Black Liquor Evaporation
Optimizing Performance

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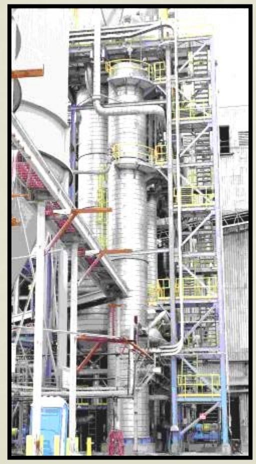
Topics

- 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.

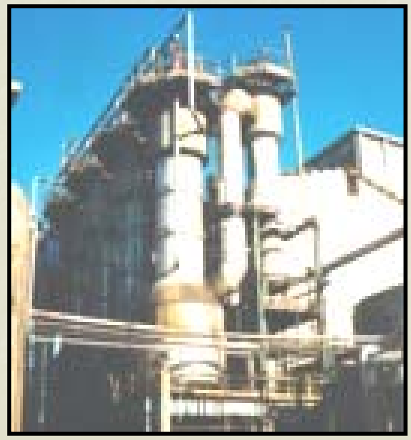


A New Era : Environmental Regulations

- 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 ΔT
  - Translates into a loss in evaporation capacity

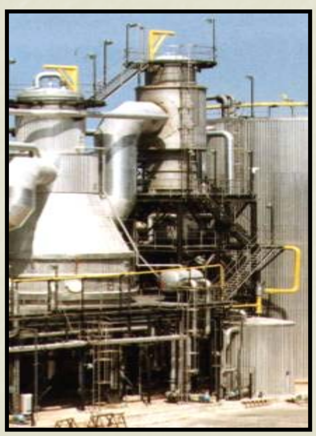
Poor Vacuum Impact on ΔT

- Steam Temperature: 274 °F
- Condenser Temperature: 132 °F
- Actual ΔT: 98.3 °F inclusive of losses due to BPR

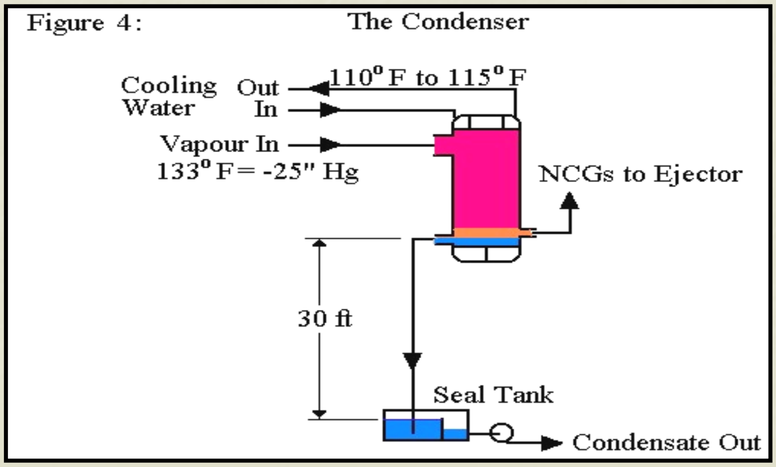
Vacuum	Cond. Temp.	Actual ΔT	Gain/Loss
25.5 ”Hg	129.0 °F	101.3 °F	+3.0%
25.0 ”Hg	132.0 °F	98.3 °F	-
24.0 ”Hg	140.0 °F	90.3 °F	-8.1%
23.0 ”Hg	146.5 °F	83.8 °F	-14.7%
22.0 ”Hg	152.0 °F	78.3 °F	-20.3%
21.0 ”Hg	156.7 °F	73.6 °F	-25.1%
20.0 ”Hg	161.0 °F	69.3 °F	-29.5%

Surface Condensers & Vacuum Systems

- Need higher steam pressure
  - Actual ΔT raised back up
  - Capacity re-gained
  - Steam economy is lost due to additional preheat loads



Surface Condensers & Vacuum Systems



Vacuum Systems

- 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

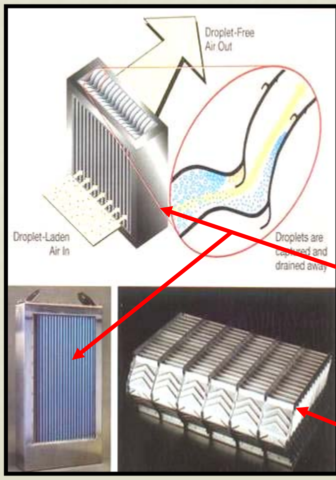
Surface Condensers

- 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

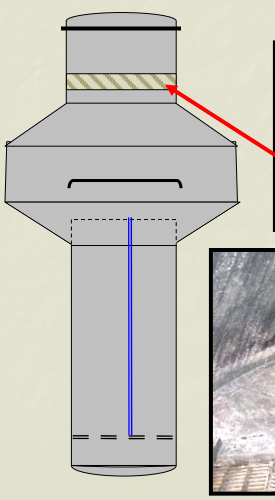


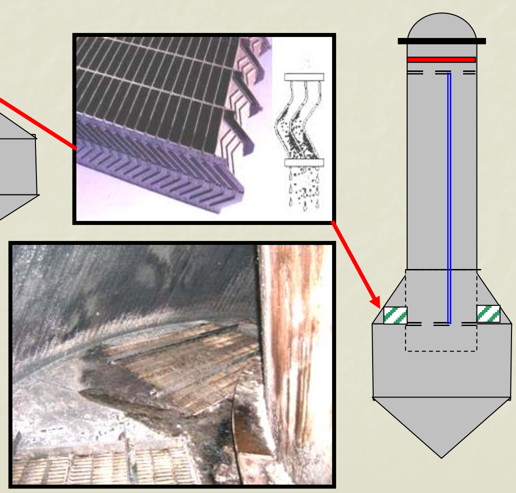
- Minimize black liquor carry-over in vapors sent to the next effect.
- Occurs in all the bodies but most prominent in vacuum effects.

Horizontal Flow

Vertical Flow

Mist Elimination





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 ΔT
  - 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

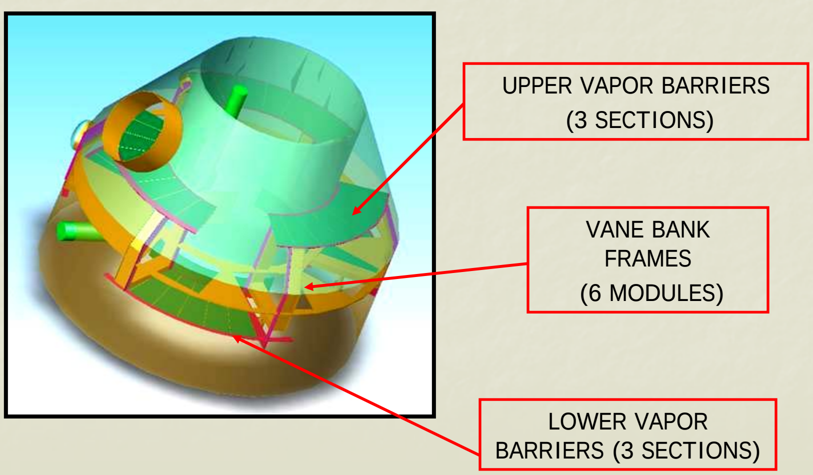
- Possible causes for excessive entrainment
  - Pushed evaporation capacity
  - Not enough elimination capacity
    - Fouled, damaged or dislodged mist eliminators
- Retrofit to <u>horizontal flow</u> mist eliminators
  - Accommodate high vapor loadings
  - High removal efficiency: ~ 5-20 ppm Na_2O

Mist Eliminator Retrofit in LTV

Old centrifugal type

New chevron type

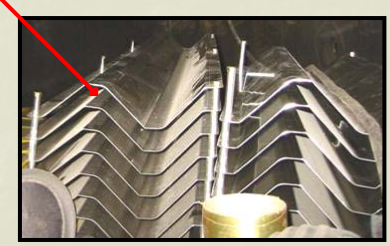
Mist Eliminator Retrofit in FF



Mist Eliminator Retrofit

Mist Eliminator Retrofit

- 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 MM / year

- MEEs are the major "water–treatment" plant to produce condensate suitable for re-use

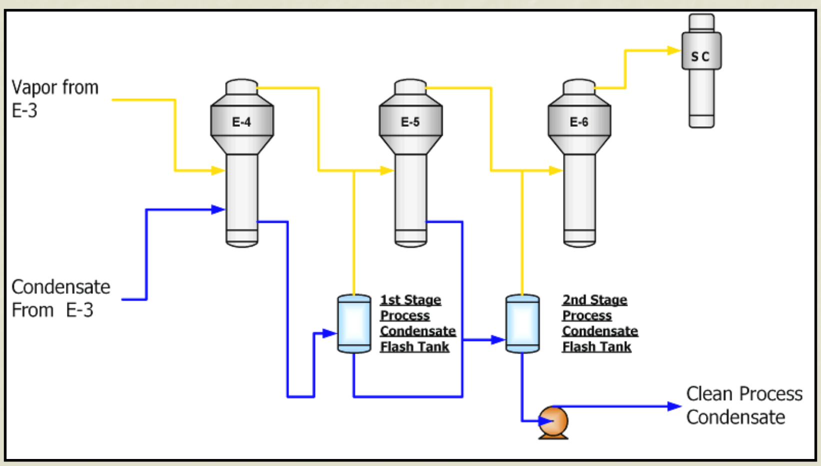
Condensate Segregation

- 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 One

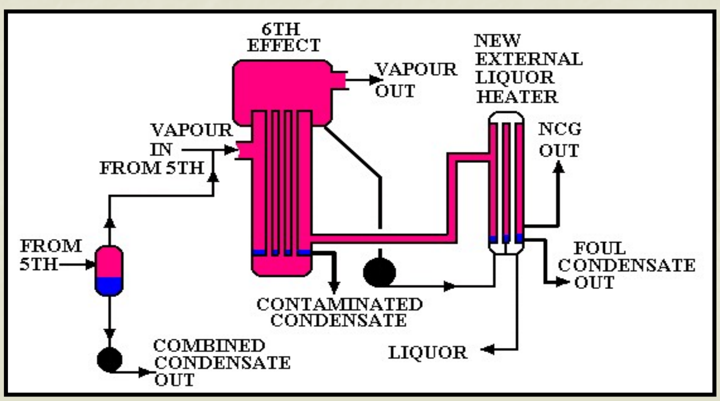


Condensate Segregation – Step Two

- 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

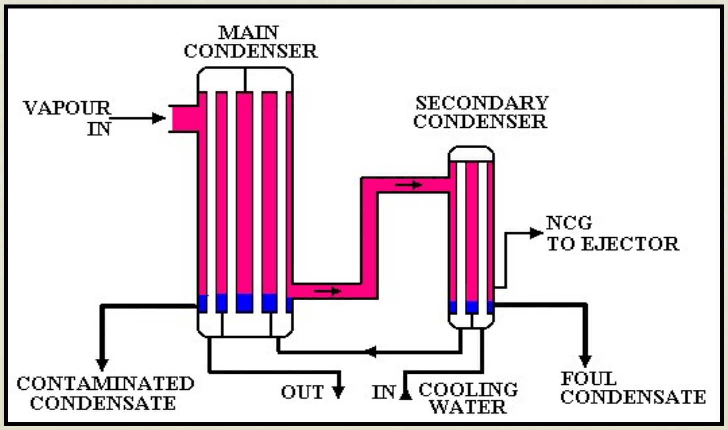
Condensate Segregation – Step Two

- Modify older LTVs by adding external heaters



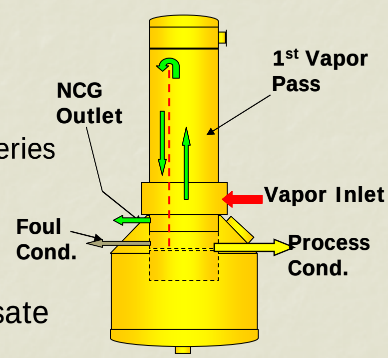
Condensate Segregation – Step Two

- Modify existing condensers the same way



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

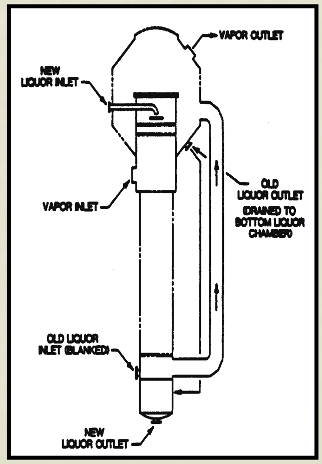
Hybrid Systems FF / LTV

- 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

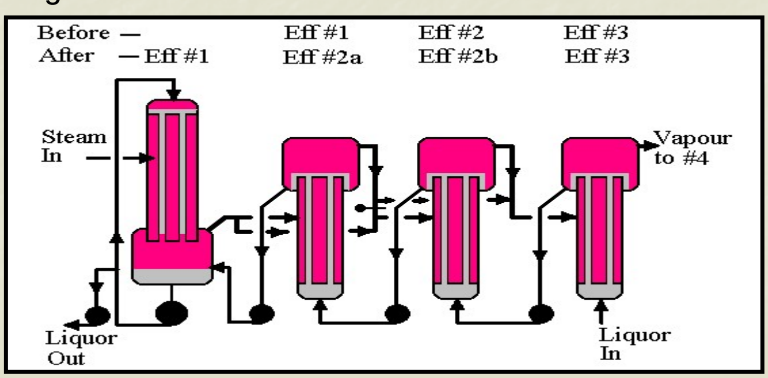
- LTV Conversion to FF
  - Bottom liquor box extension
  - New distribution device
  - New recirculation pump & piping
  - New vapor piping

  - Typically done to reduce steam pressure needed at the front end



Hybrid Systems FF / LTV

- 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

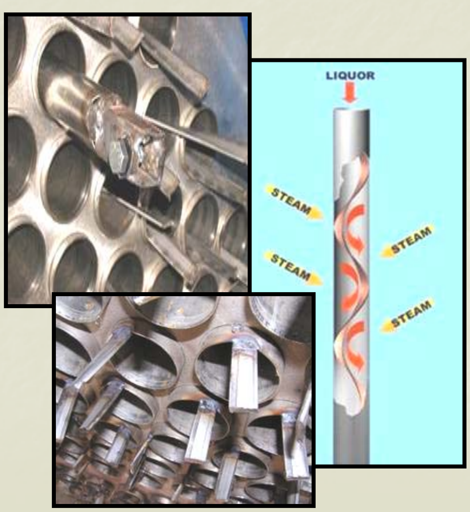
Hybrid Systems FF / LTV

- FF body as 1^{st} or 6^{th} 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

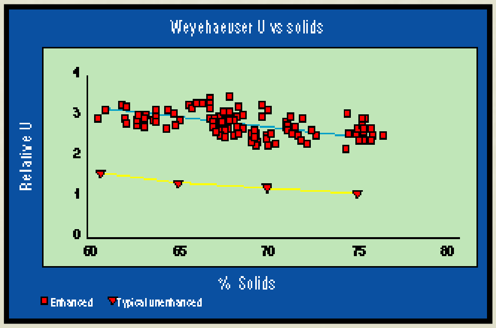
Reynolds Enhanced Crystallizer (REX)

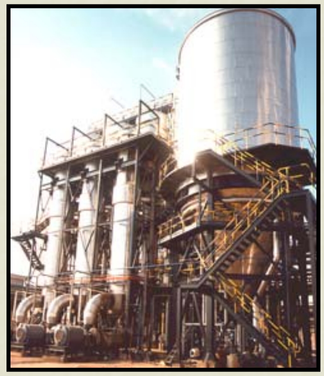


- Spiral inserts disrupt boundary layer at the tube wall
- Apparent Re in the turbulent region even at high liquor viscosities
- More efficient use of HP
  - High U coefficient
  - Lower tube velocities

Net Benefits of REX Upgrades

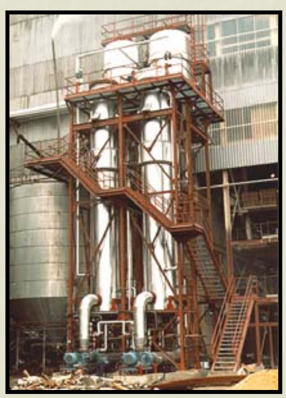
- Recirculation rate cut in half
- U Coefficient doubled
- Lower tube-side Delta-P
- 45-50% power savings





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

$$$$