Basics of Kraft Pulping & Recovery Process

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Outline

• History
• Goals
• Process Overview
• Kraft Pulping Process
• Kraft Recovery
  – Power Plant
  – Caustic Plant
History

• Soda pulping process patented, 1854.
• Soda recovery via incineration patented, 1865.
• First successful soda mill, 1866.
• Kraft pulping process patented by Dahl, 1884.
• First commercially viable kraft mill, Sweden, 1885.
• Kraft recovery furnace, 1930’s.
Kraft Pulping and Recovery: Overall Objectives

• Chemical convert wood into cellulosic pulp
• High quality, strong pulp for papermaking
• Operate safely
• Minimize impacts on air and water
• Satisfy customer needs
  – Maximum product quality
• Minimize cost
Kraft Pulping Objectives

• Use chemicals, heat, pressure to liberate fibers.
• Operate safely.
• Minimize impacts on air and water.
• Satisfy customer needs - maximum product quality.
• Minimize cost.
Kraft Recovery Objective

- Concentrate and burn black liquor.
  - Provide energy produced from organics.
  - Provide partially reconstituted pulping chemicals.
- Operate safely.
- Minimize impacts on air and water.
- Satisfy customer needs, product quality.
- Minimize cost.
Kraft Caustic Plant Objective

• Final step in reconstituting pulping chemicals.
  – Provides fresh cooking liquor.
  – Regenerates lime from lime mud.

• Operate safely.
• Minimize impacts on air and water.
• Satisfy customer needs, product quality.
• Minimize cost.
The Kraft Pulping and Recovery Process

- Process overview.
The Kraft Pulping and Recovery Process Flow Diagram
The Kraft Pulping and Recovery Basic Process Flow

- White Liquor
  - NaOH
  - Na₂S

- Pulp Mill
  - Cooking
  - Washing

- Black Liquor

- Turpentine

pulp
Raw Material
Structure of Wood Fibers
Chemical Structure of Fibers

Extractives 2 – 8 %

40 – 47 %

25 – 35 %

20-30 %
Physical Structure of Fibers

Cellulose embedded in lignin – hemicellulose matrix.
Kraft Yields

<table>
<thead>
<tr>
<th>Extractives</th>
<th>Pine Wood</th>
<th>50% Yield Kraft</th>
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</thead>
<tbody>
<tr>
<td>Lignin</td>
<td>30 kg</td>
<td>5 kg</td>
</tr>
<tr>
<td>Cellulose</td>
<td>45 kg</td>
<td>40 kg</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>20 kg</td>
<td>2.5 kg</td>
</tr>
<tr>
<td>Extractives</td>
<td>5 kg</td>
<td>0 kg</td>
</tr>
</tbody>
</table>
Chip Quality

- Hardwood vs. Softwood
- Wood Density
- Roundwood vs. Chips
  - SMC
  - Thinnings

Juvenile (8 – 12)

Mature
Chip Storage

- Manage Chip Pile
  - By-Products
  - Acid Hydrolysis
  - Yield
Chip Preparation

Chips

Roundwood

Longwood

Slasher

Barking Drum

Chipper

Chip Storage

Chip Screens

Boiler

Magnet

Pulp Mill

Rechipper
Kraft Pulping

- **White Liquor**
  - NaOH + NaSH
  - Dissolve & Fragment Lignin
  - Peeling and Chain Scission of Polysaccharides
Kraft Chemistry

\[ \text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^- \]

\[ \text{Na}_2\text{S} \rightarrow 2\text{Na}^+ + \text{S}^{2-} \]

\[ \text{S}^{2-} + \text{H}_2\text{O} \rightarrow \text{SH}^- + \text{OH}^- \]

\[ \text{NaOH} + \text{Na}_2\text{S} + \text{H}_2\text{O} \rightarrow 3\text{Na}^+ + 2\text{OH}^- + \text{SH}^- \]

\[ \text{Na}_2\text{CO}_3 \]
Kraft Pulping

- **Digesters**
  - Batch and Continuous Reactors
  - Dissolve & Fragment Lignin
  - 341-350°F
  - 105-120 psi
  - pH 12-14
Kraft Pulping

White Liquor

Chip Feed System

Digester

Blow Tank

Knotters

Washers

Screens/Cleaners

Evaporators (Recovery)
Batch Digesters

- 20+ ft. Height
- 10 – 15 ft. Diameter
- Carbon Steel
- Pressure Vessel
Batch Digesters

- Locking Pin
- Liquor Top Off
- Level & Pressure Sensors
- Blowline
- Chip Chute
- Capping Valve
- Gasoff Vent
- Temperature Probes
- White and Black Liquor
Continuous Digesters: Chip Feed System

- Pressurized Feed System
Continuous Digesting System

- Carbon Steel
- Pressure Vessel
- 200 – 250 ft Height.
Pulp Preparation

- Blow Tank
- Knotters
- Chip Bin
- Counter Current Washers
- Screens/Cleaners
- Pulp Storage

Flow:
- Liquor from First Stage to Evaporators
- Hot Water to Final Washing Stage Shower
- Liquor from Later Stages to Shower Earlier
Kraft Chemistry

• Extractives
  – Dissolved
  – Turpentine
  – Tall Oil
Extractives

- Digester Relief
  - Cyclone Separators
    - Black Liquor
  - Condensers
    - Decanter
    - Storage
The Kraft Pulping and Recovery Process Flow Diagram
Power Plant

• Kraft Recovery
  – Black Liquor Evaporation
  – Recovery Boiler
The Kraft Recovery Boiler

- Recovery Boiler
  - Water Evaporation
  - Burns Organics
  - Steam
  - Reduces Oxidized Sulfur Compounds
  - Recovers Inorganics as Smelt
Kraft Recovery Boiler

- **Green Liquor**
  - \( \text{Na}_2\text{CO}_3 \)
  - \( \text{Na}_2\text{S} \)

Diagram:
- Pulp Mill
- Black Liquor
- Power Plant
- Green Liquor
- White Liquor
- Caustic Plant
The Kraft Recovery Boiler

- Concentrated BL from Concentrator
  - Salt Cake
  - Black Liquor Mix Tank
  - Liquor Heater
  - Steam

- Precipitator

- Dissolving Tank
The Kraft Recovery Boiler

- Precipitator
- Boiler Feed Water
- Economizer
- Boiler Section
- Superheater
- Turbines
- Hot Combustion Gas
- Furnace Wall
- Screen
The Kraft Recovery Boiler

Oxidation
\[ \text{Na}_2\text{S} + \frac{3}{2} \text{O}_2 + \text{CO}_2 \rightarrow \text{Na}_2\text{CO}_3 + \text{SO}_2 \]

Pyrolysis
\[ \text{Na}_2\text{S} + \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{S} \]

Reduction
\[ \text{Na}_2\text{SO}_4 + 2\text{C} \rightarrow \text{Na}_2\text{S} + 2\text{CO}_2 \]
\[ \text{Na}_2\text{SO}_4 + 4\text{C} \rightarrow \text{Na}_2\text{S} + 4\text{CO} \]
The Kraft Pulping and Recovery Process Flow Diagram

Pulp Mill

White Liquor

Caustic Plant

Black Liquor

Green Liquor

Power Plant
The Kraft Pulping and Recovery Process Flow Diagram
The Kraft Chemical Recovery Process Flow Diagram

Smelt - Na₂CO₃

CaO (Lime)

CaO + H₂O → Ca(OH)₂ (Slaked Lime)

Slaker

Na₂CO₃ + Ca(OH)₂ → NaOH (Caustic) + CaCO₃ (Lime Mud)

Pulp Mill
The Kraft Caustic Plant Process
Flow Diagram

Green Liquor Clarifier

Slaker

Causticizers

White Liquor Clarifier

Lime Silo

Filter

Mud Washer

Kiln

Dregs Washer or Filter
Safety

- **Pulp Mill - Acid Cleaning**
  - Digester, Liquor Heaters, Inline Drainers
- **Power Plant - Smelt Water Explosions**
- **Caustic Plant - Gas in Kiln**
Environmental Concerns

- Water
  - Acid Cleaning
  - Liquor Spills
- Air
  - Stacks