Bubbling Fluidized Bed Boiler

Unit 18
Applications

• Bubbling fluidized bed boilers has replaced nearly all small sized solid fuel fired boilers.

• It is used to fire
  - Coal, lignite, anthracite
  - Bio-mass like wood-chips, rice husk
  - Garbage incineration, medical waste, sewage sludge etc.
Why fluidized bed boiler is insensitive to the quality of fuel?

• Large thermal inertia of hot bed-solids allows most fuels to be heated to their ignition temperature without losing much of its own heat.

• Excellent mixing of bed-solids makes it possible to dissipate the released heat and the fresh fuel particles around the bed for easy ignition.
What makes **Fluidized Bed** ever so fuel flexible?

a) Large Thermal Inertia of combustion zone
b) Excellent mixing
Bubbling fluidized bed boiler

- Twin compartment compact boiler
- Coal fed from sides
- Air comes from bottom
- Bed tubes are inclined superheaters
Waste-Energy BFB boiler
Wood fired BBF Boiler
Bubbling Fluidized Bed Boiler

- The upper part is freeboard has light concentration of solid.
- Lower part is dense bed containing heat exchange tubes.
- Coal is fed into it and extracted mostly from bottom
DESIGN OF BBF BOILER

• **a) Grate area**
A thumb rule for a wide range of fuels

Heat released per unit grate area,

\[ q = \frac{3.3U}{\alpha} \text{ MW/m}^2 \]

- \( U \) - fluidization velocity ref to 300K,
- \( \alpha \) - excess air fraction

‘\( q \)’ ~ about 2 MW/m\(^2\) with cooling tubes,
~ 1.0 MW/m\(^2\) without cooling tubes in the bed.

• **b) depth of the bed.** It must be adequate to:
- accommodate bed-cooling tubes,
- provides minimum gas residence time
- minimize the pressure across the bed.
HEAT LOAD DISTRIBUTION

- Boiler absorbs heat through economizer ($Q_{ec}$), evaporator, ($Q_{ev}$), superheater ($Q_{su}$) and re heater ($Q_{re}$).
- Heat duties of these components are found from the enthalpy of steam.
- For greatest temperature difference between gas and steam/water, economizer is located in the end of gas passage. Evaporator is located in the furnace. Superheater and reheater are located between the furnace exit and economizer.
- A judicious design choice on their positions is made considering several factors.
- Gas temperatures along the gas path is calculated from heat balance of these elements.
HEAT BALANCE in Bed

• The amount of heat to be extracted from the bed $Q_{ext}$ is found from a heat balance around the bed.

• $Q_{ext} = Q_{comb} + Q_{in} - Q_{rad} - Q_{gas} - Q_{drain}$

• Heat transfer gives $Q_{ext} = h. LMTD. S.$

• Overall heat transfer coefficient $h$ for a bubbling fluidized bed boiler is in the range of 220-340 W/m$^2$K.

• Heat transfer coefficient in splash zone $h_{sp}$ is estimated by interpolation between dense and lean bed zones

• $h_{sp} = h \exp[-((10+38.7z)/25.8)^{2.2}]$

• Heat of combustion in the bed $Q_{comb} = m_f HHV_f X_{bed}$ where $X_{bed}$ is the fraction of heat released in bed.
# FEED SIZE

<table>
<thead>
<tr>
<th></th>
<th>BFB</th>
<th>CFB</th>
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<tbody>
<tr>
<td>Coal size d_{max}</td>
<td>&lt;25-30 Over-bed</td>
<td>&lt;3-9</td>
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<tr>
<td></td>
<td>&lt;10 Under-bed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25% &lt; 1 Over-bed</td>
<td>d_{50} = 0.5-1.0</td>
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<tr>
<td></td>
<td>20% &lt; 0.5 Under-bed</td>
<td></td>
</tr>
<tr>
<td>Sorbent, d_{max}</td>
<td>&lt;10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>d_{50}</td>
<td>1-2</td>
<td>0.2</td>
</tr>
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</table>
FUEL FEED SYSTEM

• Crusher
• Screen
• Metering device
• Feeder
UNDER BED FEED

Coal is pneumatically carried to selected points and injected underneath the bed through coal nozzle.

Requires larger number of feed points

Low combustible loss

Erosion of bed tubes may occur
OVER-BED FEEDING

• Fuel is sprayed over the bed surface by means of spreader
• Lower number of feed points
• High combustible loss
No of feed points depends on grate area

<table>
<thead>
<tr>
<th>Type</th>
<th>Input MW</th>
<th>Nos of points</th>
<th>MW/point</th>
<th>Bed area/point (m²)</th>
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<tbody>
<tr>
<td>Overbed</td>
<td>193</td>
<td>10</td>
<td>19.3</td>
<td>9.3</td>
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<tr>
<td>Brooklyn Overbed</td>
<td>75</td>
<td>4</td>
<td>24</td>
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<tr>
<td>Overbed</td>
<td>51</td>
<td>2</td>
<td>26</td>
<td>17</td>
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<tr>
<td>Underbed</td>
<td>365</td>
<td>120</td>
<td>3.0</td>
<td>1.95</td>
</tr>
</tbody>
</table>
Power Requirement

• Fan power = $\frac{\Delta m_s}{\dot{E}}$
Assignment

• Find how the heating surface inside the bed could change when the ash content of the fuel changes in a bubbling fluidized bed boiler. Draw a graph.

• Given: Bed area = 2mx3m
  Bed temperature = 823 C
  Tube wall temp = 300 C, Freeboard temperature = 400 C, 10% of the fuel burns in freeboard

• Assume the fuel to comprise of carbon and ash. Given heating value of carbon, 32814 kJ/kg, ash, 0 kJ/kg