Design and operation of 600MW CFB boiler in China

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History of the CFB in Tsinghua and China

1st 1980-1990, learning

2nd 1990-2000, improvement

3rd, 2000-2005 scaling-up and maturating

4th, 2005-present developing

35-75t/h

75-130t/h

100MW-300MWe

SC 600MW
Effect of steam parameters

Ultra-supercritical, dual loop reheat from 566°C to 720°C
\[ \Delta \eta = 5\% \]

Ultra-supercritical, single loop reheat to 600°C
\[ \Delta \eta = 4\% \]

Supercritical, single loop reheat
\[ \Delta \eta = 3\% \]

Subcritical, single loop reheat

T=25°C cooling water in the condenser

\[ \eta = 37 \sim 38\% \]

Saving Fuel

\( \sim 30\% \)

\( \sim 20\% \)
comparison of the heat flux along the boiler height between PC(red) and CFB(blue)
Features of heat flux in CFB

• 50% lower than that of the PC boiler, the highest mainly in the taped section covered with anti erosion layer
• The flow rate can be lower as 500—700 kg/m²-s, much lower than that of PC boiler of >1000 kg/m²-s
• Lower flow rate has the feature of nature circulation for Benson straight tube, i.e. flow rate increases with higher heat flux
• The temperature deviations decreases
• Smooth tube can be used

The advantage of supercritical parameters with CFB boiler
Schedule of the developing of 600 MW SCCFB

- 2003  fundamental studies
- 2007,1,17  design approved
- 2009,2,24  DBC contract signing
- 2010,11,26  boiler erection
- 2012,7,5  cold commissioning
- 2012,12,30  hot commissioning
- 2013,4,14  passed 168 h test
CFB combustion and supercritical steam cycle

- High generation Efficiency
- SCCFB as a technical route

Efficiency VS steam parameters

- Develops at the same time with FW and independently

10th five year plan (continue):
  solve the feasibility study
“863”:
  solve the Technical scheme and key parameter-heat flow density
11th five year plan:
  key technology and project
Key technologies

Basic researches facing application

- Flow regimes in ultrahigh riser (1 PhD)
- Feasibility of vertical tube (1 PhD)
- Maldistribution among multi cyclones (1PhD + 1M.S)
- Stability of ultra-large bed (1 M.S)
- Technical scheme (1PhD + 1 M.S)
- Hydrodynamic of low mass flow (1 PhD)
- Dynamic model of boiler (2 PhD)
- SCFB simulator (1 M.S)
- Key auxiliaries (2 M.S)

Key points for SCCFB boiler

Basic and applied basic research

Achievements

- 100 papers
- 50 patents

Combination of theory and Practice
Concept of 600 MW supercritical CFB suggested by Tsinghua

T shape

6 cyclone

6 EHE

Benson smooth tube furnace

Mass flux in tube can be lower as 800kg/m².s
600MWe made by DEC in Baima

- high efficiency, economic-effective
- high availability, reliability
- low emission

- highly flexible in operation, turn-down ratio,
- low maintenance cost
- high fuel flexibility
Design coal properties and boiler parameters for the 600MWe SC-CFB

### Design Coal Properties

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar</td>
<td>%</td>
<td>7.58</td>
</tr>
<tr>
<td>A_ar</td>
<td>%</td>
<td>43.82</td>
</tr>
<tr>
<td>V_daf</td>
<td>%</td>
<td>14.74</td>
</tr>
<tr>
<td>Q_net,ar</td>
<td>kJ/kg</td>
<td>15173</td>
</tr>
<tr>
<td>C_ar</td>
<td>%</td>
<td>41.08</td>
</tr>
<tr>
<td>H_ar</td>
<td>%</td>
<td>1.62</td>
</tr>
<tr>
<td>O_ar</td>
<td>%</td>
<td>2.06</td>
</tr>
<tr>
<td>N_ar</td>
<td>%</td>
<td>0.54</td>
</tr>
<tr>
<td>S_ar</td>
<td>%</td>
<td>3.3</td>
</tr>
</tbody>
</table>

### Design parameters of the boiler

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam output (BMCR)</td>
<td>t/h</td>
<td>1900</td>
</tr>
<tr>
<td>Main steam pressure</td>
<td>MPa</td>
<td>25.4</td>
</tr>
<tr>
<td>Main steam Temperature</td>
<td>°C</td>
<td>571</td>
</tr>
<tr>
<td>Reheat steam flowrate</td>
<td>t/h</td>
<td>1568.2</td>
</tr>
<tr>
<td>Inlet/outlet pressure of reheated steam</td>
<td>MPa.a</td>
<td>4.58/4.43</td>
</tr>
<tr>
<td>Inlet/outlet temp. of reheated steam</td>
<td>°C</td>
<td>317/569</td>
</tr>
<tr>
<td>Feeding water Temp</td>
<td>°C</td>
<td>284</td>
</tr>
</tbody>
</table>
Design features of the 600MWe SC-CFB

- Pant-leg, single face middle wall, even pressure wind box
- Feeding coal in loop seal
- Combined ignition
- Ash drain from side wall, 8 roller ash cooler
- 6 cyclone, 6 EHE
- Single second pass
- 4 regenerated air heaters with 4 sectors
Water and steam system

Inlet of cyclone → cyclone → outlet of cyclone → cover wall → hanging tubes → LTS → 1st attem → ITS1 → 2nd attem → ITS2 → 3rd attem → HTS

controlled by the ratio of coal to water, and attemerator.

LTR → spray attemperator → HTR
controlled by the ash flow rate in EHE
The largest 600MW SCFB boiler pass the 168h test

- 8am, 2013-4-14, the 600MW SCCFB boiler developed with TH technology passed the 168h test
- The operation parameters meet the design values and operates stably
- Such boiler with the largest capacity and highest parameters means TH CFB technology is among the advanced in the world

- Shenhua Baima
Steam/water parameters at BECR loads

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>606MW</th>
<th>604MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam output</td>
<td>t/h</td>
<td>1735</td>
<td>1724</td>
</tr>
<tr>
<td>Main steam pressure</td>
<td>MPa</td>
<td>24.40</td>
<td>24.25</td>
</tr>
<tr>
<td>Main steam Temperature</td>
<td>℃</td>
<td>569</td>
<td>570</td>
</tr>
<tr>
<td>Reheat steam flowrate</td>
<td>t/h</td>
<td>1568.2</td>
<td></td>
</tr>
<tr>
<td>outlet pressure of reheated steam</td>
<td>MPa.a</td>
<td>3.84</td>
<td>3.86</td>
</tr>
<tr>
<td>outlet temp. of reheated steam</td>
<td>℃</td>
<td>571</td>
<td>559</td>
</tr>
<tr>
<td>Feeding water Temp</td>
<td>℃</td>
<td>280</td>
<td>280</td>
</tr>
</tbody>
</table>

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Outlet Temperatures of heating surfaces at BECR loads

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Unit</th>
<th>606MW</th>
<th>604MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outlet of the water wall</td>
<td>℃</td>
<td>403</td>
<td>400</td>
</tr>
<tr>
<td>Outlet of the middle wall</td>
<td>℃</td>
<td>423</td>
<td>427</td>
</tr>
<tr>
<td>Outlet of the LTS</td>
<td>℃</td>
<td>455</td>
<td>454</td>
</tr>
<tr>
<td>Outlet of the ITS1</td>
<td>℃</td>
<td>491</td>
<td>489</td>
</tr>
<tr>
<td>Outlet of the ITS1</td>
<td>℃</td>
<td>522</td>
<td>520</td>
</tr>
<tr>
<td>Outlet of the LTR</td>
<td>℃</td>
<td>480</td>
<td>477</td>
</tr>
<tr>
<td>Furnace temperature</td>
<td>℃</td>
<td>895</td>
<td>895.4</td>
</tr>
</tbody>
</table>

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## Economic and emission Performance

<table>
<thead>
<tr>
<th>item</th>
<th>Unit</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon content in fly ash</td>
<td>%</td>
<td>4.0-6.0</td>
</tr>
<tr>
<td>Carbon content in bottom ash</td>
<td>%</td>
<td>1.0-2.0</td>
</tr>
<tr>
<td>O2 in air pre-heater</td>
<td>%</td>
<td>3.5-4.0</td>
</tr>
<tr>
<td>Temperature of the flue gas</td>
<td>℃</td>
<td>130-135</td>
</tr>
<tr>
<td>SO2 (not modified)</td>
<td>Mg/Nm³</td>
<td>320-360</td>
</tr>
<tr>
<td>Nox (not modified)</td>
<td>Mg/Nm³</td>
<td>112-164</td>
</tr>
<tr>
<td>Boiler efficiency</td>
<td>%</td>
<td>91.8-92.3</td>
</tr>
</tbody>
</table>

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Performance data

• Furnace tem.: operation and design <5°C
• Furnace outlet gas tem.: operation and design <10°C
• Flue gas tem.: operation and design <5°C
• Nox emission: <150mg/m³
• Carbon content in fly ash: 3%~4%

Safety data

• Measured steam temperature distribution along the wall width meet the calculation, validating the fundamental researches on heat transfer
Some problems in operation

1: damage of the ignition gun

2: coking in furnace
   - Fan trip causing bed material collapse
   - Bed material size is too coarse
   - Coal feeding is not even

3: ash leakage in the EHE
Thanks for attention!