Operation Experience & Considerations in a Large Scale CFB Boiler

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Technology & Market Trend (1)

- Coal Conversion for Electric Power Generation
  - Stable & Economic Electric Power Supply → high efficiency, large scale [SC/USC]
  - CO₂ Reduction Measures Preparation → high efficiency, Co-combustion, CCS
  - Optimum Tech.: CFB Conversion Tech.
    : optimum for fuel flexibility
    : highly adaptable to SC/USC steam circuit

- CFB Market Growth in the World
  - Since ’95, more than 500 CFB units BD
  - Increase of SC[USC]-CFB annual growth - 12%
  - Increase of CFB market share : more than 17% market share to ’20
Status of CFB Plant [KEPCO Group’s]

Cebu CFB
- Capacity: 100 MW x 2 units
  - #1: ’11. 2
  - #2: ’11. 5
- Designer: Foster Wheeler
- Feature: Compact Cyclone, INTREX, Sub-bituminous, Prob.: Erosion

Donghae CFB
- Capacity: 200 MW x 2 units
  - #1: ’98. 9
  - #2: ’99. 9
- Designer: Alstom
- Feature: FBHE, FBAC, Korean Anthracite, Prob.: Coal supply

Yeosu CFB
- Capacity: 300 MW x 2 units
  - #1: ’16. 3 (Cons.)
  - #2: ’11. 10
- Designer: Foster Wheeler
- Feature: Compact Cyclone, w/o INTREX, Wingwall Tube, Prob.: Erosion etc

Samcheok CFB
- Capacity: 2 units [550 MW x 2-CFB x 1-Turbine]
  - #1: ’15. 12 (Cons.)
  - #2: ’16. 06 (Cons.)
- Designer: Foster Wheeler
- Feature: SC-CFB type, 257 bar/603°C, 3,900 kcal/kg

More than 30 units of small & medium scale CFB boilers in Korea
Schematic Diagram of Large CFBs

Alstom

- **DongHae 200 MWe CFB**

Foster Wheeler

- **YeoSu 340 MWe CFB**
- **Samcheok 550 MWe CFB**
<table>
<thead>
<tr>
<th></th>
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<th></th>
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<tbody>
<tr>
<td>Furnace LP Width</td>
<td>15.2</td>
<td>18.9</td>
<td>33.8</td>
<td>39.6</td>
<td>19.5</td>
<td>27.6</td>
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<tr>
<td>Furnace LP depth</td>
<td>3.0</td>
<td>3.8</td>
<td>4.1</td>
<td>5.4</td>
<td>3.8</td>
<td>5.3</td>
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<tr>
<td>Furnace LP Height</td>
<td>4.9</td>
<td>7.6</td>
<td>6.2</td>
<td>8.3</td>
<td>5.8</td>
<td>8.1</td>
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<tr>
<td>Furnace UP Width</td>
<td>15.2</td>
<td>19.2</td>
<td>33.8</td>
<td>39.6</td>
<td>19.5</td>
<td>27.6</td>
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<tr>
<td>Furnace UP Depth</td>
<td>6.0</td>
<td>7.2</td>
<td>8.1</td>
<td>10.8</td>
<td>7.5</td>
<td>10.6</td>
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<tr>
<td>Furnace UP Height</td>
<td>22.9</td>
<td>24.4</td>
<td>35.2</td>
<td>43.7</td>
<td>29.5</td>
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<td>Furnace Total Height</td>
<td>27.8</td>
<td>32</td>
<td>41.5</td>
<td>52</td>
<td>35.3</td>
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<tr>
<td>Taper angle</td>
<td>18°</td>
<td>15°</td>
<td>18°</td>
<td>18°</td>
<td>18°</td>
<td>18°</td>
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<tr>
<td>Fuel</td>
<td>sub-bituminous</td>
<td>anthracite</td>
<td>sub-bituminous</td>
<td>sub-bituminous</td>
<td>lignite</td>
<td>bituminous</td>
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<tr>
<td>Design</td>
<td>FW</td>
<td>Alstom</td>
<td>FW</td>
<td>FW</td>
<td>Dongfang</td>
<td>FW</td>
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### Feeder Arrangement of Large CFBs

<table>
<thead>
<tr>
<th>CFB</th>
<th>MW</th>
<th>Design coal</th>
<th>Feeder #</th>
<th>Bed area/feeder (m²/feed)</th>
<th>Feeder type</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Front</td>
<td>Rear</td>
<td>Sum</td>
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<tr>
<td>Cebu</td>
<td>100</td>
<td>Sub bituminous</td>
<td>4</td>
<td>-</td>
<td>4</td>
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<tr>
<td>Donghae</td>
<td>200</td>
<td>Anthracite</td>
<td>6</td>
<td>-</td>
<td>6</td>
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<tr>
<td>Yeosu</td>
<td>340</td>
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<td>6</td>
<td>4</td>
<td>10</td>
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<tr>
<td>Samcheok</td>
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<td>Sub bituminous</td>
<td>8</td>
<td>8</td>
<td>16</td>
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<td>Sumsel-5</td>
<td>175</td>
<td>Lignite</td>
<td>6</td>
<td>0</td>
<td>6</td>
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<td>Lagisza</td>
<td>460</td>
<td>Bituminous</td>
<td>7</td>
<td>7</td>
<td>14</td>
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</tbody>
</table>

### Samcheok CFB Feeder Arrangement

- **Fuel Feeder Number and Arrangement**
  - Generally symmetric arrangement → Yeosu CFB: non-symmetric – affects bed temp. control
  - Bed area per feeder (20~28 m²/#) → depends on fuel (moisture, volatile, size)
Operation Experience in Large CFBs (1)

- **During start up,**
  - PA control failure
  → separate windboxes (2~3) in large CFBs
  → needs uniform PA distribution

- **Defluidization [during heating up BM],**
  - Local poor fluidization
  → flatten the bed surface [swing PA]
  → careful operation [training operators]
Main Steam Temperature Lower than Designed [ex: Yeosu 300MWe etc]

- needs to review basic design (heat absorption area/arrangement etc)
- needs to review heat & mass balance btw boiler and turbine [FW/RH/SH ‘s temp, FR]
- needs to increase HT to SH [Yeosu : wingwall in the furnace]

Operational Control

- Generally, to increase HT
  - increase solid hold up
  - PA/SA ratio control
  - inventory control
  - solid particles size control and so on

Modification

- Heat absorption area control (reducing EV)
  - increase refractory lines
  → bed temperature ↑
Operation Experience in Large CFBs (3)

- Bed Temperature Higher than Designed, and Un-Uniformity
  - depends on coal de-volatilization and combustion reactivity
  - depends on coal size distribution and feeding point
  - needs to check solid circulation rate & cyclone efficiency [Donghae: cyclone modification]

Cebu CFB

Yeosu CFB

Donghae CFB
Operation Experience in Large CFBs (4)

- Un-Uniform Temp. in Horizontal Direction of the Furnace [due to uneven fuel feeding]
  - fuel feeding: possibility of error if done by volume control of each feeder
  - air: difficult to control PA flow in horizontal direction except with separate windbox

- Horizontal monitoring of O$_2$ conc. in flue gas → control the fuel feeding rate at each feeder
Operation Experience in Large CFBs (5)

- How to control bed temperature & un-uniformity?

When?

- Higher Bottom Temp.  
  \(> 950 \degree C\)
  - fuel reactivity \(\uparrow\)
  - lower solid circulation
  - lower cyclone efficiency
  - combustion efficiency \(\uparrow\)
  - \(\text{SO}_2\) capture efficiency \(\downarrow\)
  - Operation stability \(\downarrow\)

- Higher Upper Temp.  
  \(> 950 \degree C\)
  - fuel reactivity \(\downarrow\)
  - lower solid circulation
  - lower cyclone efficiency
  - combustion efficiency \(\uparrow\)
  - \(\text{SO}_2\) capture efficiency \(\downarrow\)
  - Operation stability \(\downarrow\)

- Un-uniform Temp.  
  \(> 100 \degree C\)
  - fuel reactivity(volatiles) \(\uparrow\)
  - fuel size \(\downarrow\)
  - local excess air unbalance
  - feeder #/location/space
  - \(\text{SO}_2\) capture efficiency \(\downarrow\)
  - Operation stability \(\downarrow\)

Reason/Phenomena!

How to?

- Higher bottom temp. : PA \(\uparrow\) / [PA/SAC] Ratio \(\uparrow\) / Inventory \(\uparrow\) / Bed media size \(\downarrow\)
- Higher upper temp. : PA/SAC Ratio \(\uparrow\) / Inventory \(\uparrow\) / Bed media size \(\downarrow\)
- Un-uniform temp. : control of PA(through separate windbox) and fuel size, SA \(\uparrow\)

- if not, consider modification of cyclone and feeder location/space [Donghae, Yeosu]

If design is acceptable,
Operation Experience in Large CFBs (6)

- General Tube Erosion Cases
  - Erosion of boundary aspect between refractory and wall tube
  - Erosion of tube coating boundary aspect
  - Erosion of irregular tube surface due to overlaying and poor extent of tube straight
  - Erosion of lower part of wall tube [in the vicinity of kick out] due to up-flowing particles
Operation Experience in Large CFBs (7)

- Management of Particle Size and its Distribution in the Furnace
  - Check bed media drain-injection system & quantity and period

Example Cebu CFB

![Graph showing particle size distribution](image)

- Unit #1, particle size < 0.5mm
- Unit #2, particle size < 0.5mm
- Unit #1, particle size > 0.5mm
- Unit #2, particle size > 0.5mm

Bottom Ash Sampling Date

<table>
<thead>
<tr>
<th>Date</th>
<th>Mass Fraction of Particles (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>09월 06일</td>
<td>Unit #1, particle size &gt; 0.5mm</td>
</tr>
<tr>
<td>09월 09일</td>
<td>Unit #2, particle size &lt; 0.5mm</td>
</tr>
<tr>
<td>09월 12일</td>
<td>Unit #1, particle size &lt; 0.5mm</td>
</tr>
<tr>
<td>09월 15일</td>
<td>Unit #2, particle size &lt; 0.5mm</td>
</tr>
<tr>
<td>09월 18일</td>
<td>Unit #1, particle size &gt; 0.5mm</td>
</tr>
</tbody>
</table>

Ash Drain 작동 면출
Summary of Experiences in Large CFBs

- Considerations relating to Design Aspect of Large CFB Boiler
  - Needs to consider Easy control of PA relating to fuel feeding conditions
    - Combustion and temperature control for low grade fuels
    - Local erosion control around and upper part of fuel feeder
    - Easy start-up and preventing particle agglomeration
  - Needs to check heat transfer coefficient in the furnace
    - Steam quality and heat balance in the system
  - Needs to check cyclone efficiency in the CFBS
    - Temperature control in the furnace
    - Increase of SO<sub>2</sub> capture efficiency and operation stability
  - Needs to develop easy management system of particle size in the furnace
    - such as monitoring system of particle size in the furnace
    - automatically drain and injection systems for good bed media quality
Thank You for Your Attention~!