Meeting Increasingly Stringent Emissions Regulations for New Coal Fired Power Plants

- Emissions limits for Coal Fired Power Plants – status and trends
- Boiler and emission controls technologies – current state-of-the-art
New Build Coal Fired Power Plant Trends
Power Plant Orders > 250MW

All coal fired power plant orders for unit sizes above 250MWe (Gross)
[Raw data from McCoy Power Reports]
### New Build Coal Fired Power Plant Trends
Reducing Stack Emissions Limits

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>IED / European Standard</th>
<th>World Bank (WB) IFC, (1)</th>
<th>CHINA GB 13223-2011</th>
<th>TURKEY</th>
<th>INDONESIA</th>
<th>INDIA³,⁴</th>
<th>SOUTH KOREA²</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>150 mg/Nm³</td>
<td>200 mg/Nm³</td>
<td>100 mg/Nm³ (6)</td>
<td>200 mg/Nm³</td>
<td>750 mg/m³ (10)</td>
<td>(300 mg/Nm³) 100 mg/Nm³</td>
<td>164 mg/Nm³ (80 ppm)</td>
</tr>
<tr>
<td>SO2</td>
<td>150 mg/Nm³</td>
<td>200 mg/Nm³</td>
<td>100 mg/Nm³ (6)(9)</td>
<td>200 mg/Nm³</td>
<td>750 mg/m³ (10)</td>
<td>(200 mg/Nm³) 100 mg/Nm³</td>
<td>228.8 mg/Nm³ (80 ppm)</td>
</tr>
<tr>
<td>PM</td>
<td>10 mg/Nm³</td>
<td>30 mg/Nm³</td>
<td>30 mg/Nm³ (8)</td>
<td>30 mg/Nm³</td>
<td>100 mg/m³ (10)</td>
<td>(50 mg/Nm³) 30 mg/Nm³</td>
<td>20 mg/Nm³</td>
</tr>
<tr>
<td>HG</td>
<td>Not defined / 0.03 mg/Nm³ (5)</td>
<td>Not defined</td>
<td>0.03 mg/Nm³ (7)</td>
<td>Not defined</td>
<td>Not defined</td>
<td>0.03 mg/Nm³</td>
<td>Not defined</td>
</tr>
</tbody>
</table>

*mg/Nm³ = milligrams per normal cubic meter at 6%O₂, 273.15 K and 1.013 bar except Indonesia – note 10*

1. Emission guidelines from World Bank IFC, 2008 Environmental, Health, and Safety Guidelines. (for DA areas (DA = Degraded Airshed = poor air quality))
2. Generation capacity > 500MWe, from 1st Jan 2005 to 2016
4. Bold values for new plant after Jan 01 2017 Plant > 500MWe
5. From German Regulation / 13. BimSchV
6. Increased to 200 in certain provinces.
7. From 2015
8. Reduced to 20 for certain regions.
9. Reduced to 50 for certain regions.
10. mg/Nm³ = milligrams per normal cubic meter at 7%O₂ 25°C and 1.013 bar.
New Build Coal Fired Power Plant Trends
Reducing Stack Emissions Limits

Future Ultra-Low Emission Limits

- Drive to even lower emission limits for NOx, SOx and PM – eg new South Korean limits:
  - PM – 5 mg/Nm$^3$
  - SO$_2$ – 25ppm (71.5 mg/Nm$^3$)
  - NO$_2$ – 15ppm (30.8 mg/Nm$^3$)

PM$_{2.5}$

- In most countries particulate matter from coal fired power plant is not distinguished by size at the stack, but may be distinguished in ambient air.
- PM$_{2.5}$ concern because of possibility for deep penetration to lungs.
- PM$_{2.5}$ classified as primary and secondary:
  - Primary is filterable fine particulate matter (eg fly-ash)
  - Secondary is formed by reactions of other pollutants (eg SOx, NOx, NH$_3$)
Doosan State-of-the-Art Technologies for Boilers and Emission Controls
Ultra-Supercritical Boiler Technologies for High Efficiency

- Highest efficiency achieved via steam cycle optimisation by a combination of:
  - USC steam parameters at turbine inlet
  - Regenerative feedwater heating to increase boiler feed water temperature
  - Condenser pressure / LP Turbine last stage blade optimisation

- Emission reduction resulting from higher efficiency is substantial:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Supercritical</th>
<th>Ultra-Supercritical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Steam Pressure / Temperature</td>
<td>245 bar / 565 C</td>
<td>280 bar / 600 C</td>
</tr>
<tr>
<td>Reheat Steam Pressure / Temperature</td>
<td>40 bar / 565 C</td>
<td>60 bar / 610 C</td>
</tr>
<tr>
<td>Net Plant Efficiency (% LHV)</td>
<td>41.8</td>
<td>44.0</td>
</tr>
<tr>
<td>Emissions (CO₂, SO₂, NOx, PM)</td>
<td>Base</td>
<td>-5%</td>
</tr>
</tbody>
</table>

All coal fired power plant orders for unit sizes above 250MWe (Gross) [Raw data from McCoy Power Reports]
Ultra-Supercritical Boiler Technologies for High Efficiency

GHECO-ONE, THAILAND
1 x 700MW
SH 569°C/ RH 569°C 255 atg
Sub-bituminous Coal

AIN SOKHNA, EGYPT
2 x 650MW
SH 540°C/ RH 540°C 265 atg
Mazout Oil

YEONG HEUNG 5,6, S. KOREA
2 x 870MW
SH 569°C/ RH 596°C 251 atg
Sub-Bituminous and Bituminous Coals

SHINBORYEONG, S. KOREA
2 x 1000MW
SH 613°C/ RH 624°C 274 atg
Sub-Bituminous and Bituminous Coals

EVOLUTION IN STEAM CONDITIONS
Ultra-Supercritical Boiler Technologies for High Efficiency

Boiler Features – 1000 MW Design

- Vertical mills with dynamic classifiers
- Proven Two pass arrangement (Pendent and Horizontal)
- Once-Through boiler technology with proven lower spiral wall tube and upper vertical wall tube
- Stable RH steam temperature control for wide range coals with flue gas bias damper – higher efficiency at lower load
- Proven capability for rapid starting with two shift operation
  - 2 Axial FD fans
  - 2 Axial ID fans
  - 2 Axial PA fans
  - 2 Trisector AHs
- High performance Low NOx burner And OFA

DOOSAN
Current USC steam parameters require a spectrum of ferritic and austenitic alloy steels for highest temperature components.

Material selection mainly depends on:
1. Strength as a function of tensile and creep properties
2. Resistance to steam side oxidation
3. Careful design of flow distribution can reduce operating conditions

Tube Temp. (Outlet Header Side)
State-of-the-Art Emissions Controls Technologies

Typical Arrangement on Modern Plant

- **Primary NOx Control**
  - Low-NOx Combustion System

- **Secondary NOx control**
  - SCR

- **Electro-static Precipitator or Bag Filter**

- **Flue Gas Desulphurisation and Gas-Gas Heater**
Project fuel ranges become ever wider to ensure flexibility to accommodate changes in international coal sourcing.

Mature low NOx combustion systems deliver primary NOx reduction:

- Current performance expectation circa 200 to 300 mg/Nm³ NOx with <3% Carbon in Ash
State-of-the-Art Emissions Controls Technologies
Primary NOx Control
State-of-the-Art Emissions Controls Technologies
SCR for NOx Control

- Capable of up to 80-90% NOx reduction
State-of-the-Art Emissions Controls Technologies
Flue Gas Desulphurisation

Wet Lime / Limestone FGD
- 205 absorbers installed (110 absorbers in China)
- 71 GW_e total capacity
- Maximum absorber size: 1,000 MW_e

Seawater FGD
- 14 absorbers installed
- 8 GW_e total capacity
- Maximum absorber size: 700 MW_e

Circoclean® FGD / FGC
- 90 reactors installed (18 reactors in China, 26 in the USA)
- 13 GW_e total capacity
- Maximum reactor size: 305 MW_e
### Oxy-Coal

<table>
<thead>
<tr>
<th>Full Scale Burner Test</th>
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<tbody>
<tr>
<td>40MWt</td>
</tr>
<tr>
<td>Safe and stable operation over a wide operational envelope and smooth transition between air and oxyfuel firing achieved.</td>
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</tbody>
</table>

### PCC

<table>
<thead>
<tr>
<th>Pilot Test, 1 t/day</th>
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<tbody>
<tr>
<td>Ability to test wide range of coals and other fuels</td>
</tr>
<tr>
<td>High degree of flexibility and accuracy to test wide range of solvents and other modifications</td>
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</tbody>
</table>

### Pilot Plant Test – Vattenfall Europe

<table>
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<tr>
<th>Ferrybridge, 100 t/day</th>
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<tbody>
<tr>
<td>Largest post carbon capture demonstration plant in the UK</td>
</tr>
<tr>
<td>Long-term testing and validation of process and solvent performance</td>
</tr>
<tr>
<td>Evaluate transient conditions and process control</td>
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<tr>
<td>Extensive monitoring planned</td>
</tr>
</tbody>
</table>
Conclusions

- Energy demand growth in Asia, India and some other regions continues to drive investment in new coal fired power plants.

- Ultra-Supercritical Technology with steam temperature > 600°C is now state-of-the-art with unit sizes between 350MW and 1000MW – project developers and financers are implementing this technology with consequent increase in efficiency and reduction in emissions for new coal fired fleet.

- Emissions legislation is rightly becoming increasingly stringent, both in emission limits and in scope albeit with some regional anomalies.

- State-of-the-art emissions control technologies can meet the requirements of the current legislation, project developers and financers. However, the time is never more urgent for R&D efforts for ever greater emissions reduction.
Thank you

Questions?

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