Recovery Boiler Optimization

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International Paper

TAPPI Kraft Recovery Course
References

  – Chapter 15 – Automatic Control
• **Combustion control strategy**
  • Flue gas emissions control strategy
  • Green liquor production & quality
  • Steam flow rate & temperature
• **Others**
  – Fireside deposit control
  – Safety systems and training
• **Implications for recovery boiler operations**
Combustion Control Strategy

- Black liquor volumetric flow control
- Black liquor pressure control
- Black liquor solids mass flow control
- Consumed air control (constant energy release)
Black liquor volumetric flow (traditional)

- Header or nozzle flow
- Fixed number of nozzles
- Liquor pressure varies
- Energy release in the furnace is sensitive to
  - Changes in percent fired solids
    - As percent fired solids decrease, energy release decreases
Black liquor pressure (traditional)

- Header or nozzle pressure
- Fix number of nozzles
- Working pressure range 5 – 10 psi
- Liquor flow varies
- Energy release in the furnace is partially “self-correcting”
  - With respect to changes in percent fired solids
    - As percent fired solids increase, BL flow decreases
Black liquor solids mass flow control

- Incorporates percent solids measurement
- Header or nozzle mass flow
- Volumetric flow and pressure vary
- Energy release in the furnace is less sensitive
  - To changes in percent fired solids
  - Remains subject to variations in BLS heating value
- Air supply & distribution often a function of BLS rate
Consumed air control (constant energy release)

• Maintain constant amount of air (O2) consumed
  – Energy release based on BTU/lb O2 similar for many materials

• Incorporates measurement of flue gas excess O2

• BL volumetric flow and pressure vary

• Energy release in the furnace is less sensitive
  – To changes in % solids and in BLS heating value

• Requires high-level DCS and added instrumentation
Typical Trends in Consumed Air Control
(constant energy release)

- steam flow
- excess O2
- BL flow
- % fired solids
- BL HHV

(Process response)
(setpoint)
(adjustment)
(disturbances)
Best practice: Consumed air control
(constant energy release)

• Improve process stability and predictability
• Increase BLS firing rate & run time
• Increase steam generation / BLS fired
• Improved green liquor reduction & dregs
• Reduce emissions levels and/or excursions
• Control is based on models between each manipulated variable (MV) and all controlled variables (CV).

• Most CVs do not have setpoints; operation within a range is allowed.
**Model Inputs and Outputs**

**Terminology:**

CV – Controlled Variable (Setpoint or range)

MV – Manipulated Variable (Cascade Setpoint to PID)

FV – Feedforward Variable
Motivations for Optimization

• Improved control reduces operating variability

With Multi-Variable Control
Reduced operating envelope

Constraint

With Optimization
Closer approach to optimum

Most profitable operating point

Optimization locates the best operating point

MVC allows closer control to optimum point
Case 1: Consumed air control, benefits

- Low odor RB with close-coupled Concentrator
- Part of major RB rebuild in the early 1990s
  - Vendor supplied package integrated into DCS
- Incorporated production rate and percent fired solids control
  - BLS rate ramped up and % solids unchanged
  - During Concentrator wash with lower percent fired solids the RB steam flow remains stable.
- Excellent operator acceptance (after 2-weeks), uptime >90%.
Case 2: Consumed air control, impact

- Total air flow and air distribution changes with liquor firing
  - Economizer exit O2 std. dev. decreased from 0.45% to 0.11% units
  - Economizer exit O2 decreased from 2.8% to 1.5% (dry basis)
  - Total excess air decreased from 115% to 108%
  - Actual flue gas weight decreased by 5.5%

Reference for this work:
Case 2: Consumed air control, value

- Overall performance metrics
  - Black liquor capacity increased by 8%
    - (Note: typical increase is 2%)
  - Thermal efficiency increased 0.35%, i.e. 3.24 to 3.25 ton stm /ton bls
  - Decreased fouling of boiler convection surfaces

Reference for this work:
Case 3: Consumed air control, optimization

- Model predictive control used to develop models and continuously optimize

- “While the boiler is running more or less steady, one of the input variables is “bumped” and the boiler response is monitored…”

- “This gives both the time response and the magnitude of the impact…”

Reference for this work:
Case 3: Consumed air control, value

• Achieved significant reduction in natural gas use for SO2 control

• Able to operate at lower black liquor firing rates without use of natural gas

• Generator bank plugging was minimized.

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SO2 control strategy

• High temperature lower furnace
  – Result of many process conditions, not a control variable
  – Overall indicator of furnace and boiler “health”
TRS control strategy

- Time / temperature / turbulence / O2
  - Result of final oxidation step, not a control variable
  - Fugitive TRS sources from high temperature liquor tanks
CO control strategy

- Time / temperature / turbulence / O2
  - Integral part of excess O2 control
  - As a constraint or as a controlled variable
NOx control strategy

• Air delivery system design
  – Result of process conditions, including nitrogen content of BL, not a control variable
  – Some ability to lower via “air-staging”
    • Increase air split to highest level in boiler
    • Addition of quaternary air to increase ability to stage air
    • Typically 10-20% reduction in NOx can be achieved
  – Also a function of percent BLS and firing rate
  – Use of SCR has been investigated but no long term demonstrated examples
Particulate control strategy

- Electrostatic precipitator design
  - Achieve desirable fume chemistry with high temperature in lower furnace, avoiding “acidic deposits” associated with low temperatures
  - Minimize excess air to improve collection efficiency
Overall: Good emissions control

- Air system with 3 or more levels
- Excess flue gas O2 control with CO constraints
- Management of air flow and distribution with BLS firing rate
- Management of air port pressures (manual or auto)
  - Automatic port rodders preferred approach
  - Velocity dampers at all air levels also preferred
Case 4: High SO2 incidents

• Low odor RB with a 3-level air system
• Periods of high SO2, environment & process issues
• Most likely causes:
  – Increase in the digester EAOW charge (major)
    • Increased dead load chemical, lowered BLS HHV
    • Monitor steam to dry solids ratio to track changes in black liquor heating value
  – Decrease in % BL solids (a few)
    • Increased water to furnace, lowered furnace temperatures
• Resolution:
  – Closer monitoring of up-stream operations
  – Improved communications between pulping & recovery
Outline

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GL total titratable alkali (TTA)

- Controlled with surrogate signals, e.g., density, refractive index, conductivity, etc., with adjustments from TTA tests
- Controlled by weak wash flow adjustments
- Stabilization tank & control after dissolving tank improves control
GL dregs content and settling rate

- Sometimes monitored, but not controlled
- Affected directly by lower furnace & BL spray conditions
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Steam flow rate and temperature

- Black liquor solids heating value
  - Dependent on pulping, dead load chemicals, makeup chemicals, and ash return strategy
- Overall thermal efficiency parameters
  - Examples in Jim Brewster’s talk on Energy
- Superheater fouling and deposit chemistry
  - Liquor cycle Cl & K chemistry
  - Sootblowing effectiveness
Case 5: Steam temperature

- Single-drum low odor RB
- Replacement for 3 DCE RB early 1990s
- Steam temperature decreased, no attemperation in less than 6 months
- Water wash(s) required in less than 12 months
Case 5: Steam temperature (con’t)

- Extensive testing of air & liquor delivery systems showed no improvements
- Reduced liquor cycle chloride (by ash purging)
  - Achieved stable steam temperature
  - Run time between water washes increased to 12 months
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Fireside deposit control

• Remember what Honghi has just told you!
Safety systems and training

• Prerequisite for equipment to run and to become a qualified operator

• Recovery boiler system controls have been identified as very challenging compared to other industrial processes

• Black Liquor Recovery Boiler Advisory (BLRBAC) Committee key industry safety organization.
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• Implications for recovery boiler operations
Implications (1)

- Foundations of recovery boiler operation
  - Consumed air control (constant energy release) combustion strategy
  - Manage liquor cycle with respect to Cl, K, and dead load chemicals
- Control of emissions is achieved with operating practices that improve recovery boiler throughput and thermal efficiency
Implications (2)

• Place a high priority on achieving good lower furnace operation, which is key to
  – Good green liquor quality
  – Good upper furnace ash chemistry

• Instill in operating staff the complexity of the recovery boiler and the need to always be on safety alert.