Circulating Fluidized Bed Technology

4th EU South Africa Clean Coal Working Group Meeting

Presented by Arto Hotta
Foster Wheeler Energia Oy
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Republic of South Africa
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Foster Wheeler Business Groups

**Engineering & Construction**

Designing, constructing, and managing projects for some of the world’s largest process plants in a wide range of industries, including oil and gas, chemicals, and pharmaceuticals.

**Global Power Group**

Designing, manufacturing, and erecting a full line of boilers, and environmental products for utility, industrial, and cogeneration clients. A world-leading expert in combustion technology.
FW Worldwide Offices
A global business with approximately 12,000 highly-skilled people

A global network of high-quality resources, enabling us to deliver local service and local content, and to access local labor markets
Foster Wheeler Global Power Group Products & Services

- **Steam Generators**
  - Circulating Fluid Bed
  - Pulverized Coal
  - Biomass
  - Oil & Gas
  - Solar
  - Bubbling Fluid Bed
  - Package
  - Grate and MSW
  - Metallurgical Waste Heat
  - HRSG

- **Auxiliary Equipment**
  - Condensers
  - Feedwater Heaters
  - Biomass Gasifiers

- **Aftermarket Services**
  - Engineered and Replacement Pressure Parts
  - Weld Overlay and Refractory Upgrades
  - Replacement Parts
  - Cyclone Burner Retrofits
  - Coal Mill Service and Upgrades
  - Boiler and HRSG Maintenance
  - Outage Construction

- **Environmental Products**
  - Circulating Dry Ash Scrubber Retrofits
  - Fabric Filter Retrofits
  - SCR and SNCR Retrofits
  - Low NOx Combustion Systems
  - Biomass Combustion Retrofits
  - Coal/Air Control System Upgrades

- **Plant Operation**
FW Power Group Global References
2,351 Units totaling Over 208 GWe Sold Since 1929

<table>
<thead>
<tr>
<th>Total Sold FW Units</th>
<th>Units</th>
<th>MWe</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>325</td>
<td>106,770</td>
</tr>
<tr>
<td>CFB</td>
<td>385</td>
<td>28,037</td>
</tr>
<tr>
<td>Oil &amp; Gas</td>
<td>323</td>
<td>41,537</td>
</tr>
<tr>
<td>HRSG</td>
<td>355</td>
<td>18,476</td>
</tr>
<tr>
<td>Industrial</td>
<td>963</td>
<td>13,591</td>
</tr>
<tr>
<td>Total</td>
<td>2,351</td>
<td>208,681</td>
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</tbody>
</table>

- Circulating Fluidized Bed (CFB) Boilers
- Bubbling Fluidized Bed (BFB) Boilers
- Heat Recovery Steam Generators
- Waste Heat Boilers
- PC Boilers
Foster Wheeler’s Path to Advancement of CFB
391 units (31 GWe) logging over 30 million hours of operation

Foster Wheeler CFB Evolution

Global CFB Market Share over 2006-2010

Source: FW sales database for FW served markets (China excluded)
Key Advantages of the Foster Wheeler CFB

- **Fuel flexibility is an operational and economic advantage**
  - Wide range for design fuels
  - Can Handle Difficult to burn fuels (lignites, high ash, low volatiles, high moisture etc.)
  - Ease of Co-Firing of Opportunity fuels (biomass, pet cokes, etc.)
- **Excellent emission performance**
  - Low \( \text{SO}_x / \text{NO}_x \) Emissions without Expensive Backend Equipment
- **Exceptional Availability** Proven with > 30 million hours of operation
Foster Wheeler CFB Fuel Flexibility

- Coal
  - Anthracite
  - Bituminous
  - Subbituminous
  - Lignite

- Waste Coal
  - Anthracite Culm
  - Bituminous Gob
  - Coal Slurry

- Woody Biomass
  - Bark
  - Wood Chips
  - Sawdust
  - Forest Residues
  - Willow/Salix

- Agricultural Residues
  - Olive Waste
  - Straw
  - Bagasse
  - Rice Husk
  - Sunflower
  - Dried Fruits
  - etc.

- Waste Derived Fuels
  - Recycled Wood/Paper
  - Plastics
  - Solid Recovered Fuel
  - Tire Derived Fuel
  - Sludge
    - Pulp and Paper Mill
    - Municipal
  - Gas
  - Oil
  - Petroleum Coke

- Peat
Drivers for Consideration for CFBC Selection

- CFB available with USC designs up to 800 Mwe with projected plant efficiencies in the ~45% (LHV)
- Lower quality fuel available at economical prices; high ash, low heating value, high sulphur, moisture etc.
  - Ability to secure future fuel contracts based on price not technology
- Emissions Requirements More Stringent (< 400 Mg/nm3)
- No SCR or FDG Required in Most Applications
- Ability to co-fire biomass without major modifications
Important Foster Wheeler Milestones

• 2009-
  – Lagisza 460 Mwe Project in Poland in Commercial Operation – Worlds first Super Critical CFB and Worlds Largest CFB –
    – Original Bid Tender was PC
    – Good operational record for nearly 3 years
• 2011-
  – Kospo Samcheok Green Power Project Korea – 4 x 550 Mwe Supercritical CFBC Units _ Construction Begins
    – Largest CFBC Plant in the World @ 2200 MWe
    – Adding Phase two will bring a total of 4400 MWe
Łagisza 460 MWₐ Supercritical CFB – Project
361/306 kg/s, 275/55 bar, 560/580 °C

- Customer: Południowy Koncern Energetyczny SA (PKE)
- 460 MWₑ supercritical OTU - CFB
- Foster Wheeler providing boiler island supply and erection with foundations

- Start of Project Execution (NTP): December 2005
- Actual Hand Over June 2009

- Net plant efficiency 43.3 %

- Fuel flexibility
  Bit. coals from 10 different mines

- Low Emissions
  Meets EU large combustion plant (LCP) directive without scrubbers
Łagisza 460 MWₜ
Korea goes Ultra Supercritical with CFB
Kospo Samcheok 4 x 550 MWe
A New Era for Green Power – 4 x 550 MWe CFB Supercritical Units

- Launches the CFB Super Critical platform to compete on a 1000 MWe Scale

  • Features State-of-the-art Utility CFB Technology
    - 4 x 550 MWe CFBs powering 2 x 1000 MWe steam turbines
    - Advanced supercritical vertical tube steam technology
    - 603/603 C Steam Temperatures
    - Firing a wide range of import and domestic coals including biomass

- Commercial Operation expected
  - Units 1 and 2: Mid 2015
  - Units 3 and 4: End of 2015
### Samcheok 4 x 550 MWe Supercritical CFB Boiler

<table>
<thead>
<tr>
<th>Each Unit</th>
<th>English</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Capacity</td>
<td>550 MWe</td>
<td>1,600 MWth</td>
</tr>
<tr>
<td>Unit Steam Flow (SH/RH)</td>
<td>3,461 / 2,820 kpph</td>
<td>437 / 354 kg/s</td>
</tr>
<tr>
<td>Main Steam Pressure (SH/RH)</td>
<td>3,728 / 783 psi</td>
<td>257/53 bar (a)</td>
</tr>
<tr>
<td>Main Steam Temp.</td>
<td>1,117 / 1,117 °F</td>
<td>603 / 603 °C</td>
</tr>
</tbody>
</table>

**Full Load Emissions**
- SOx < 100 mg/Nm³
- NOx < 100 mg/Nm³

**Fuel : Coal**
- Moisture: 20-43%
- Ash in dry fuel: 1.5-17.0%
- Sulfur in dry fuel: 0.1-1.0%
- Biomass co-firing
Boiler Performance

State of the art supercritical steam values
- Main steam 436.7 kg/s, 256.5 bar(a), 603°C
- Reheated steam 356.4 kg/s, 53.1 bar(a), 603°C
  => Estimated plant net efficiency (LHV) 42.4%

Fuel Flexibility
- Wide coal range:
  - Moisture 20 – 43%
  - Ash in dry fuel 1.2 – 17.0% in dry fuel
  - Sulfur in dry fuel 0.1 - 1.0% in dry fuel
- Biomass co-firing (5%)

Low emissions
- SOx 50 ppmv achieved with limestone injection to furnace
  ⇒ No separate DeSOx plant needed
- NOx 50 ppmv with SCR plant
Global Coal Prices Favor CFB’s Ability to Burn Wider Ranges of Fuels

- Historical & future global coal price projections suggest that in the long term, pricing will drop from the current peak of around $110/tonne FOB and settle in at around $80/tonne FOB in 5 years & stabilize for 15 years.
- Since fuel pricing is the largest component of a plant's operating cost, it plays a significant role in the financial success of a coal project.

Recent & Predicted Global Coal Pricing

![Graph showing recent and predicted global coal pricing]

- Fuel Price Differential

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**FOSTER WHEELER**
Selecting Fuels based on Price and not Technology can offer High Value to Plant Owners

600 MWe (Net) Supercritical CFB Coal Power Plant Operating at 90% Capacity Factor

<table>
<thead>
<tr>
<th>Plant Parameter</th>
<th>Units</th>
<th>6000 Kcal West Russian Coal</th>
<th>4900 kcal Indoneisan Sub-bituminous Coal</th>
<th>Annual Fuel Arbitrage ($/yr)</th>
<th>10 yr NPV Fuel Arbitrage ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Net Power</td>
<td>MWe</td>
<td>600</td>
<td>600</td>
<td></td>
<td></td>
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<tr>
<td>Fuel Cost</td>
<td>$/ metric Ton</td>
<td>80</td>
<td>60</td>
<td></td>
<td></td>
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<tr>
<td>Fuel Heating Value</td>
<td>kcal/kg</td>
<td>6000</td>
<td>4900</td>
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<tr>
<td>Fuel Heating Value</td>
<td>MJ/Kg</td>
<td>25.1</td>
<td>20.5</td>
<td></td>
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<tr>
<td>Plant Capacity Factor</td>
<td>%</td>
<td>90%</td>
<td>90%</td>
<td></td>
<td></td>
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<tr>
<td>Fuel consumption</td>
<td>metric ton/year</td>
<td>1,698,232</td>
<td>2,079,467</td>
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<tr>
<td>Fuel Cost</td>
<td>$/year</td>
<td>135,858,560</td>
<td>124,768,020</td>
<td>$11,090,540</td>
<td>$72,033,734</td>
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Potential Value of Fuel Flexibility
Conclusions

• The CFB boiler has long been viewed and accepted in the industry as viable technology in the 20 -350 MWe sub critical class units.
• 30 Million plus hours of CFB operating experience with high availability demonstrated
• CFB’s ability to burn low rank and waste coals available at lower economical pricing
  • Secure future fuel contracts based on price not technology
• Co-fire biomass to satisfy renewable (green) programs if neccessary
• Foster Wheeler CFB units are offered in larger sizes up to 800 MWe with super critical steam values.
• Proven track record with Lagisza in commercial operation tied to Polish National Grid for 3 years
• Kospo Samcheok Super Critical CFB’s competed head to head and were selected over PC due to the multiple fuel capability which allows for more favorable emission flexibility as well as reduced variable O&M costs.
• FW is developing a 300 Mwe oxy fire CFB for the Compostilla CCS power plant in Spain. The project is funded by the EU’s EEPR program