capital cost & short outage period
  - ELV of 45 mg/m$^3$ met
  - 99.65% collection efficiency
## Retrofit and new build ESP

<table>
<thead>
<tr>
<th>ESP variation</th>
<th>Main advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colder side ESP</td>
<td>- Lower parasitic load</td>
</tr>
<tr>
<td></td>
<td>- Smaller site footprint</td>
</tr>
<tr>
<td>Moving electrode ESP</td>
<td>- Effective ‘rapping’ for highly resistive ash</td>
</tr>
<tr>
<td></td>
<td>- Smaller site footprint</td>
</tr>
<tr>
<td>Wet ESP</td>
<td>- Aerosol capture</td>
</tr>
<tr>
<td></td>
<td>- Plume free stack</td>
</tr>
<tr>
<td></td>
<td>- Smaller site footprint</td>
</tr>
<tr>
<td>Electromechanical double-zone ESP</td>
<td>- High collection efficiencies with high and low resistivity fly ash</td>
</tr>
</tbody>
</table>
Colder side ESP

- Operates at 90-100°C
- Increases specific collecting area, decreases resistivity and parasitic load
- Increases fouling and corrosion
- Tosho Nanyo (Japan): Colder side ESP by Alstom:
  - 6.7 mg/m³ emission
  - 50% power reduction
- Mitsubishi Heavy Industries installed on >10 GW of Japanese coal plant
Moving electrode ESP (MEEP) Hitachi

- Rapping causing excessive re-entrainment
- Rapping replaced with brushing in last fields
- Reduces re-entrainment
- Smaller site footprint
- 99.4% with highly resistive fly ash
- 30 Installation in Japan
Wet ESP

- Water washes off fly ash from plate electrodes
- High collection of all resistivity fly ash
- Can condense out water for a plume-free stack
- Incorporated into wet scrubbers = multi-pollutant control
Electromechanical double-zone ESP

- Fujian LongKing
- Separate zones and power supply
- ~80 kV DC
- 99.96% collection efficiency
- 74 Installations in China in 2011
Cross Flow ESP (Alstom)
Fabric Filters (FF)

- 120 to 180°C
- Essentially a vacuum cleaner
- ‘High O&M costs
- Pulse jet’ cleaning
**Table 3 Fabric types (Stark, 2012; Popovici, 2011; Johnson and McMenus, 2011)**

<table>
<thead>
<tr>
<th>Name</th>
<th>Maximum operating temperature</th>
<th>Remarks</th>
<th>Relative cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic felt (PAN or polyacrylnitrile)</td>
<td>130°C</td>
<td>Lowest maximum operating temperature.</td>
<td>£</td>
</tr>
<tr>
<td>PPS felt (Polyphenylenesulphide)</td>
<td>190°C</td>
<td>Degrades at higher temperatures with &gt;12% oxygen. Resist chemical and thermal attack. Effective when laminated with ePTFE.</td>
<td>££</td>
</tr>
<tr>
<td>Aramid felt</td>
<td>204°C</td>
<td>Not as capable as PPS in chemically active flue gas</td>
<td>££££</td>
</tr>
<tr>
<td>Woven fibreglass</td>
<td>260°C</td>
<td>Fragile, require tight tolerances. Suitable with reverse-air cleaning systems.</td>
<td>£</td>
</tr>
<tr>
<td>P84 felt by Evonik Fibres (polyimide, PI, multiloval, tri-lobal)</td>
<td>260°C</td>
<td>Dimensional stability over 204°C but requires oversizing of filter to maintain proper bag to cage fit. Small pore size of 0.5-1 μm (traditional needle felt scrim have a pore size of 15-20 μm).</td>
<td>££££</td>
</tr>
<tr>
<td>Pleated elements</td>
<td>Dependant on scrim fabric</td>
<td>A/C &lt;3.5:1. Applicable only when additional cloth area is needed to lower A/C ratio and eliminate inlet abrasion.</td>
<td>££££££</td>
</tr>
</tbody>
</table>
### FF: Treatments and coatings

**Table 4  Fabric treatments and coatings** (Stark, 2012)

<table>
<thead>
<tr>
<th>Treatment name</th>
<th>Maximum operating temperature</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTFE coating (not membrane)</td>
<td>260°C</td>
<td>Improve filter cake release, sacrifices ability to maintain consistent airflow leading to increased cleaning frequency or high pressure loss.</td>
</tr>
<tr>
<td>Expanded PTFE (ePTFE) membrane</td>
<td>260°C</td>
<td>Laminated to collection surface, average pore size of this scim is 0.5 to 1 µm, low pressure drop with long filter bag lifetime.</td>
</tr>
<tr>
<td>Singeing</td>
<td>–</td>
<td>Removes some fabric surface area, improves filter cake release</td>
</tr>
<tr>
<td>Teflon</td>
<td>–</td>
<td>Resistance against acid attack. High pressure drop and potential blinding with cohesive particulate.</td>
</tr>
<tr>
<td>Glazing and silicone</td>
<td>–</td>
<td>Improve cake release</td>
</tr>
<tr>
<td>Calcium hydroxide</td>
<td>–</td>
<td>Most common</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>–</td>
<td>Most common</td>
</tr>
</tbody>
</table>

**PPS felt (fabric) laminated with ePTFE (coating) is effective**
FF: Microprocessor control

- Cleaning schedule

- Only clean bags when necessary
  - Prolong lifetime (minimum abrasion)
  - Maximum particulate capture from filter cake

- Random cleaning order minimizes re-entrainment
Traditional methods (physical models and in situ trial and improvement tests)

- Time consuming
- Expensive

Computational fluid dynamics (CFD)

- Quick
- Lower cost
Sorbent injection: Multi-pollutant control

- Sorbent injection upstream of the FF
- Reaction in filter cake
- Activated carbon for mercury / ammonia for NOx / sodium based sorbent or lime for sulphur dioxide
- Contaminated fly ash not sold, treated or landfilled
Hybrid ESP/FF Systems

**ESP**
- Low pressure drops
- Low costs all round

**FF**
- High collection efficiency (will capture rapping peaks)
- Multi-pollutant capture

Power Supply

\[ \text{~45-85kV} \]
**Electric Power Research Institute (USA)**

**COHPAC**
- Compact hybrid particulate collector
- Small FF downstream of ESP
- Proven technology

**TOXECO**
- COHPAC coupled with sorbent injection
- Successful small scale demonstration
Fujian LongKing (China)

- Electrostatic-fabric integrated collector (EFIC)

660 MWe unit at Boasham power plant (China):
- 99.8% collection efficiency
- 30 mg/m³ outlet emission
## Summary

<table>
<thead>
<tr>
<th></th>
<th>Cold side dry ESP</th>
<th>FF (pulse jet)</th>
<th>Hybrid ESP/FF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection efficiency (%)</td>
<td>99.81</td>
<td>&gt;99.95</td>
<td>99.80</td>
</tr>
<tr>
<td>Pressure drops</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Parasitic load</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Reliability</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Other pollutants *could contaminate fly ash</td>
<td>No</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td>Capital cost of new build</td>
<td>££</td>
<td>££££</td>
<td>£££</td>
</tr>
<tr>
<td>Capital cost of retrofit, given old ESP installed</td>
<td>£ (upgrade)</td>
<td>££ (install in ESP case)</td>
<td>£ (last field) ££ (polishing)</td>
</tr>
<tr>
<td>Operating and maintenance cost</td>
<td>££</td>
<td>££££</td>
<td>£££</td>
</tr>
</tbody>
</table>
Thank you for listening

Questions?

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