Pulp and Paper
Waste Minimization Technology Review
Agenda

- HPD Introduction
- Pulp and Paper Review
- Discussion of Process / Technology Innovations for Pulp and Paper
  - BFR: Bleached Filtrate Recovery
  - CRP: Chloride Removal Process
  - MRP: Metals Removal Process
  - ZLD: Zero Liquid Discharge
HPD Pulp & Paper Industry Systems

- Liquor Concentration
  - Kraft
  - Soda Cook
  - NSSC or Sulfite
  - Non-wood
- Foul Condensate Stripping
  - Methanol Rectification
- NCG Collection and Incineration
- CRP / BFR
- Blow Heat Recovery
- Soap Recovery Systems
Falling Film Evaporator Train

HPD
Enhanced Force Circulation and CRP System
BFR Process

› Developed by Champion International

› Process recovers filtrates from the bleach plant and re-uses them in pulp washing

› Dissolved solids from bleaching ultimately contained in black liquor
BFR System

› Process Requirements
› Design Methodology
› System Description
› Features/Benefits
› Case Study
Chemical Pulping – The Kraft Process

1. Wood
2. Cooking → Washing → Bleaching → Pulp
3. Causticizing → Recovery
4. Dregs Grits → Liquor Losses
5. Bleach Filtrate

HPD
Schematic of the MRP Installed at the Canton Mill

- #2 Fiber Line
- D₁ Filtrate Tank
- Fiber Filter
- Untreated Filtrate Tank
- Media Filters
- Fiber Returned To No. 2 Fiber Line

To No. 2 Fiber Line
- Pre-Washer
- & D₁ Washer
- Lower Ponds

- Treated Filtrate Tank
- Softeners
- Filtered Filtrate Tank
Non-Process Metal Behavior in Current Mill

Unbleached Pulp → D100 → SHOWER (20%) → EOP → SHOWER (20%) → Final D Stage

80% → 0%
Non-Process Metal Behavior Under Recycle Conditions

[Diagram showing flow of materials through D100, EOP, and Final D Stage with washers and re-use for pulp washing]
Integration of Metal Removal Process Into D100 Stage

Unbleached Pulp → Mix → D100 → Wash → EOP Filtrate

- $\text{H}_2\text{SO}_4$
- $\text{ClO}_2$

Metal Purge → Metals Removal Process → D100 Pulp
MRP Major Issues Resolved

- Numerous Mechanical Failures
- Filtration Capacity
- Softener Pluggage
- Resin Oxidation
- Water Infiltration
Metals Removal Process

Performance Indicators

TARGET vs ACTUAL

- Calcium
- Magnesium
- Manganese
- Throughput

Bars indicate performance levels for each metal and throughput category.
Why Chloride / Potassium Removal?

› Mill Closure Can Cycle Up NPE’s
  › NPE’s Enter Cycle via Make-up
  › NPE’s Enter Cycle with Wood

› Cl / K Can Build Up
  › Reduction in Sticky Temperature Within Upper Furnace
  › Upper Furnace Plugging Potential
  › Corrosion Potential
Precipitator Ash Treatment
Available Technologies

› Chloride & Potassium
  › Inputs = Wood, Makeup Chemicals, Bleach Plant, Water
  › Outputs = Spills, Pulp, Stack
  › Most Concentrated in Precipitator Ash
  › Most Efficient Place to Remove from Cycle

› Technologies
  › Ash Dumping
  › Leaching
  › Ion Exchange
  › CRP - Forced Circulation Recrystallization
Ash Dumping
Technology Summary

› Design Strategy
  › Dump Ash to Control Mill Chemistry

› Design Characteristics
  › Add Rotary Valve and Water Mix Tank
  › Drain or Pump Ash to Sewer
Ash Dumping Application

**Advantages**
- Little or No Capital Investment
- Simple Flow Scheme

**Disadvantages**
- Large Salt Cake Losses Result in High Operating Cost
- Only Minor Moves in Mill Chemistry Are Possible
- Increases TDS in Mill Effluent

**Application**
- Mills with Low NPE Inputs
- Mills with Low TDS Discharge Limits
- Temporary Measure to Prove Effects on Recovery Boiler
Ash Leaching Technology Summary

› Design Strategy
  › Create Slurry of Ash and Brine
  › Maintain Brine at Concentration that Allows Selective Dissolving (Leaching) K and Cl from Ash

› Design Characteristics
  › Attempt to Control Close to Saturation but Far Enough Below to Provide Driving Force for Leaching
  › Solid Bowl Centrifuge to Dewater Paste from Leaching
  › Steam Added to Maintain Temp to Prevent Plugging
  › Automatic Wash System for All Lines to Minimize Downtime
<table>
<thead>
<tr>
<th><strong>Advantages</strong></th>
<th><strong>Disadvantages</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>No Evaporation</td>
<td>Little or No Commercial Experience as Early Attempts at This Technology Failed</td>
</tr>
<tr>
<td>Apparently Simple Flow Scheme</td>
<td>Lower Achievable K and Cl Concentrations in Purge Increase Salt Cake Losses</td>
</tr>
<tr>
<td>Lower steam usage</td>
<td>Multiple Systems Required as Capacity Increases</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Application</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal Improvement at Smaller Mills</td>
<td>Many Problems with Solids Handling Due to Small Particle Size</td>
</tr>
<tr>
<td>Temporary Measure to Prove Effects on Recovery Boiler</td>
<td>High Level of Operator Attention</td>
</tr>
</tbody>
</table>
Ion-Exchange Technology Summary

» Design Strategy
  » Dissolve Ash in Water and Use Ion Exchange to Remove Chloride
  » Put Treated Brine in Weak Black Liquor

» Design Characteristics
  » Dissolving Tank
  » Typical Ion Exchange System
  » Regeneration System
### Ion Exchange Application

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>No K removal, requires ash dumping to remove K</td>
</tr>
<tr>
<td></td>
<td>Large evaporation load increase from dissolved brine put into evaporator feed</td>
</tr>
<tr>
<td></td>
<td>Salt cake in evaporator reduces critical solid and will make the #2 effect evaporator scale in most mills</td>
</tr>
<tr>
<td></td>
<td>Chemical cost of regeneration</td>
</tr>
<tr>
<td></td>
<td>Disposal of regeneration stream</td>
</tr>
</tbody>
</table>

**Application**
- Only Looked At on Research Level
- No Commercial Applications
CRP Separation Efficiency

Na₂SO₄ Recovery = 80-90%
Chloride Removal = 85-90%
Potassium Removal = 80-90%

Mass Flowrate, lb/hr

- Ash
- Salt Cake
- Purge

Legend:
- Carbonate
- Chloride
- Potassium
- Sulfate
- Sodium

HPD
Benefits of CRP

- Improved Boiler Performance
  - Operate at higher temperature
  - Reduce or eliminate chill and blows
  - Reduce soot blowing (some mills have gone from double to single soot blowing)
  - Reduce corrosion (boiler and throughout mill)
  - Increased boiler life
Champion International BFR™ Process
Closed Cycle ECF Bleach Plant
The BFR™ Process can potentially operate in a closed cycle, at which point bleach plant effluent would approach zero.
AOX Determination for Simulated BFR Process

- 91% AOX Reduction Prior to Recovery Boiler
- 73% AOX Reduction Through Brownstock Washing and Black Liquor Storage
BFR Operating Cost

<table>
<thead>
<tr>
<th>Description</th>
<th>US$ / tonne Pulp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleach Chemicals</td>
<td>1.00</td>
</tr>
<tr>
<td>MRP Chemicals</td>
<td>0.75</td>
</tr>
<tr>
<td>CRP Chemicals</td>
<td>0-0.50</td>
</tr>
<tr>
<td>Steam @ $2 / ton</td>
<td>0.25</td>
</tr>
<tr>
<td>Power @ $0.05 / kWh</td>
<td>0.75</td>
</tr>
<tr>
<td>Labor @ $60 / man-yr</td>
<td>0.50</td>
</tr>
<tr>
<td>Maintenance</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4.25-4.75</strong></td>
</tr>
</tbody>
</table>
Bleach Filtrate Recycle – A Tool for Color Reduction

Blue Ridge Paper Products, Inc.
Canton, NC
Major Contributors for Improvements

› Canton Modernization Project

› Bleach Filtrate Recycle (BFR™)

› Best Management Practices
<table>
<thead>
<tr>
<th>Pre - Modernization</th>
<th>Post - Modernization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Effluent Flow</strong></td>
<td><strong>Effluent Flow</strong></td>
</tr>
<tr>
<td>45 MGD</td>
<td>29 MGD</td>
</tr>
<tr>
<td><strong>Effluent Color</strong></td>
<td><strong>Effluent Color</strong></td>
</tr>
<tr>
<td>115 kg/tonne of pulp</td>
<td>30 - 35 kg/tonne of pulp</td>
</tr>
<tr>
<td><strong>Effluent BOD</strong></td>
<td><strong>Effluent BOD</strong></td>
</tr>
<tr>
<td>1.6 kg/tonne of pulp</td>
<td>0.5 - 1.0 kg/tonne of pulp</td>
</tr>
</tbody>
</table>
Canton Mill Secondary Effluent
Color Annual Average

[Bar chart showing color annual average from 1988 to 1993.
- 1988: 370,000 lbs/day
- 1989: 340,000 lbs/day
- 1990: 300,000 lbs/day
- 1991: 300,000 lbs/day
- 1992: 250,000 lbs/day
- 1993: 200,000 lbs/day]
Demonstration of Bleach Filtrate Recycle (BFR™) 1995 - 1996

- Chloride Removal Process
- Metals Removal Process
- Closure of first two bleach stages of Pine fiberline
Calcium

› Calcium build up and its removal using the precipitation or ion exchange process during the laboratory simulation of recycle of bleach filtrates of a southern softwood pulp bleached by the OD (EOP) sequence

![Graph showing Calcium build up and its removal using precipitation or ion exchange process during laboratory simulation of recycle of bleach filtrates of a southern softwood pulp bleached by the OD (EOP) sequence.](Image)
FIBERLINE OPERATION WITH BFR™

› Reduced bleach plant effluent from 19 m³/tonne to 6 m³/tonne
› Increased operating cost ~10%
› No serious scaling issues to date
› No detected change in corrosion
### Canton Mill Secondary Effluent Environmental Performance

**Post-Modernization**

- **Flow**: 29 MGD
- **Color**: 30 - 35 kg/tonne of pulp
- **BOD**: 0.5 - 1.0 kg/tonne of pulp
- **AOX**: 0.13 - 0.22 kg/tonne of pulp

**BFR™ Operation**

- **Flow**: 29 MGD
- **Color**: 20 - 25 kg/tonne of pulp
- **BOD**: 0.5 - 0.8 kg/tonne of pulp
- **AOX**: 0.04 - 0.12 kg/tonne of pulp
Canton Mill Secondary Effluent
Color Annual Average

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>332,638</td>
<td>300,754</td>
<td>306,814</td>
<td>243,009</td>
<td>120,085</td>
<td>63,478</td>
<td>50,352</td>
<td>41,048</td>
<td>43,386</td>
<td>42,681</td>
<td>41,167</td>
<td>379,851</td>
<td>82,851</td>
<td>75,740</td>
<td>78,390</td>
</tr>
</tbody>
</table>
Canton Mill Secondary Effluent Flow Annual Average

Flow (Million Gallons per Day)


45.06 44.68 42.67 32.72 25.60 27.27 27.58 27.36 25.55 24.50 24.67 24.13 24.09
Canton Mill Secondary Effluent
BOD Annual Average

<table>
<thead>
<tr>
<th>Year</th>
<th>BOD (kg/tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>1.92</td>
</tr>
<tr>
<td>1992</td>
<td>1.34</td>
</tr>
<tr>
<td>1993</td>
<td>0.78</td>
</tr>
<tr>
<td>1994</td>
<td>0.62</td>
</tr>
<tr>
<td>1995</td>
<td>0.68</td>
</tr>
<tr>
<td>1996</td>
<td>0.72</td>
</tr>
<tr>
<td>1997</td>
<td>0.67</td>
</tr>
<tr>
<td>1998</td>
<td>0.63</td>
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<tr>
<td>1999</td>
<td>0.46</td>
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<tr>
<td>2000</td>
<td>0.44</td>
</tr>
<tr>
<td>2001</td>
<td>0.47</td>
</tr>
<tr>
<td>2002</td>
<td>0.60</td>
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</tbody>
</table>
Canton Mill Secondary Effluent COD Annual Average

COD (kg/tonne)

<table>
<thead>
<tr>
<th>Year</th>
<th>COD (kg/tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>44.00</td>
</tr>
<tr>
<td>1992</td>
<td>35.28</td>
</tr>
<tr>
<td>1993</td>
<td>22.00</td>
</tr>
<tr>
<td>1994</td>
<td>15.47</td>
</tr>
<tr>
<td>1995</td>
<td>15.57</td>
</tr>
<tr>
<td>1996</td>
<td>15.54</td>
</tr>
<tr>
<td>1997</td>
<td>12.28</td>
</tr>
<tr>
<td>1998</td>
<td>10.59</td>
</tr>
<tr>
<td>1999</td>
<td>8.40</td>
</tr>
<tr>
<td>2000</td>
<td>9.70</td>
</tr>
<tr>
<td>2001</td>
<td>11.01</td>
</tr>
<tr>
<td>2002</td>
<td>10.96</td>
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</tbody>
</table>
Canton Mill Secondary Effluent
AOX Annual Average

<table>
<thead>
<tr>
<th>Year</th>
<th>AOX (kg/tonne)</th>
</tr>
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<tbody>
<tr>
<td>1995</td>
<td>0.17</td>
</tr>
<tr>
<td>1996</td>
<td>0.15</td>
</tr>
<tr>
<td>1997</td>
<td>0.09</td>
</tr>
<tr>
<td>1998</td>
<td>0.11</td>
</tr>
<tr>
<td>1999</td>
<td>0.09</td>
</tr>
<tr>
<td>2000</td>
<td>0.10</td>
</tr>
<tr>
<td>2001</td>
<td>0.09</td>
</tr>
<tr>
<td>2002</td>
<td>0.08</td>
</tr>
</tbody>
</table>
Zero Liquid Discharge (ZLD)

- Wastewater treatment regulation allowing no aqueous waste
- Common in several industries including chemical production, automotive, power generation (conventional/nuclear)
- Evaporators / concentrators use MVR (Mechanical Vapor Recompression)
Typical ZLD Objectives

› **System Objectives**
  › Eliminate liquid waste
  › Generate landfillable solids
  › Generate high-quality water for reuse in upstream processes

› **Design Objectives**
  › Minimize capital and operating costs
  › Minimize manpower requirements
  › Safe, simple, and reliable system operation
  › Maximum flexibility (turndown capability)
  › Accommodate frequent start-ups, shut-downs, and periods of stand-by operation
Water Recovery Difficulty

<table>
<thead>
<tr>
<th>Technology</th>
<th>Utility</th>
<th>Relative Capital</th>
</tr>
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<tbody>
<tr>
<td>MF/RO</td>
<td>10 kWh/1000gal</td>
<td>1.0 $/gpm</td>
</tr>
<tr>
<td>Evaporation</td>
<td>70 kWh/1000gal</td>
<td>2.5 $/gpm</td>
</tr>
<tr>
<td>Crystallization</td>
<td>250 kWh/1000gal</td>
<td>5.0 $/gpm</td>
</tr>
</tbody>
</table>

![Water Recovery Difficulty Diagram](image_url)
<table>
<thead>
<tr>
<th></th>
<th>Examples</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Oxides</td>
<td>Iron</td>
<td>Feedwater</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>Corrosion</td>
</tr>
<tr>
<td></td>
<td>Aluminum</td>
<td>Clarifiers</td>
</tr>
<tr>
<td>Scaling salts</td>
<td>Calcium carbonate</td>
<td>Feedwater</td>
</tr>
<tr>
<td></td>
<td>Calcium fluoride</td>
<td>Surface water</td>
</tr>
<tr>
<td></td>
<td>Calcium sulfate</td>
<td>SDI 10 - 175</td>
</tr>
<tr>
<td></td>
<td>Barium sulfate</td>
<td>Corroding pipes</td>
</tr>
<tr>
<td></td>
<td>Strontium sulfate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silica</td>
<td></td>
</tr>
<tr>
<td>Colloids (SDI)</td>
<td>Clay</td>
<td>Surface water</td>
</tr>
<tr>
<td></td>
<td>Silt</td>
<td>SDI 10 - 175</td>
</tr>
<tr>
<td></td>
<td>Rust</td>
<td>Corroding pipes</td>
</tr>
<tr>
<td>Biological</td>
<td>Organics</td>
<td>Non-chlorinated feed</td>
</tr>
<tr>
<td></td>
<td>Organic slimes</td>
<td>Off-line units</td>
</tr>
<tr>
<td></td>
<td>Bacteria</td>
<td>Surface water</td>
</tr>
</tbody>
</table>
Implications of Feed Chemistry
Evaporation / Crystallization

- Scale (sparingly soluble salts)
  - $\text{SO}_4$, $\text{CO}_3$, $\text{SiO}_2$

- Distillate Quality
  - VOC, Alkalinity

- BPR
  - Mg, Cl, Na

- Salt Residue (readily soluble salts)
  - Mg, Cl
Softening via Reaction Clarification

- Softening Chemicals
- Raw Water
- Reaction Clarifier
- Overflow
- Sludge Thickener
- Filter Press
- Filter
- Press
- Filtrate Recycle
- Underflow
- pH Adjust
- Softened Water
- Media Filter
- Solids to Disposal
Brine Evaporator

Chemicals

Feed

Feed Tank

Feed Preheater

NCG Vent

Deaerator

Brine Concentrator

Compression Device

Concentrated Brine

Recirculation Pump

Seed Recycle

Recovered Water
Preheat Falling Film Evaporator

- **Steam**
- **External Plenum**
- **Vent**
- **Manway**
- **Condensate**
- **Vapor Body**
- **Vapors**
- **Chevron Separator**
- **Feed**
- **Product**
- **Recirculation Pump**
Falling Film Heat Transfer

- Liquor film on tube formed by vapor generation
- Gravity pulls liquor down the tube.
- Vapor generation creates high velocities and therefore high heat transfer coefficients
Falling Film Evaporation Systems

Over 400 Systems in 50 Applications

› Caustic
› Glaubersalt
› Nutrasweet
› Sodium Chloride
› Black Liquor
› Calcium Chloride
› Waste Brine
› Cooling Tower Blowdown
› Potassium Hydroxide
› Sodium Bicarbonate
Brine Crystallizer

Crystallizer Vapor Body

Compression Device

Dewatering Device

Slurry Tank

Solids to Disposal

Recovered Water

Feed

NCG Vent

Crystallizer Heater

Recirculation Pump

HPD
Forced Circulation Crystallizer

- Vapors
- Vapor Body
- Liquor
- Heating Element
- Steam
- Condensate
- Recirculation Pump
Forced Circulation Crystallizer

- Flooded tube prevents evaporation inside tubes
- Temperature rise limited to prevent temperature sensitive inorganic scale
- Liquor forced by mechanical means at high velocity producing high turbulence and heat transfer coefficients
Crystallization Systems

Over 150 Systems in 50 Applications

› Sodium Chloride
› Sodium Carbonate
› Sodium Bicarbonate
› Sodium Sulfate
› Ammonium Sulfate
› Glyphosate
› Sodium / Potassium Nitrate
› Citric Acid
› Sodium Metabisulfite
› Ammonium Metavanadate
› Calcium Chloride
› Waste Salts
CDR Pigments, Kentucky

Zero Liquid Discharge System
Chemical Market
Methods of Achieving Evaporation

› **Live Steam**
  • Very Low Capital $$$
  • Costly to operate and requires cooling water

› **Thermocompressor**
  • Low Capital $
  • More efficient, but still requires motive steam and cooling water

› **Centrifugal Fan**
  • Medium Capital $$$
  • Low rotational speed, low lift device

› **Positive Displacement Blower**
  • Medium Cap. $$
  • Can generate high lift at low rotational speed, but capacity is limited

› **Centrifugal Compressor**
  • High Capital $$$
  • High rotational speed and high lift.
HPD Experience - MVR

Installations
- Sodium Chloride Crystallization
- Sodium Sulfate Crystallization
- Black Liquor
- Component Recovery
- Wastewater

Equipment
- Centrifugal (AC, I-R, Sulzer)
- PD Rotary Lobe (Roots)
- Radial Blade Fan (ABB Flakt)
- MultiStage (Lamson)
- Screw
MR Evaporation
Centrifugal
Turbo Fans

Offers medium lift in a single stage at low rotational speeds

- Low speed minimizes maintenance costs and the cost for warehousing spare parts
- Low speed reduces harmful effects of liquid carryover and/or foaming
- Medium lift limits heater fouling
- Heavy Duty Construction ID Fan - Designed for Steam
Inlet Guide Vanes

Closed

Open
Rotary Lobe Type Blowers

Offers high lift in a single stage at low rotational speeds

› Low speed minimizes maintenance costs and the cost for warehousing spare parts
› Low speed reduces harmful effects of liquid carryover and/or foaming
› Limited capacity: good for up to ~100 gpm
PD Rotary Lobe Blower
Solids Separation Options

- Filter Press
  - Batch operation – labor intensive
- Centrifugal Filter
  - Unable to accommodate fine particles
  - Susceptible to filter blinding
- Belt Filter
  - Can be difficult to operate, especially on slurries with wide particle size distributions
- Decanter Centrifuge
  - High capital cost, but provides reliable continuous operation
- Spray Drier
  - High energy consumption (natural gas.) Is an emission source, and may require permitting
Wastewater Zero Liquid Discharge Systems

Over 100 ZLD Systems

- Power Conventional and Nuclear
- Chemical
- Automotive
- Recycle Paper
- Petrochemical
- Microelectronics
ZLD in Power Generation Industry
HPD Case Studies

Harquahala Generating Company

Calpine Rocky Mountain Generating Station
Harquahala Generating Station

- 1000 MW Combined Cycle Power Facility
- Operational Winter 2002
- Turnkey ZLD Process System
  - 2600 gpm Sidestream Softener
  - RO Concentration System
  - Evaporation/Crystallization System
    - Mechanical Vapor Recompression (MVR)
    - 2 – 260 gpm evaporators
    - 2 – 26 gpm crystallizers
- Only waste is dry cake
Harquahala ZLD System

Soda Ash Silo
Lime Silo
Brine Evaporators
Brine Crystallizers
RO Reject Storage Tank
RO Permeate Forwarding Tank
Lab/MCC
RO Modules
RO Feed Tank
MMFs
Sidestream Softeners
Sludge Thickener / Storage
Sludge Presses
RO Modules
Calpine – Rocky Mountain Energy Center

- 600 MW Combined Cycle Power Facility
- Start-up Winter 2003
- HPD Team Provided Complete DB including:
  - Raw Stream Softening
  - ZLD Evaporation using MVR
  - De-min System
  - Complete Infrastructure – Chemical/Electrical/Control/Buildings
Calpine Overall Layout
Case Study: Durango-McKinley Paper

Prewitt, NM, U.S.A.

Corrugated product using 100% recycled containers as raw material

Remote location in the desert with only artesian raw water resources

ZLD since 1994
Water Reclamation Flowsheet

Figure 1
ZLD Process – Two Distinct Loops

- **Primary loop**: separates long fiber, dirt and fiber fines from stock preparation
  - Disc screen to remove fiber, debris
    - Filtrate to dissolved air flotation, debris to press
  - Dissolved air flotation flocculation with air bubbles and polymer to float fiber fines
    - Recovered water to Secondary Loop, debris combined with disc screen material to belt press
ZLD Process – Two Distinct Loops

› Water in secondary loop process in large basins by biological treatments
  › Dosed with nutrients to promote growth
› Tertiary microfiltration treatment removal of suspended solids
  › Flitrerate moves to R.O. as next step
  › Debris back to primary loop
› Reverse osmosis (R.O.) permeate to mill tank
  › Brine to crystallizer / concentrator
› Crystallizer final step separates clean distillate from brine liquor using MVR to mill tank
  › Vapors condensed to form distillate
  › Brine sent to press cake for landfill, fuel source or composting