Advanced CFB technology for utilization of standardized SRF

Juha Sarkki
Foster Wheeler
juha.sarkki@fwfin.fwc.com

RECOMBIO final conference
June 13, 2013, Helsinki
Foster Wheeler AG, Business Groups

The Global Engineering & Construction (E&C) Group

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.

The 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.
A global business with approximately 3,000 highly-skilled people
World Leader in Fluidized Bed Combustion (CFB) Technology

- First BFB boilers delivered in the 1970s, and world’s first CFB boiler supplied in 1979.
- World’s first once-through supercritical CFB boiler started operation in 2009 in Lagisza, Poland.
- Flexi-Burn® - air/oxy flexible CFB boiler commercially available by the end of 2013.
- CFB boiler fuel flexibility and multifuel capability provide for efficient utilization of fossil and renewable fuels.
- 111 Biomass CFB boilers (full biomass and co-combustion)
- Biggest units under construction 550 MWe Benson supercritical CFBs for coal in Korea

411 - Circulating fluid bed (CFB) boilers
- 375 delivered
- 36 under construction
- Biggest unit in operation 460 MWe

136 - Bubbling fluidized bed (BFB) boilers
- 136 delivered

11 - Atmospheric fluidized bed gasifiers
- 11 delivered

PKE Lagisza, Poland
Äånevoima Oy, Finland
Lahti Energia, Finland

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Foster Wheeler Global Power Reference Base
2,533 Units - over 220 GWe

Total Sold FW Units

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>MWe</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>331</td>
<td>109,801</td>
</tr>
<tr>
<td>CFB</td>
<td>411</td>
<td>31,854</td>
</tr>
<tr>
<td>Oil &amp; Gas</td>
<td>324</td>
<td>41,462</td>
</tr>
<tr>
<td>HRSG</td>
<td>410</td>
<td>26,290</td>
</tr>
<tr>
<td>Industrial</td>
<td>1,007</td>
<td>14,445</td>
</tr>
<tr>
<td>Solar</td>
<td>50</td>
<td>2,209</td>
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<tr>
<td>Total</td>
<td>2,533</td>
<td>220,061</td>
</tr>
</tbody>
</table>

- Circulating Fluidized Bed (CFB) Boilers
- Bubbling Fluidized Bed (BFB) Boilers
- Heat Recovery Steam Generators
- Waste Heat Boilers
- PC Boilers
- Gasifires
Kauttua 65 MWth, 25 kg/s, 83 barg, 500 °C

Co-firing REF with wood residue, peat and coal
Burn tests of used packaging in 1992-1993
Fuel map in 1998
CFB Technology opens the door to Fuel Flexibility and Carbon Neutral Fuels

Heating Value, MJ/kg

- PETROLEUM COKE
- ANTRACITE COAL
- BITUMINOUS COAL
- BROWN COAL, LIGNITE
- PEAT
- WASTE COAL
- BARK
- POLYOLEFIN PLASTICS (PE, PP, PC..)
- COLORED OR PRINTED PLASTICS, CLEAN
- COLORED OR PRINTED MIXED PLASTICS
- RDF
- CONSUMER SRF
- MIXED PLASTICS
- WOOD & PLASTICS
- PAPER & WOOD
- OIL SHALE
- SEWAGE SLUDGE
- DEINKING SLUDGE
- BIO & FIBER SLUDGE
- PLASTICS
- BROWN COAL, LIGNITE
- COAL
- PETROLEUM
- OIL
- SHALE

Burning Difficulty

CFB Fuel Range

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FW’s multiple Boiler Concepts for waste fuels and biomass

- Söderenergi
  - IKV
  - Demolition wood up to 100%
  - REF < 25%
    - CFB
    - Intrex™
    - Short empty pass
    - Easily exchangable superheaters

- Mälarenergi
  - Bio fuels with low portion of recycled fuels
    - BFB/CFB

- Lomellina II
  - Bio fuels with low portion of recycled fuels
    - BFB/CFB

- Prokon Nord
  - RDF&REF
    - CFB
    - Intrex™
    - Easily exchangable superheaters
    - Empty pass
    - Water cannons in empty pass
    - Stoker fuel feeding
    - Spring hammer SH soot blowing

St Ambrose

Steam parameters

Challenging fuel

Fuel class

Easy fuel

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Design Basis of FW CFB Concept for waste fuels

  RDF
  59 MW_{St}, 24.1 kg/s, 62 bar, 443°C

- Viken Energinett (2001)
  SRF (selected high calorif. ind. fractions)
  34.5 MW_{t}, 16 bar, 204°C

- Högdalen (2000)
  REF
  91 MW_{St}, 31.8 kg/s, 60 bar, 480°C

- >30 CFB references for co-firing various types of waste

- 10 Altholz plants in Germany, Holland and Belgium (1996-2010)
  60-100 MW_{St}, 90 bar, 520°C

CFB-Concept for SRF and RDF
Multifuel CFB for Waste and Clean Biomass (CHP)
Igelsta (Söderenergi AB, Södertälje)

240 MW$_{th}$, 73 MW$_{e-net}$, 209 MW$_{DH}$, 92 kg/s, 90 bar, 540 C

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Mix 1</th>
<th>Mix 2</th>
<th>Mix 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass [%]$_{LHV}$</td>
<td>75</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Rec.wood [%]$_{LHV}$</td>
<td>0</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>REF pellets [%]$_{LHV}$</td>
<td>25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moisture [%]$_{ar}$</td>
<td>44.3</td>
<td>35.6</td>
<td>50.0</td>
</tr>
<tr>
<td>Ash [%]$_{dry}$</td>
<td>6.5</td>
<td>4.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Nitrogen [%]$_{dry}$</td>
<td>0.6</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Sulfur [%]$_{dry}$</td>
<td>0.09</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>Chlorine [ppm]$_{dry}$</td>
<td>1200</td>
<td>800</td>
<td>200</td>
</tr>
<tr>
<td>LHV [MJ/kg]$_{ar}$</td>
<td>9.7</td>
<td>11.0</td>
<td>8.3</td>
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</tbody>
</table>

Total plant efficiency ~110%$_{LHV}$ = 90%$_{HHV}$

<table>
<thead>
<tr>
<th>Emissions</th>
<th>6%O$_2$, dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_x$ [mg/MJ]</td>
<td>35*</td>
</tr>
<tr>
<td>SO$_2$ [mg/m$^3$n]</td>
<td>75</td>
</tr>
<tr>
<td>CO [mg/m$^3$n]</td>
<td>50*</td>
</tr>
<tr>
<td>Dust [mg/m$^3$n]</td>
<td>10</td>
</tr>
<tr>
<td>NH$_3$ ppm</td>
<td>10</td>
</tr>
<tr>
<td>TOC [mg/m$^3$n]</td>
<td>10</td>
</tr>
<tr>
<td>HCl / HF [mg/m$^3$n]</td>
<td>10 / 1</td>
</tr>
<tr>
<td>Cd+Tl / Hg / HM [mg/m$^3$n]</td>
<td>0.05 / 0.05 / 0.5</td>
</tr>
<tr>
<td>PCDD+F [ng/m$^3$n]</td>
<td>0.1</td>
</tr>
</tbody>
</table>

*) only at 100% load with Mix 1, 2, and 3
RDF FIRED CFB BOILER
E.ON Värme Sverige AB, Norrköping, Sweden

85 MWth, 30 MWe, 31 kg/s, 66 bar, 450 °C

FUEL DATA

Refuse Delivered Fuel (RDF)
Sulphur 0.3 % ds
Chlorine 0.9 % ds
Moisture 27%
Ash (as received) 14.3%
LHV (as received) 12.9 MJ/kg

DESIGN PERFORMANCE, O₂ 11%
in dry gases

Flue Gas Exit Temperature 168 °C
Boiler Efficiency 90.2%
Emissions
- NOₓ < 35 mg/MJ
- CO < 50 mg/Nm³

- Biomass based combustible fraction is 60 % of RDF
# Emission permit values

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<tr>
<th></th>
<th>$\text{mg/Nm}^3$</th>
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<tr>
<td>Dust</td>
<td>10</td>
</tr>
<tr>
<td>CO</td>
<td>50</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>50</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>200</td>
</tr>
<tr>
<td>Total C</td>
<td>10</td>
</tr>
<tr>
<td>HCl</td>
<td>10</td>
</tr>
<tr>
<td>HF</td>
<td>0.5</td>
</tr>
<tr>
<td>Cd, Tl</td>
<td>0.05</td>
</tr>
<tr>
<td>Hg</td>
<td>0.05</td>
</tr>
<tr>
<td>Heavy metals: Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn</td>
<td>0.5</td>
</tr>
<tr>
<td>PCDD/PCDF</td>
<td>0.1</td>
</tr>
</tbody>
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Fuel feeding
Intrex SH
Spring Hammers: Idle pass & Horizontal pass
Tube bank with FW-spring hammer cleaning

FEATURES:
• spring anvil raises the frequency but conveys high impact force
• sequence controlled (10 blows at a time - waiting time adjusted)
• no steam consumption
Bottom Ash Removal System

Bottom ash removal system:
- Discharge chutes
- Water-cooled bottom ash screws
- Rotating Screen
- Coarse material from screen to bottom ash container
- Reinjection of fine material to furnace
Heating value of SRF vs time

Calculated & analysed LHV [kJ/kg]

Date


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Combustion Technology: Fuel spec

Boiler supplier in flow chain for SRF
SRF standard in use

- Common definition of SRF for the supplier and the customer
- Improved understanding of SRF as fuel
- Improved business environment for WtE applications
- Model for good practice
- Link between waste and power
- Testing methods for characterization of SRF
- Tools for quality assurance
- Product improvement and development
Standards provide tools for SRF with consistent quality and quantified properties

Foster Wheeler CFB technology is a proven solution for SRF in power generation with high steam parameters and with good emission performance