Recovery Boiler Air Systems

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Outline

• Air supply and delivery
• Combustion air flow arrangements
• Gas flow in the furnace
• Air system problems
Objectives of Air Systems

- Supply air for complete combustion (3 Ts: time, temperature, turbulence)
- Control temperature and chemical environment around char bed
- Minimize carryover of black liquor spray
- Minimize emissions (CO, NO$_x$, TRS, SO$_2$)
- Achieve uniform flow and temperature entering superheater tube banks

Air System Components (3-Levels)
Air System Components

- Fans
- Ducts
- Heaters

Combustion System Fans

- Forced draft fans deliver combustion air
- Induced draft fans remove combustion gas
- Slightly negative draft is maintained in furnace (-1 to -2 inches H₂O)
- Firing rate can be limited by fan capacity
FD Fans & Air Preheating

Typical Air System Designs

<table>
<thead>
<tr>
<th>Total Number of Levels</th>
<th>Air Levels</th>
<th>Static Pressure in. H₂O</th>
<th>Percent of Total Air Flow</th>
<th>Temp. °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Primary</td>
<td>2 - 4</td>
<td>50 - 70</td>
<td>200 - 400</td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>4 - 8</td>
<td>30 - 50</td>
<td>200 - 400</td>
</tr>
<tr>
<td>≥ 3</td>
<td>Primary</td>
<td>2 - 4</td>
<td>30 - 40</td>
<td>200 - 400</td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>6 - 12</td>
<td>20 - 50</td>
<td>200 - 400</td>
</tr>
<tr>
<td></td>
<td>Tertiary</td>
<td>6 - 20</td>
<td>15 - 40</td>
<td>Ambient</td>
</tr>
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</table>
Characteristics of Turbulent Jets

- Jet Penetration
- Jet Expansion

![Diagram of turbulent jet characteristics]

z = distance from nozzle
D_n = nozzle diameter
V_c = centerline velocity
V_n = nozzle velocity

The Role of Primary Air

- Primary air controls the char bed perimeter
  - Controls bed burning near primary air ports
  - Pushes wall-shed material away from port
  - Pressure is important, too low is common problem
- Primary air keeps smelt hot and fluid
  - Blowing on a fire increases burning rate and temperature
  - Campfire and blacksmith are examples
Primary Air Arrangement

- Many, small ports on all four walls feed air to perimeter of the char bed
- Isolation dampers control local burning rates and bed shape
- Hot air improves combustion stability

The Role of Secondary Air

- Secondary air controls char bed height
  - Jet penetration to center of furnace needed
  - Large ports and high pressure air required
- Secondary air burns char and volatiles
  - Intensive mixing of air and combustion gases
  - Heat release needed to dry liquor spray
- Optimized to match liquor firing conditions
Secondary Air Arrangements

4-wall air jet arrangement
2-wall full interlace
2-wall partial interlace

Flow Pattern for a Full Interlace
Flow Pattern for Partial Interlace

Alternate Secondary Air Arrangements

- Single level, full- or partial-interlace (front/rear walls, or side walls)
- Multiple (2-3) levels, full interlace (vertically aligned ports)
- Rotary firing (swirling flow)
The Role of Tertiary Air

- Tertiary air completes mixing and burning of combustible gases (CO, H₂S, etc.)
  - Jet penetration to center of furnace needed
  - Large ports with high pressure air required
- Tertiary air is essential for staged combustion
  - Reducing conditions in lower furnace
  - Oxidizing conditions in upper furnace

Tertiary Air Arrangements

Interlaced Tertiary Air  Concentric Tertiary Air
Alternate Tertiary Air Arrangements

- Single level, full interlace (front/rear walls)
- Multiple (2-4) levels, full interlace (vertically aligned ports)
- Two separate levels, 10 to 20 feet apart (upper most level - quaternary air)
- Concentric tertiary air, or tangential tertiary air (swirling flow)

Multi-level Air Systems

- Advantages of multi-level secondary and tertiary air systems
  - Reduced fouling by carryover
  - Better mixing and emissions control
- Potential disadvantages
  - Difficult to control char bed combustion at low-medium solids
  - Accelerated corrosion by reducing gases reaching above composite tube line
Selecting An Arrangement

- The best arrangement depends on furnace design, liquor properties, spray conditions, and firing rate
- Arrangement is optimized by CFD and combustion modeling
- Performance is demonstrated by field testing and operating experience

Air System Operating Problems

- Air delivery systems are inflexible
  - $\Delta P$ proportional to square of flow
  - Limits recovery boiler turndown
  - Port velocity control dampers increase flexibility
- Air ports need frequent cleaning
  - Automatic port rodders improve performance
Air Port Dampers

Louver damper
- Adjusts flow rate
- Pressure and velocity decrease with flow rate

Velocity damper
- Adjusts air port nozzle area and flow rate
- Maintains higher pressure and velocity

Automatic Port Cleaning

Extended
Retracted
Air System Design Problems

- Insufficient fan capacity for increased loads
- Duct size, length, and bends can limit flow
- Duct flow is not always uniform
- Duct arrangement can affect nozzle flow
- Boiler supports limit duct/nozzle placement

Windbox Flow Problems

Before Modification

After Modification

Isolation Damper
Air Port Opening
Damper Flow Problems

Jet Interference

4-wall Secondary Air Arrangement

2-wall Secondary Air Arrangement
Implications for RB Air Systems

- Total quantity of air is most important
  - Impacts thermal efficiency, reduction, emissions
- Vertical distribution and pressure are next
  - Impacts char bed stability, carryover, emissions
- Air nozzle arrangement is third
  - Impacts channeling, carryover, temperature distribution into superheater, emissions
Implications for RB Air Systems

- Recovery boiler air systems can limit firing capacity and performance
- Velocity dampers increase flexibility
  - Variations in firing conditions and firing rate
  - Fine tuning possible
- Ports require frequent cleaning for good operation of recovery boiler