PULVERIZED COAL FIRED FURNACE

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Unit 15
435 MWe tangential fired PF
A PF boiler plant
Oil/gas/ PF fired furnace
Furnace size depends on Fuel

Amount of flue gas, burning rate of fuel and slagging propensity also affects the furnace volume.
Characteristic temperatures of ash

1. Cone Before Heating
2. IT (or ID) Initial Deformation Temperature
3. ST Softening Temperature \( (H=\frac{1}{2}W) \)
4. HT Hemispherical Temperature \( (H=\frac{1}{2}W) \)
5. FT Fluid Temperature
Burner locations in tangential PC
Axial heat flux in a PC furnace

- The heat flux in mid-height is much more than elsewhere
Axial temperature distribution in PC

![Graph showing the Axial temperature distribution in PC. The y-axis represents the Furnace elevation, m, ranging from 0 to 50. The x-axis represents the Temperature, $T_{gas}$, in °C, ranging from 1100 to 1600. The graph includes three curves labeled B.E. L-4, B.E. 1-5, and B.E. 2-6.]
Isothermal in PC furnace

- Highest temperature is 2000\(^0\)
- Considerable temperature non uniformity in furnace
Heat release rates

• Volumetric heat release rate

\[ q_v = \frac{B \times LHV}{V} \quad \text{kW/m}^3 \]

\( B = \) kg/s fuel burnt

• Grate heat release rate

\[ q_F = \frac{B \times LHV}{F_{\text{grate}}} \quad \text{kW/m}^2 \]

\( B \times LHV = \) Heat released in furnace in kW
Furnace volume is shown by hatched area
## Typical values of Vol. Heat release rate, $q_v$

<table>
<thead>
<tr>
<th>Coal Type</th>
<th>Dry-bottom furnace</th>
<th>Grate release rate</th>
<th>Grate velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthracite</td>
<td>0.110-0.140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi anthracite</td>
<td>0.116-0.163</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bituminous</td>
<td>0.14-0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lignite</td>
<td>0.09-0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oil</strong></td>
<td><strong>0.23-0.35</strong></td>
<td><strong>1.5-3.5 MW_t/m^2</strong></td>
<td><strong>6.1 m/s</strong></td>
</tr>
<tr>
<td>Biomass</td>
<td>0.176</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>0.35</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Upper limits of Average Grate heat release rate, $q_F$

<table>
<thead>
<tr>
<th>Boiler capacity (tons/h)*</th>
<th>Upper limit of $q_F$ in MW/m² (ST= Softening Temperature)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ST ≤1300 °C</td>
</tr>
<tr>
<td>130</td>
<td>2.13</td>
</tr>
<tr>
<td>220</td>
<td>2.79</td>
</tr>
<tr>
<td>420</td>
<td>3.65</td>
</tr>
<tr>
<td>500</td>
<td>3.91</td>
</tr>
<tr>
<td>1000</td>
<td>4.42</td>
</tr>
<tr>
<td>1500</td>
<td>4.77</td>
</tr>
</tbody>
</table>

- One ton/h steam is roughly equivalent to 0.75 MWth heat input.
- To get the electrical power output (MWe) of the plant multiply heat input with (plant efficiency/100), which gives 1 t/h approx equal to 0.3 MWe.
Minimum depth of furnace

It ensures that flame does not hit the wall facing the burner causing damage

<table>
<thead>
<tr>
<th>Boiler capacity (t/h)</th>
<th>130</th>
<th>220</th>
<th>420</th>
<th>670</th>
<th>&gt;670</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal (m)</td>
<td>6.0</td>
<td>7.0</td>
<td>7.5</td>
<td>8.0</td>
<td>≥(5-6)(d_r)^*</td>
</tr>
<tr>
<td>Oil (m)</td>
<td>5.0</td>
<td>5.0</td>
<td>6.0</td>
<td>7.5</td>
<td>5</td>
</tr>
</tbody>
</table>

\(d_r\)^* - maximum nozzle diameter of swirl burner

Note: A square cross-section is good for tangential firing. However the depth must not be shallower than the above limit.
Burner region heat release rate, $q_b$

$$q_b = \frac{B \cdot LHV}{2(a + b)H_b}$$

$B.LHV = $ Furnace heat release in MW/m$^2$

It ensures that the peak heat flux and temperature is not too high to cause dry out and other severe conditions in wall

<table>
<thead>
<tr>
<th>Fuel</th>
<th>$q_b$ in MW/m$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown coal &amp; Bituminous coal</td>
<td>0.93 - 1.16</td>
</tr>
<tr>
<td>Anthracite and semi-anthracite</td>
<td>1.4 - 2.1</td>
</tr>
<tr>
<td>Lignite</td>
<td>1.4 - 2.32</td>
</tr>
</tbody>
</table>
Shortest distance between burner and Heating surface ($H_{fu}$)

It avoids any potential flame impingement on the Superheaters hanging from the wall, which might rupture the tubes.

$H_{fu}$ is the height between top of the burner zone and superheater section.

<table>
<thead>
<tr>
<th>Boiler capacity (t/h)</th>
<th>65-75</th>
<th>130</th>
<th>220</th>
<th>420</th>
<th>670</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthracite (m)</td>
<td>8</td>
<td>11</td>
<td>13</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>Bituminous (m)</td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Oil (m)</td>
<td>5</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Furnace exit gas temperature (FEGT)

- High FEGT makes the furnace compact but increases potential for fouling (coal firing) or corrosion (oil firing)
- \( FEGT < 1250-1400^\circ C \) for oil
- \( FEGT < \text{Lesser of Ash } DT \text{ or } (ST-100) \) C
- Gas temp before Platen < 1100-1250 C
- Gas temp. after platen \(< (DT-50) \text{ or } (ST-150) \) C

Where, \( DT \) and \( ST \) are ash deformation & softening temperatures
Heat transfer in furnace

• Furnace heat absorbed, $Q_{abs}$

$$Q_{abs} = \phi B (Q_{fu} - I_{ou}) = \phi B V C_p (T_{th} - FEGT) = a_s \psi \sigma F (T_{fl}^4 - T_{fw}^4)$$

*F* - furnace surface area, $\psi$ – fraction of flame radiation absorbed by surface, $a_s$ – flame-wall emissivity, $T_{fl}$, $T_{fw}$ – Temperature of flame and wall respectively

• $FEGT$ is related to flame temperature

$$\theta_{fl} = \frac{T_{fl}}{T_{th}} \propto \left( \frac{FEGT}{T_{th}} \right)^n \propto \theta_{ou}^n$$

Substitution yields

$$\frac{a_s C}{B_0} \theta_{ou}^{4n} + \theta_{ou} - 1 = 0$$
Furnace heat transfer

• From experimental results \((a_s \sim a_{fu})\)

• From above we get heat transfer surface area, \(F\)

• \(FEGT (T_{ou})\) from empirical relation

\[
\frac{\theta_{ou}}{1 - \theta_{ou}} = \frac{1}{M} \left( \frac{B_0}{a_{fu}} \right)^{0.6}
\]

\[
F = \frac{B . q'}{\sigma a_{fu} \psi M \cdot T_{th}^3 T_{ou}} \left[ \frac{1}{M} \left( \frac{T_{th}}{T_{ou}} - 1 \right) \right]^{0.66}
\]

\[
T_{ou} = \frac{T_{th} \cdot B_0^{0.6}}{M \cdot a_{fu}^{0.6} + B_0^{0.6}}
\]
Problem

• Find the size of a dry bottom pulverized coal fired furnace to fire 19.8 kg/s medium bituminous coal having LHV of 18,289 kJ/kg. Ash softening temperature is 1350 C.