Black Liquor Evaporation
Optimizing Performance

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Topics

- Introduction
- Surface Condensers & Vacuum Systems
- Condensate Segregation
- Mist Elimination
- Hybrid Falling Film / Rising Film Trains
- FC Concentrator Upgrades
A New Era for the P&P Industry

- Environmental regulations
  - Tightening of the liquor cycle
    - Reduced color and BOD discharges
    - Foul condensate stripping
    - Higher NPE load in recovery island
  - Higher firing liquor % TS
  - NCG Collection
    - Reduced air emissions.

A New Era : Environmental Regulations

- Energy Cost
  - Financial viability of operations
    - Reduce energy usage
    - Optimize on-site energy production processes
  - Get more efficient = Be more competitive
A New Era for the P&P Industry

- Evaporation plant
  - Biggest consumer of steam & cooling water
  - Emphasis: Better performance & energy efficiency
  - Modernize and upgrade evaporation facilities.

Typical Upgrade Programs

- Gain BL throughput and concentration
  - Often well above original design
  - Retire older less efficient evaporator trains

- Condensate segregation
  - Reduced foul condensate generation
  - Minimized stripping or biological post-treatment costs
  - Improved condensate re-use within the mill
Typical Upgrade Programs

- Reduce liquor entrainment
  - Minimized soda losses
  - Re-use of process condensate
- Look at the whole recovery island
  - WBL composition & % TS (Recaustizing/Washers)
  - Evaporators= Source/Sink for low grade heat
  - Concentrator upgrades for higher solids
  - Indirect Liquor Heaters

Typical Upgrade Programs

- Optimize each design parameter individually
  - Unique features of the evaporators
    - Where are the weak links?
  - Liquor properties
    - Can they be improved? (Whole mill issue)
    - NPE Removal
- Overall Power & Recovery configurations
- Upgrade goals & Budget limitations
Typical Upgrade Programs

- Review a few examples
  - Common performance problems with the MEEs
  - Typical upgrade programs that can be undertaken.

- **Caution**
  - *What worked well at some location may not be appropriate at another.*

Surface Condensers & Vacuum Systems

- **Insufficient vacuum**
  - Most common operating problem encountered
  - Poor vacuum lowers available working \( \Delta T \)
  - Translates into a loss in evaporation capacity
Poor Vacuum Impact on $\Delta T$

- Steam Temperature: 274 °F
- Condenser Temperature: 132 °F
- Actual $\Delta T$: 98.3 °F inclusive of losses due to BPR

<table>
<thead>
<tr>
<th>Vacuum</th>
<th>Cond. Temp.</th>
<th>Actual $\Delta T$</th>
<th>Gain/Loss</th>
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<tr>
<td>25.5 &quot;Hg</td>
<td>129.0 °F</td>
<td>101.3 °F</td>
<td>+3.0%</td>
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<tr>
<td>25.0 &quot;Hg</td>
<td>132.0 °F</td>
<td>98.3 °F</td>
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<td>152.0 °F</td>
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<td>161.0 °F</td>
<td>69.3 °F</td>
<td>-29.5%</td>
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</tbody>
</table>

Surface Condensers & Vacuum Systems

- Need higher steam pressure
  - Actual $\Delta T$ raised back up
  - Capacity re-gained
  - Steam economy is lost due to additional preheat loads
Many vacuum systems are grossly undersized
- Evaporator capacity has been pushed without consideration for achievable vacuum

Poor NCG pre-cooling is also very common
- Higher volume to evacuate due to moisture

Excessive air leakage
- Maintenance issue

Surface condenser problems
Surface Condensers

- Insufficient condensing surface
  - Unrealistically high heat transfer coefficient was used

- Solutions:
  - Install an auxiliary condenser
  - Increase water flow
  - Run at higher condensing temperature thus higher steam pressure (costly)

Surface Condensers

- Insufficient water flow
  - Excessive usage elsewhere
  - Worn water pump
  - Inadequate piping, flow restrictions
  - Fouled tubes on the water side
    - CaCO3 scale from hard water, etc.
    - Biological slime
    - Hydroblasting of the tubes required
Surface Condensers

- Leaky water boxes
  - Water short-circuits one or more passes
    - Some condensing area effectively by-passed

- Inadequate NCG venting
  - Typically due to poor shell baffling set-up
    - Pockets of gas accumulate in some areas of the shell
    - Additional vent nozzles may have to be installed

Surface Condensers

- Shell side fouling
  - Excessive, even if infrequent, entrainment or foaming
    - Dried up liquor
    - Anthraquinone
    - Removal is difficult
    - Best accomplished by boiling with specialty chemicals
  - Upgrade mist eliminators
Mist Elimination

- Minimize black liquor carry-over in vapors sent to the next effect.
- Occurs in all the bodies but most prominent in vacuum effects.

Horizontal Flow

Vertical Flow
Mist Elimination

- Impact on operation of excessive entrainment
  - Chemical (soda) loss
    - Compensated via additional salt-cake make-up (Cost)
  - Fouling of heating elements and condenser
    - Translates into poor heat transfer, higher $\Delta T$
  - Color contamination in condensate
    - May prevent re-use within the pulp mill
  - Poor stripping efficiency
    - Fouling of stripper preheaters
    - Foaming in stripper column

Mist Elimination

- Possible causes for excessive entrainment
  - Pushed evaporation capacity
  - Not enough elimination capacity
    - Fouled, damaged or dislodged mist eliminators

- Retrofit to horizontal flow mist eliminators
  - Accommodate high vapor loadings
  - High removal efficiency: $\sim 5$-20 ppm Na$_2$O
Mist Eliminator Retrofit in LTV

Old centrifugal type          New chevron type

Mist Eliminator Retrofit in FF

- UPPER VAPOR BARRIERS (3 SECTIONS)
- VANE BANK FRAMES (6 MODULES)
- LOWER VAPOR BARRIERS (3 SECTIONS)
Mist Eliminator Retrofit

- Upper and lower vapor barriers installed
- Mist eliminator frames installed
- Foul condensate drains

- One of six modules installed within the vapor dome.
Condensate Segregation

- Water reduction = Energy reduction = Cost savings
  - Annual cost for a typical bleached mill

$1.0 - 3.0 \text{ MM/ year}$

- MEEs are the major “water-treatment” plant to produce condensate suitable for re-use

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Condensate Segregation

- Volatile components (Methanol & TRS)
  - Quickly stripped from the WBL in the first two stages of evaporation (typ. 5th & 6th effects)
  - Highest contamination found in condensate resulting from 5th and 6th effect vapors
    - ~ 75% of the volatile BOD
    - Most of the TRS compounds

- Keep cleaner condensate from MEEs front end away from this contaminated condensate
Condensate Segregation – Step One

- Remove 4th effect condensate and flash in external FT
  - Maintains overall economy
  - Flashing further removes volatile contaminants

- Methanol under 150 ppm (typ.), TRS at a few ppm
  - Suitable for re-use on the brownstock washers
Condensate Segregation – Step Two

- Principle
  - Contaminants being more volatile than water tend to condense later than water vapors
    - Condensing contaminated vapors in two stages – in series – effectively moves most of the contaminants into the second condensing stage
  - Fairly clean condensate produced out of the 1st stage
  - Very foul condensate collected from the 2nd stage

- Modify older LTVs by adding external heaters
Condensate Segregation - Step Two

- Modify existing condensers the same way

![Diagram of condenser with multiple stages and contaminant collection]

Condensate Segregation - Step Two

- Modern FF & Condensers
  - Two-stage condensing built-in
  - Baffling of the shell
  - Two condensing sections in series

- Slightly contaminated condensate collected in the 1st vapor pass
- Foul condensate in the 2nd pass
Condensate Segregation – Step Two

- Contaminated condensate
  - Methanol level typically ~ 400 ppm
  - Suitable for re-use in recausticizing

- Foul condensate
  - Methanol level often > 6,000 ppm
  - Requires stripping before re-use

Hybrid Systems FF / LTV

- FF unit integrated with LTVs
  - Used to gain capacity
  - FF designed for lower Delta-T
    - Some driving force is freed
  - Used to push other effects harder
  - Overall capacity gain for the set

- Other factors (SC, entrainment, etc.) may limit the actual capacity gained
Hybrid Systems FF / LTV

- LTV Conversion to FF
  - Bottom liquor box extension
  - New distribution device
  - New recirculation pump & piping
  - New vapor piping
  - Typically done to reduce steam pressure needed at the front end

- New FF as first effect provides better resistance to scale and greater turndown
Hybrid Systems FF / LTV

- Conversion from 5 to 6 effect operation
  - New FF body added to LTVs
    - Evaporation capacity gained: ~ 17%
    - Load on existing effects: ~ same
    - No additional steam or cooling water
  - Many conversion projects driven solely by energy savings, not capacity gained

Hybrid Systems FF / LTV

- FF body as 1st or 6th effect?
  - Heat transfer characteristics of the train
    - Where is the weak link?
  - Concentration profile changes across the train
    - Check materials
  - FF easily foam at low solids
  - LTV foul at higher solids
FC Concentrator Upgrade

- Utilities can help finance power savings projects
  - Quick, easy and reliable source of savings

- Ideal candidates
  - Existing FC concentrators and heavy liquor heaters
  - Retrofit with turbulence enhancers

Reynolds Enhanced Crystallizer (REX)

- Spiral inserts disrupt boundary layer at the tube wall
- Apparent Re in the turbulent region even at high liquor viscosities
- More efficient use of HP
  - High U coefficient
  - Lower tube velocities
Net Benefits of REX Upgrades

- Recirculation rate cut in half
- U Coefficient doubled
- Lower tube-side Delta-P
- 45-50% power savings

Conclusions

- MEEs total energy usage
  - Varies greatly from mill to mill
    - Age of the facility & capital invested over the years
    - Integration of ancillary equipment (stripping, etc.)
    - Type of evaporator (LTV, FF, etc.)
    - Environmental limits

- Different justifications at each mill
Conclusions

- Benchmarking
  - Critical to assess performance of your MEEs for energy consumption & costs against others
    - Identify MEE performance & energy use inefficiencies
    - Upgrade program developed & justification established

- Implementing such program
  - Significant improvement to the bottom line

$$$$$