



# Nonwood Fibers & Molded Products

## IMFA Annual Seminar

April 2-4, 2014

Coral Gables, FL

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# Topics

- 1) Nonwood fiber raw material availability
- 2) General comments on nonwoods
- 3) General comments on molded products
- 4) Selected nonwood fiber properties
- 5) Considerations for nonwood pulp mills
- 6) Marketing



# Global Cereal Straws

	BDMT / year
Barley	195,000,000
Oat	55,000,000
Rice	360,000,000
Rye	40,000,000
Wheat	600,000,000
Total	1,250,000,000



**Wheat Straw**



# Global Pith Containing Nonwoods

	BDMT / year
Sugarcane bagasse	102,000,000
Corn stalks	750,000,000
Grain & sweet sorghum stalks	252,000,000
Total	1,104,000,000



Sugarcane



# Global Bast Fibre Plants (whole stalk)

	BDMT / year
Textile flax, hemp, jute, kenaf, etc.	14,000,000
Oilseed flax straw	2,000,000
Cotton stalks	68,000,000
Total whole stalk	84,000,000
Bast fibre only	21,000,000



Kenaf



# Global Bamboo, Reeds & Grasses

	BDMT / year
Bamboo	30,000,000
Grass seed straw	3,000,000
Papyrus	5,000,000
Reeds	30,000,000
Sabai grass	200,000
Total	68,200,000



Reeds



# Global Cotton

	BDMT / year
Staple fibre	18,300,000
1 <sup>st</sup> & 2 <sup>nd</sup> cut linters	2,700,000
Total	21,000,000



Cotton



# Global Leaf Fibre Plants

	BDMT / year
Sisal, henequen, maguay	500,000
Abaca (Manila hemp)	100,000
Total	600,000



Sisal



# Global - All Selected Nonwoods

	BDMT / year
<b>Cereal straws</b>	<b>1,250,000,000</b>
<b>Pith containing nonwoods</b>	<b>1,104,000,000</b>
<b>Bast fibre plants</b>	<b>84,000,000</b>
<b>Bamboo, reeds &amp; grasses</b>	<b>68,000,000</b>
<b>Cotton</b>	<b>21,000,000</b>
<b>Leaf fibre plants</b>	<b>600,000</b>
<b>TOTAL</b>	<b>2,527,800,000</b>



# Other Nonwoods

- Other nonwood fibres also can be available for pulping
- Malaysia – the world's largest producer of palm oil

	BDMT / year
Oil palm empty fruit bunches (EFB)	5.5 – 6.5 million
EFB fibre	3.5 - 4.1 million
Bleached pulp (40% yield)	1.4 – 1.6 million



Oil Palm EFB



# Canada / US Nonwood Resources (bdmt/year)

<b>Raw Material</b>	<b>Canada</b>	<b>US</b>
Wheat straw	32,289,000	78,900,000
Rice straw		7,500,000
Barley straw	11,268,000	12,000,000
Oat straw	4,397,000	6,000,000
Rye straw	576,000	400,000
Grass seed straw		900,000
Flax (oilseed) straw	740,000	700,000
<b>Subtotal straws</b>	<b>49,270,000</b>	<b>106,400,000</b>



# Canada / US Nonwood Resources (bdmt/year)

<b>Raw Material</b>	<b>Canada</b>	<b>US</b>
Subtotal straws	49,270,000	106,400,000
Corn stalks	8,870,000	300,800,000
Sorghum stalks		33,700,000
Sugarcane bagasse		3,000,000
Cotton stalks		7,100,000
Cotton staple		3,500,000
Cotton linters		500,000
Cotton mote		200,000
<b>TOTAL</b>	<b>58,140,000</b>	<b>445,200,000</b>



# Nonwood Pulp Production

	<b>Total Pulp (bdmt/year)</b>
<b>Straw</b>	<b>10,900,000</b>
<b>Bagasse</b>	<b>1,460,000</b>
<b>Bamboo</b>	<b>3,240,000</b>
<b>Other Nonwoods</b>	<b>8,440,000</b>
<b>Total Nonwood Pulps</b>	<b>24,040,000</b>



# Topics

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- 2) General comments on nonwoods
- 3) General comments on molded products
- 4) Selected nonwood fiber properties
- 5) Considerations for nonwood pulp mills
- 6) Marketing



# General Comments on Nonwoods



# General Comments on Nonwoods

- **Nonwood fibers include a very wide range of raw materials, fiber characteristics and forms of delivery**
- **Exceptions are typical – “one size doesn’t fit all”**
- **Nonwoods can be broadly categorized as “common” fibers and “specialty” fibers**



# General Comments on Nonwoods

## Common nonwoods

- typically short fiber, hardwood substitutes
- pulp normally made into paper at same mill
- pulp mill capacity typically smaller than paper mill capacity – balance softwood Kraft for strength
- very few market pup mills
  - wheat straw, Hungary
  - bagasse, Thailand
  - bamboo, China

Cereal straws

Corn stalks

Grain sorghum stalks

Reeds and grasses

Sugarcane bagasse

Some bamboos



# General Comments on Nonwoods

## Specialty nonwoods

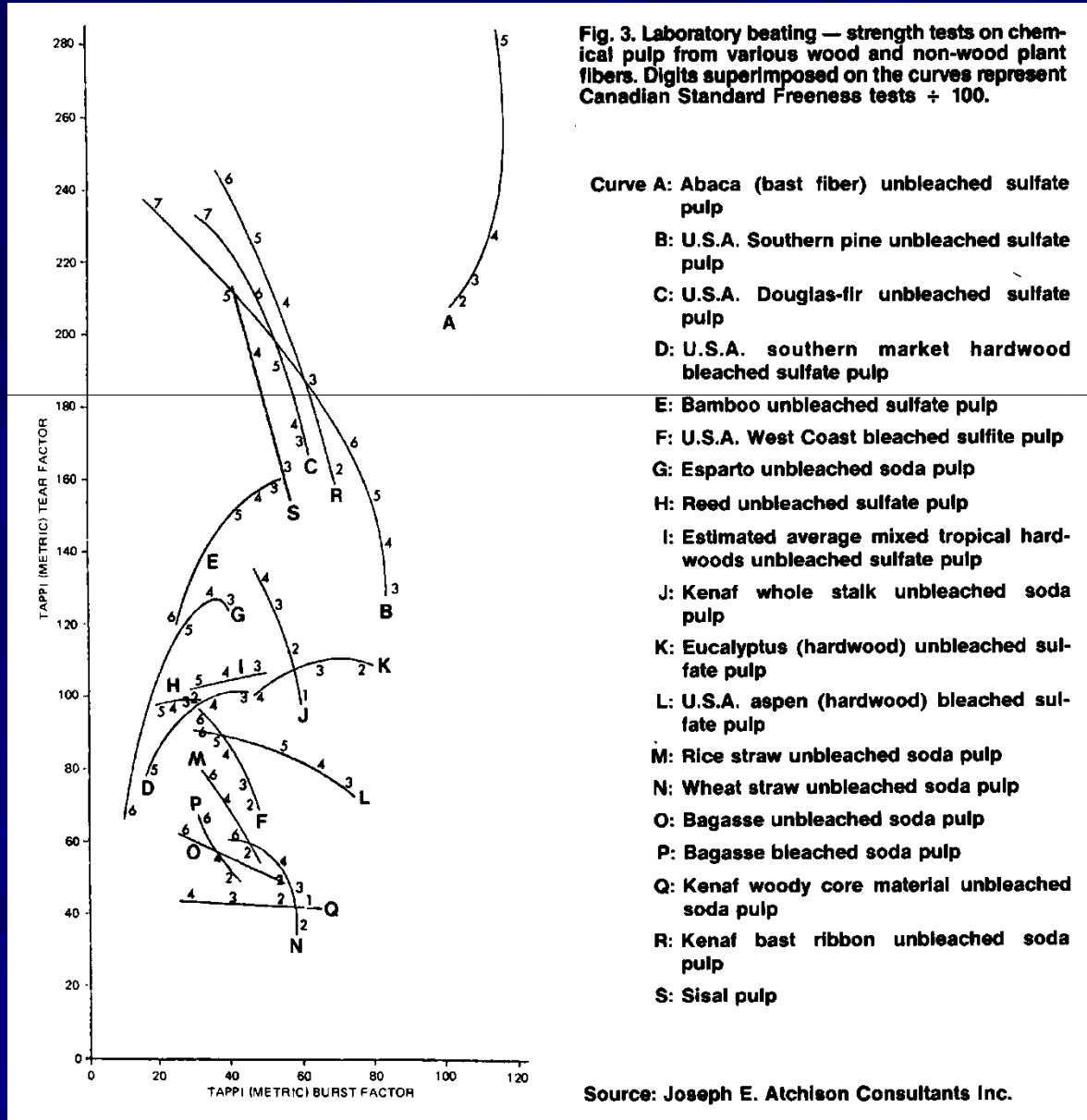
- typically long fiber
- properties equal to or better than softwood Kraft pulp
- pulp made into paper on same site or sold as market pulp
- bast and leaf fiber pulps
  - high end specialty pulps
  - very special applications
  - command very high prices
  - usually very small pulp mills

Bast fibers	flax, hemp, jute, kenaf
Cotton fibers	staple, linters
Leaf fibers	abaca, sisal
Some bamboos	

- cotton linters and bamboo pulps
  - may be produced in larger mills
  - linters pulp expensive
  - bamboo pulp typically in price range of woodpulp



# General Comments on Nonwoods



# General Comments on Nonwoods

<b>Abaca</b>	<ul style="list-style-type: none"><li>• very high strength &amp; high natural wet strength</li><li>• expensive – US\$ 3,500 - 3,750/admt</li><li>• limited raw material and market pulp availability</li></ul>
<b>Hemp (bast)</b>	<ul style="list-style-type: none"><li>• high strength</li><li>• expensive – US\$ 2,200 - 2,500/admt</li><li>• limited raw material and market pulp availability</li><li>• illegal to grow in the USA</li></ul>
<b>Kenaf (bast)</b>	<ul style="list-style-type: none"><li>• strength similar to NBSK</li><li>• expensive – US\$ 1,900 – 2,200/admt</li><li>• limited raw material and market pulp availability</li><li>• annual crop</li></ul>
<b>Sisal</b>	<ul style="list-style-type: none"><li>• high strength</li><li>• expensive – US\$ 2,200 - 2,300/admt</li><li>• limited raw material and market pulp availability</li></ul>



# Topics

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- 3) General comments on molded products**
- 4) Selected nonwood fiber properties
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- 6) Marketing



# Molded Products Made From Nonwoods

- **Virtually any molded product can be made with a nonwood fiber content**
  - can be 100% nonwoods using one or more nonwood fibers
  - can be partly nonwood and partly woodpulp
  - can be partly nonwood and partly recycled wastepaper
  - some nonwoods better suited to specific end products
- **Nonwood content depends on many factors including**
  - end product quality requirements
  - machine runnability
  - economics



# Molded Products Made From Nonwoods

- **Current molded products imported into Canada and the US made from:**
  - **sugarcane bagasse**
  - **oil palm empty fruit bunch (EFB)**
  - **bamboo**



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# Selected Nonwood Fiber Properties

## Fiber Dimensions

	Length (mm)			Diameter (microns)			L/D ratio
	Max.	Min.	Avg.	Max.	Min.	Avg.	
<b>Bagasse</b>	<b>2.8</b>	<b>0.8</b>	<b>1.7</b>	<b>34</b>	<b>10</b>	<b>20</b>	<b>85:1</b>
<b>Corn stalks</b>	<b>2.8</b>	<b>0.68</b>	<b>1.26</b>	<b>20</b>	<b>10</b>	<b>16</b>	<b>75 :1</b>
<b>Kenaf (bast)</b>	<b>7.6</b>	<b>0.98</b>	<b>2.7</b>			<b>20</b>	<b>135:1</b>
<b>Kenaf (core)</b>	<b>1.1</b>	<b>0.4</b>	<b>0.6</b>	<b>37</b>	<b>18</b>	<b>30</b>	<b>20:1</b>
<b>Rice straw</b>	<b>3.48</b>	<b>0.65</b>	<b>1.41</b>	<b>14</b>	<b>5</b>	<b>8</b>	<b>175:1</b>
<b>Wheat straw</b>	<b>3.12</b>	<b>0.68</b>	<b>1.48</b>	<b>24</b>	<b>7</b>	<b>13</b>	<b>110:1</b>
<b>Softwood</b>	<b>3.6</b>	<b>2.7</b>	<b>3.0</b>	<b>43</b>	<b>32</b>	<b>30</b>	<b>100:1</b>
<b>Hardwood</b>	<b>1.8</b>	<b>1.0</b>	<b>1.25</b>	<b>50</b>	<b>20</b>	<b>25</b>	<b>50:1</b>



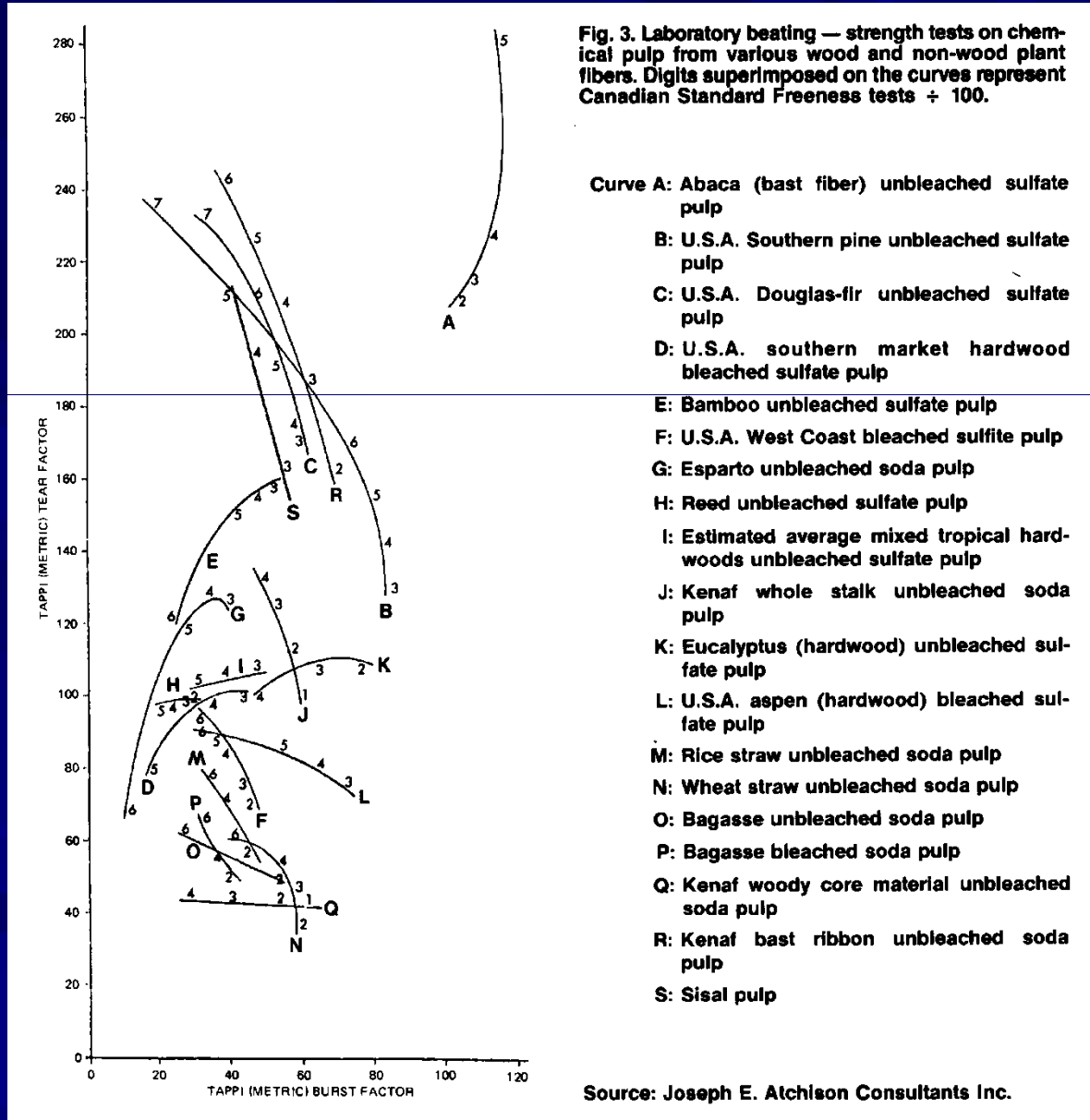
# Selected Nonwood Fiber Properties

## Chemical Properties

	<b>Alpha Cellulose (%)</b>	<b>Lignin (%)</b>	<b>Pentosans (%)</b>	<b>Ash (%)</b>	<b>Silica (%)</b>
<b>Bagasse</b>	<b>32 - 44</b>	<b>19 - 24</b>	<b>27 - 32</b>	<b>1.5 - 5</b>	<b>0.7 - 3</b>
<b>Corn stalks</b>	<b>35 - 40</b>	<b>14 - 16</b>	<b>26 - 28</b>	<b>3 - 7</b>	<b>0.4 - 3</b>
<b>Kenaf (bast)</b>	<b>31 - 39</b>	<b>15 - 18</b>	<b>21 - 23</b>	<b>2 - 5</b>	<b>&lt; 1</b>
<b>Kenaf (core)</b>	<b>34</b>	<b>17.5</b>	<b>19.3</b>	<b>2.5</b>	
<b>Rice straw</b>	<b>28 - 36</b>	<b>12 - 16</b>	<b>23 - 28</b>	<b>15 - 20</b>	<b>9 - 14</b>
<b>Wheat straw</b>	<b>29 - 35</b>	<b>16 - 17</b>	<b>26 - 32</b>	<b>4 - 9</b>	<b>3 - 7</b>
<b>Softwood</b>	<b>38 - 49</b>	<b>23 - 30</b>	<b>19 - 26</b>	<b>1</b>	<b>&lt; 1</b>
<b>Hardwood</b>	<b>40 - 45</b>	<b>26 - 34</b>	<b>7 - 14</b>	<b>1</b>	<b>&lt; 1</b>



# Selected Nonwood Fiber Properties



# Topics

- 1) Nonwood fiber raw material availability
- 2) General comments on nonwoods
- 3) General comments on molded products
- 4) Selected nonwood fiber properties
- 5) Considerations for nonwood pulp mills
  - a) General Comments
  - b) Fiber Preparation
  - c) Pulping
  - d) Washing
- 6) Marketing



# Considerations for Nonwood Pulp Mills

## a) General Comments

### Capacity

- likely relatively low for molded products
- max. size likely in 100 – 150 bdmt/d range

### Implications

- need to minimize capital costs
- influences process and equipment selections
- full chemical recovery likely is uneconomical



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation

### Nonwoods come in many forms

- large rectangular bales – cereal straws, corn stover, kenaf etc.
- large cylindrical bales – cereal straws, corn stover, kenaf etc.
- loose – sugarcane bagasse

**All contain contaminants and debris that need to be removed before pulping**



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Cereal Straw

### Oven-Dry Physical Composition - Baled Straw

	Barley (%)	Rice (%)	Rye (%)	Wheat (%)
Culms	58.8	32.4	68.1	68.5
Leaf sheaths	31.5	33.1	19.8	20.3
Rachises, glumes & nodes	1.8	11.9	7.4	4.2
Residual grain	1.1	0.7	1.3	1.0
Debris & dirt	1.9	5.5	0.5	0.5

Moisture content of air-dry straw on a wet basis is usually about 12%.



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Cereal Straw

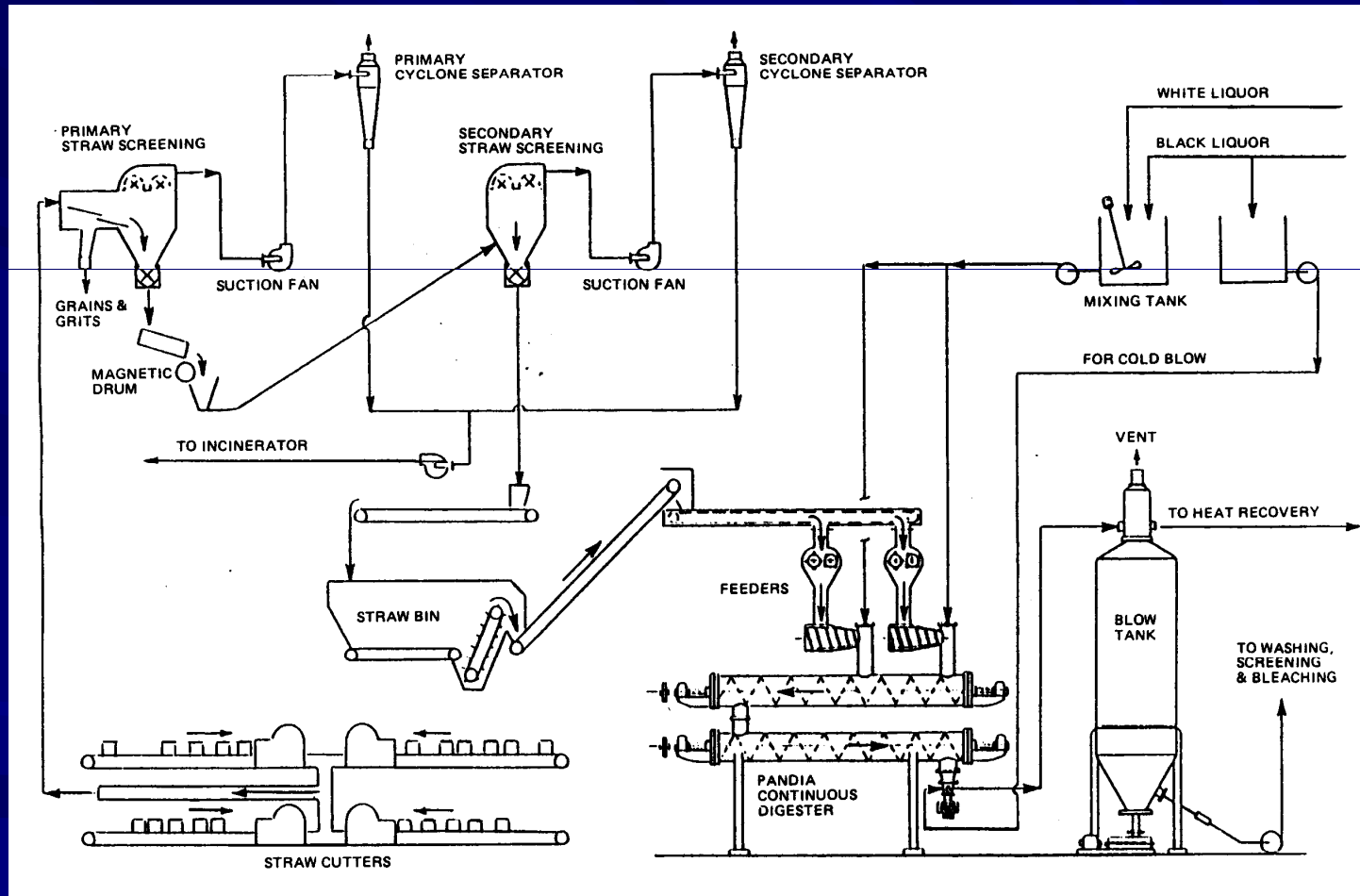
### Preparation Systems

- dry
- wet
- dry/wet



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Cereal Straw Typical Dry Preparation System

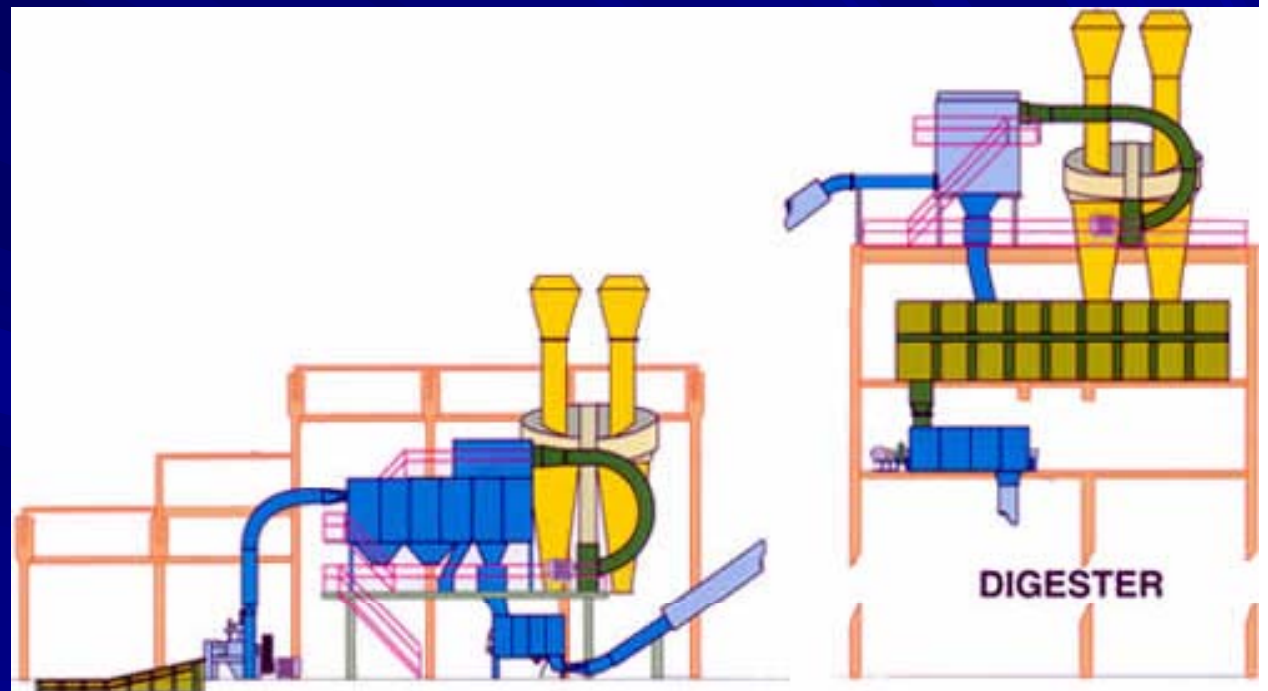


# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Cereal Straw

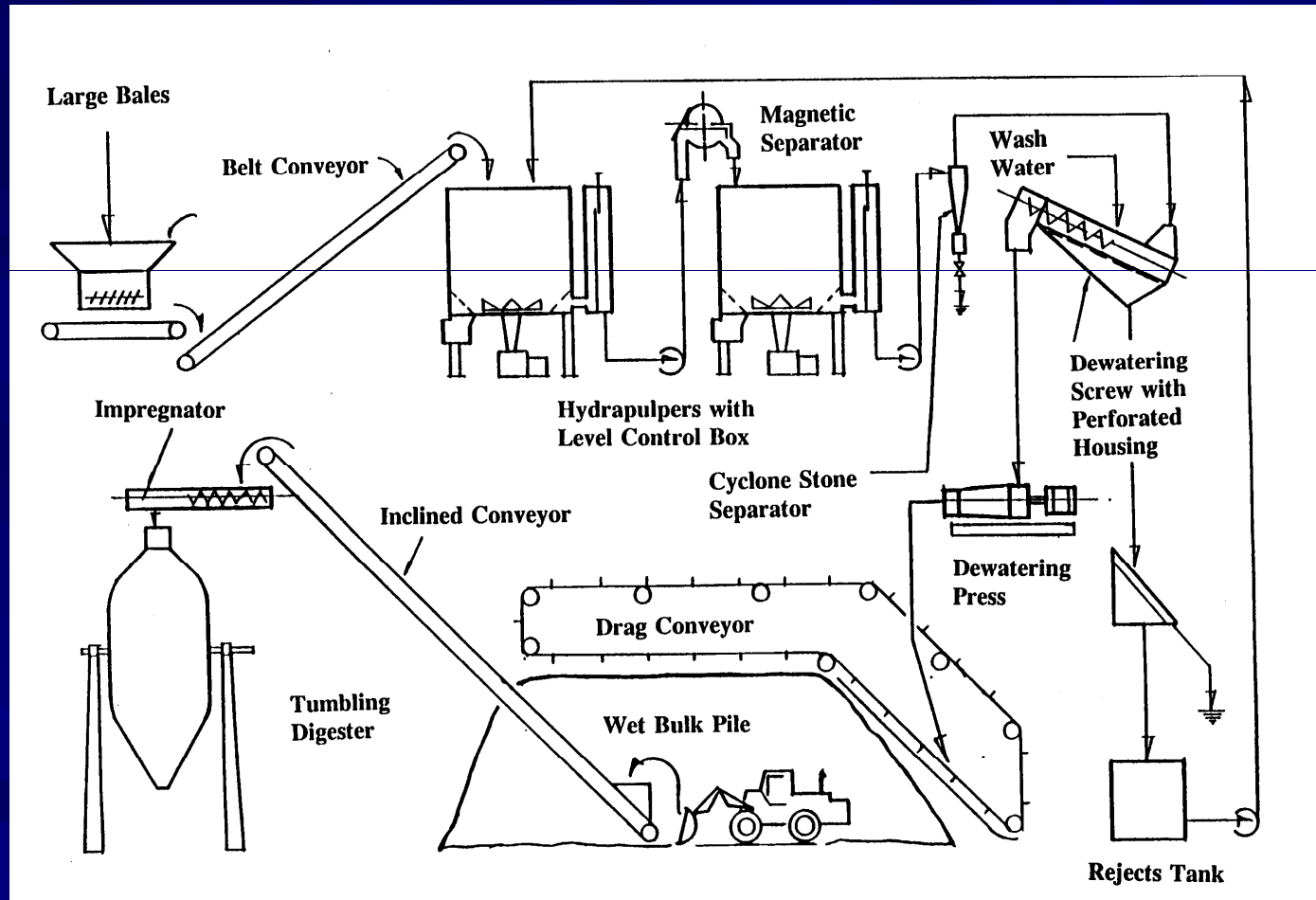
### Dry Preparation System - Robert Nyblad GmbH

1. Conveyor
2. Chaff (Straw) Cutter
3. Dedusting Sorter
4. Iron Separator
5. Deduster
6. Chaff (Straw) Dosing Bin
7. Mixing Unit
8. Cyclone



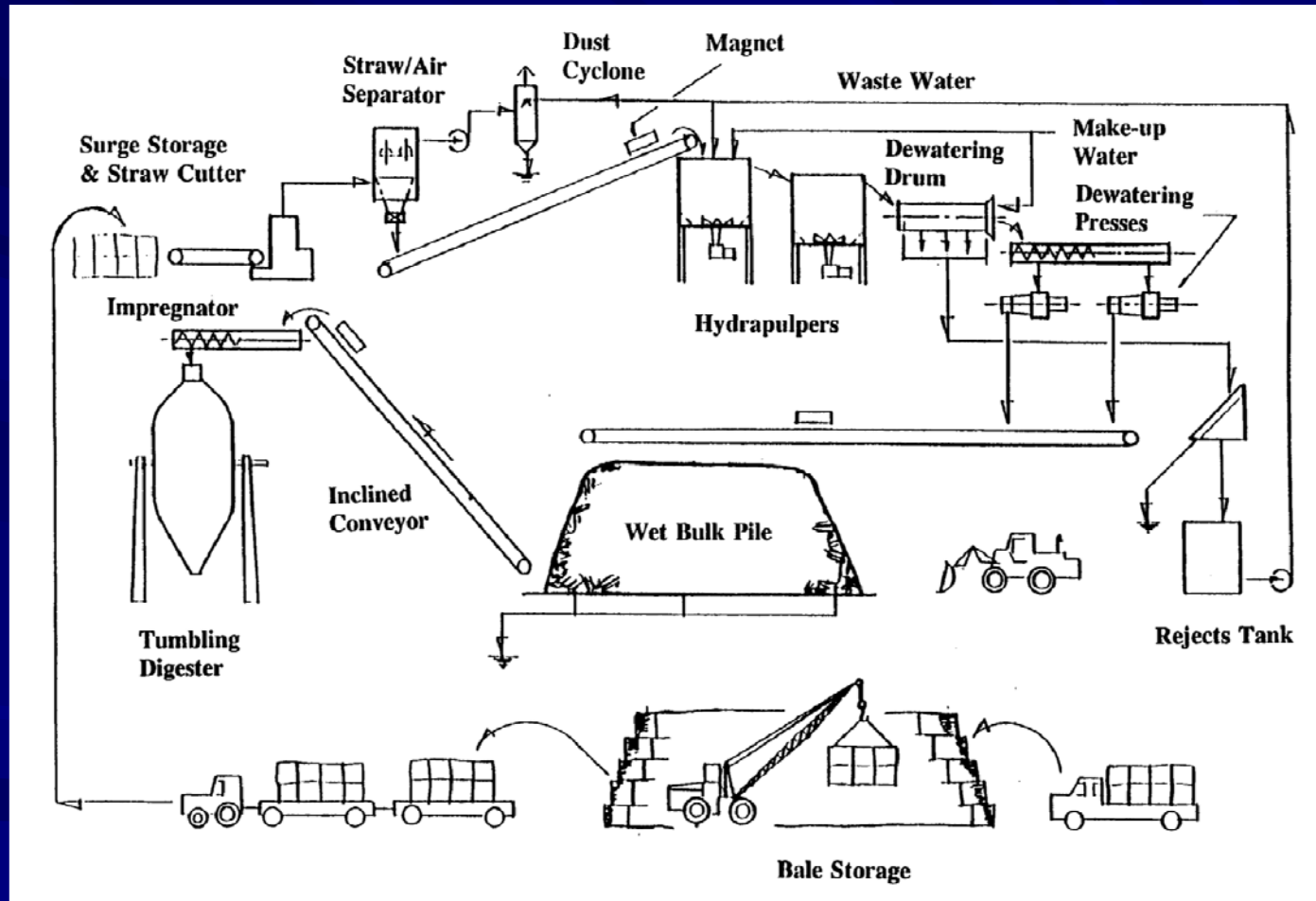
# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Cereal Straw Typical Wet Preparation System



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Cereal Straw Typical Dry/Wet Preparation System



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Cereal Straw Wet Preparation System with Desilication

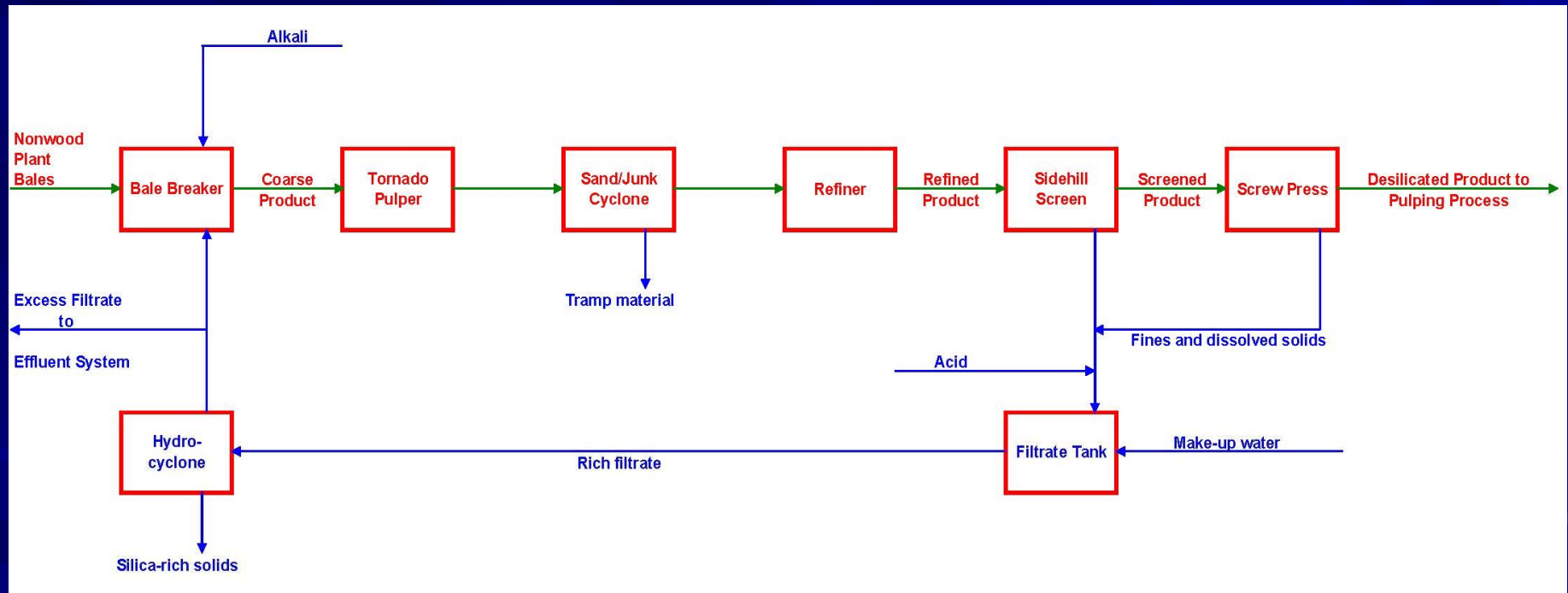
- US patent 7,364,640
- Tornado pulper is key for initial size reduction
- 60% silica removal mechanically
- up to 80% removal with small alkali dosage



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Cereal Straw Wet Preparation System with Desilication

- US patent 7,364,640



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Sugarcane Bagasse

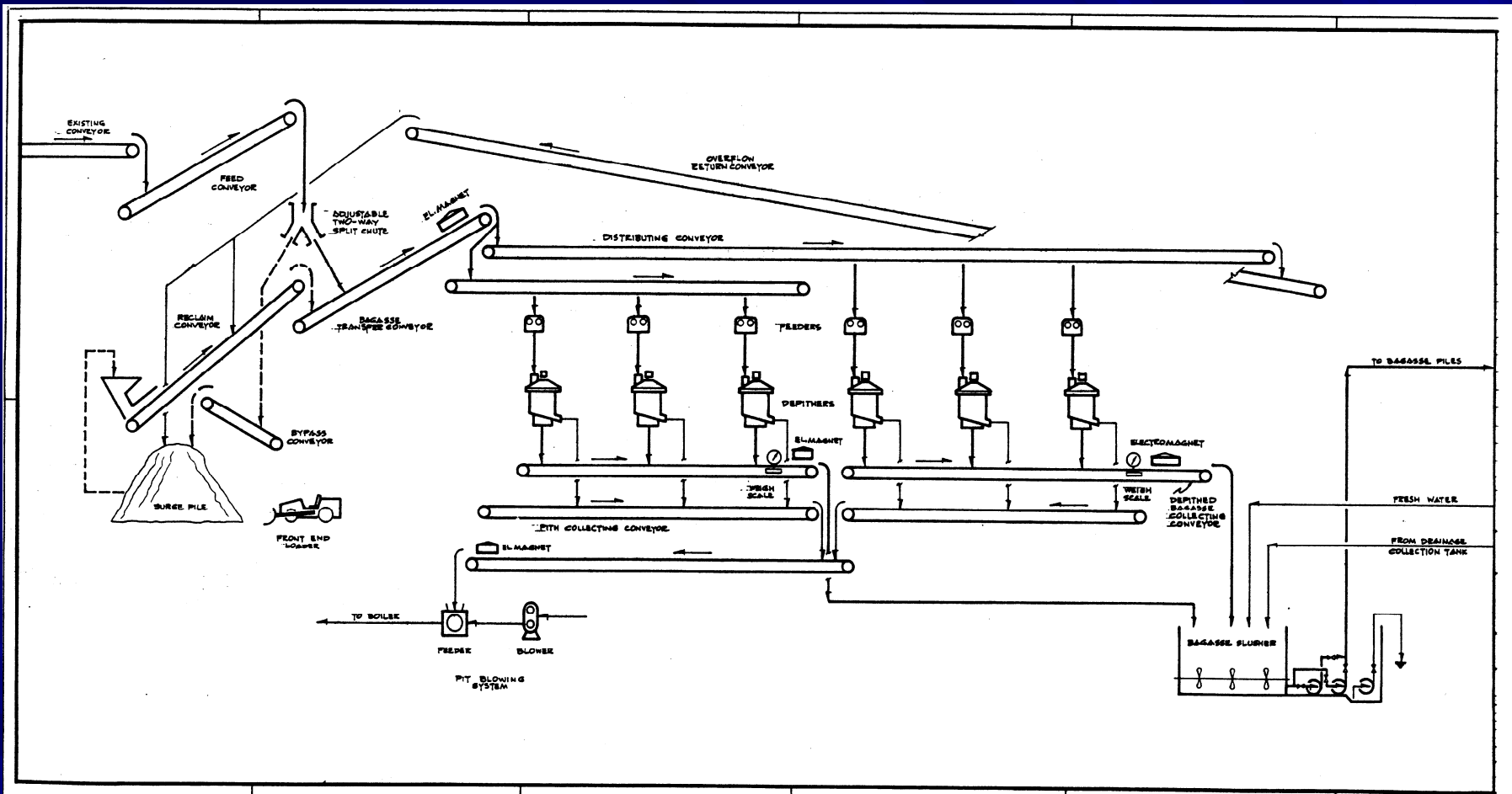
### Bagasse Oven-Dry Physical Composition – Various Sources

	Water Solubles & Dirt	Pith & Epidermal Material	Useful Fibre
Egypt	10%	25%	65%
Florida	16%	25%	59%
Hawaii	15%	30%	55%
Hawaii	8%	32%	60%
East Java	14%	20%	66%
Louisiana	10%	26%	64%
Peru	15%	28%	57%
Puerto Rico	14%	25%	61%



# Considerations for Nonwood Pulp Mills

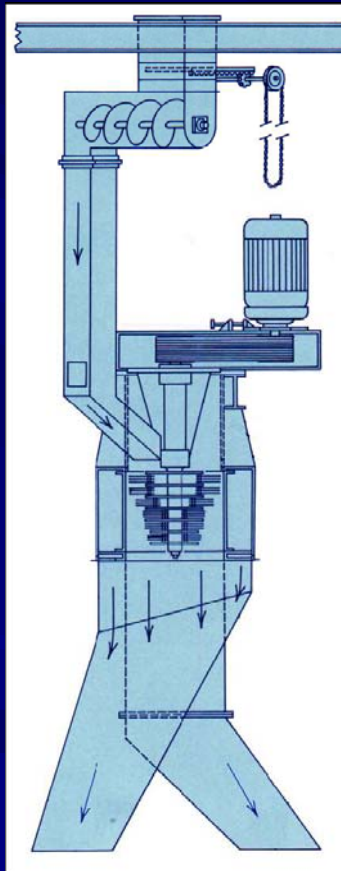
## b) Fiber Preparation – Sugarcane Bagasse



# Considerations for Nonwood Pulp Mills

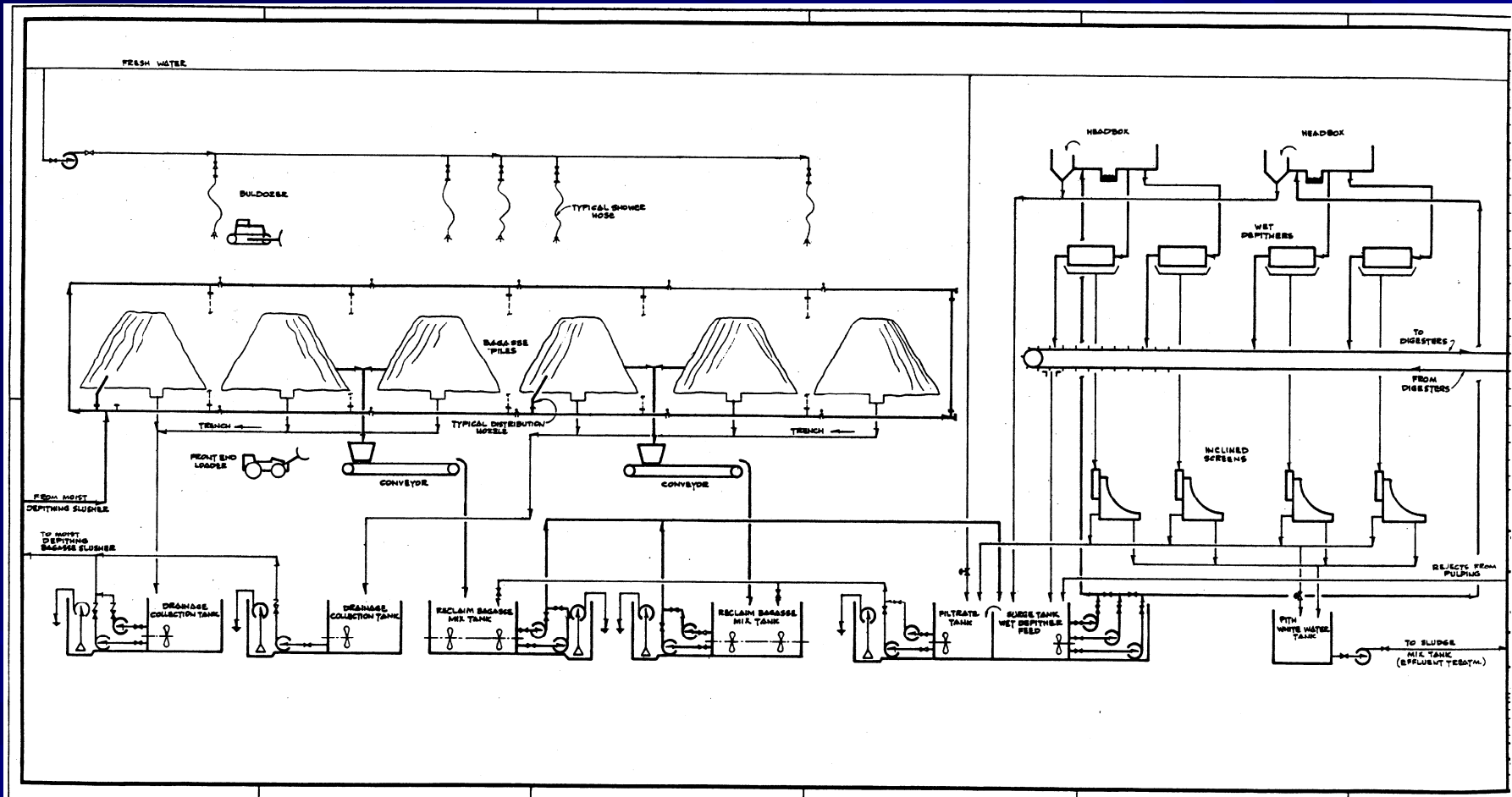
## b) Fiber Preparation – Sugarcane Bagasse

### Pro Zell Depithier



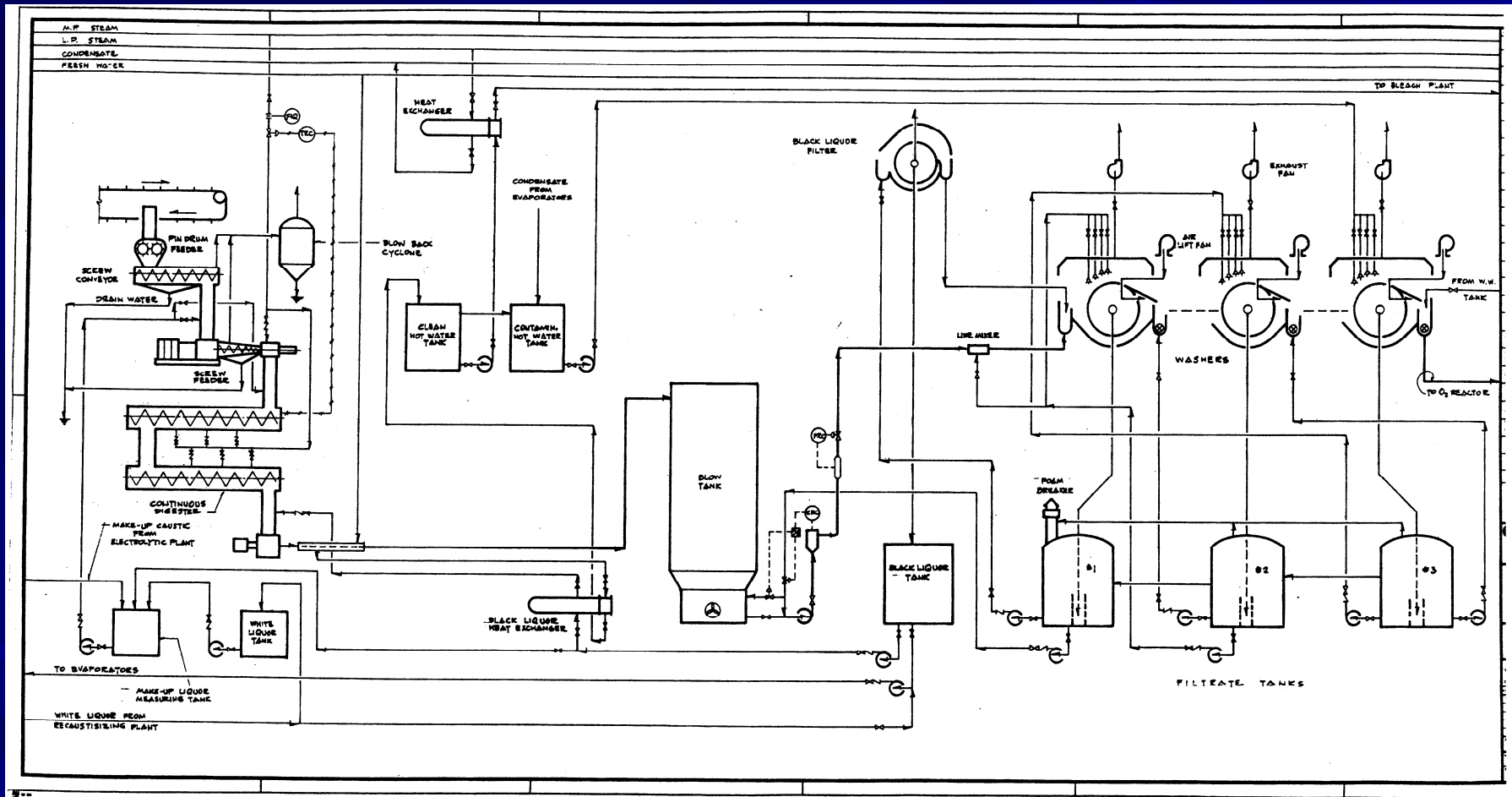
# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Sugarcane Bagasse



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Sugarcane Bagasse



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Kenaf APMP

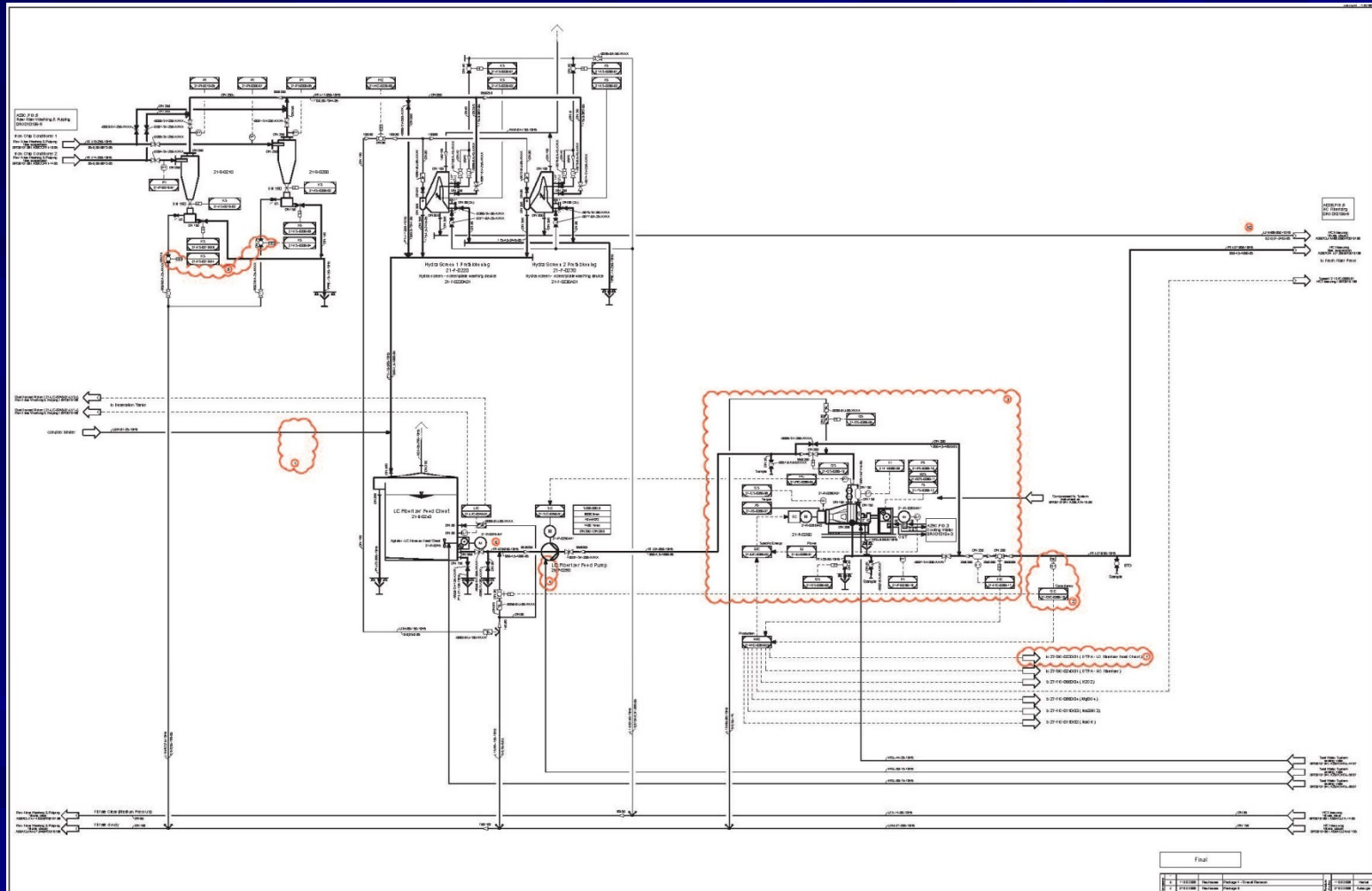
- Kenaf contains two fiber types - bast and core
- Need to clean the feedstock to remove stones and dirt
- Need to present uniform slurry to APMP refiners
- 100,000 admt/y whole stalk kenaf APMP market pulp mill, Vietnam
- Used system incorporating Tornado pulper





# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Kenaf APMP



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Summary

Losses – for pulp production			
Raw Material	Preparation System	Transportation & Storage Losses	Fibre Preparation Losses
Cereal straw	dry	1.5 – 2.5%	8 – 10%
	wet	1.5 – 2.5%	10 – 15%
Prairie grasses	dry	1.5 – 2.5%	6 – 8%
	wet	1.5 – 2.5%	8 – 12%
Corn stalks with depithing	dry	1.5 – 2.5%	20 – 30%
	wet	1.5 – 2.5%	25 – 35%
Corn stalks without depithing	dry	1.5 – 2.5%	8 – 10%
	wet	1.5 – 2.5%	10 – 15%



# Considerations for Nonwood Pulp Mills

## b) Fiber Preparation – Summary

Sugarcane Bagasse	Loss		Production
Wet depithed fibre to digester			100.00 bdm
Wet depithing loss (fibre)	5.0%	5.26 bdm	
Fibre from bagasse washing			105.26 bdm
Bagasse washing loss	2.3%	2.48 bdm	
Bagasse from storage			107.74 bdm
Storage loss (fibre)	4.0%	4.49 bdm	
Moist depithed fibre in storage			112.23 bdm
Water solubles loss	6.0%	7.16 bdm	
Moist depithed bagasse incl. water solubles to storage			119.39 bdm
Moist depithing loss	30.0%	51.17 bdm	
Whole bagasse required			170.56 bdm
Bagasse moisture	50.0%	170.56 mt	
Green whole bagasse required			341.12 mt



# Considerations for Nonwood Pulp Mills

## c) Pulping

- Nonwoods can be pulped with all conventional processes
  - Kraft –  $\text{Na}_2\text{SO}_4$
  - Soda –  $\text{NaOH}$
  - Sulfite –  $\text{Na}_2\text{SO}_3$ ,  $\text{NH}_4\text{SO}_3$ ,  $\text{CaSO}_3$ ,  $\text{MgSO}_3$
  - Bisulfite
- Most use Soda –  $\text{NaOH}$
- If no chemical recovery, may switch to another base – potassium  $\text{KOH}$ , ammonium  $\text{NH}_4\text{OH}$



# Considerations for Nonwood Pulp Mills

## c) Pulping

- Depending on pulping conditions, can produce
  - low yield full chemical bleachable pulp
  - high yield semichemical pulp
  - mechanical pulps in some cases – APMP, BCTMP
- Digesters
  - batch rotary – spherical or cylindrical
  - continuous horizontal tube
  - extrusion pulper



# Considerations for Nonwood Pulp Mills

## c) Pulping – Batch Rotary Digesters



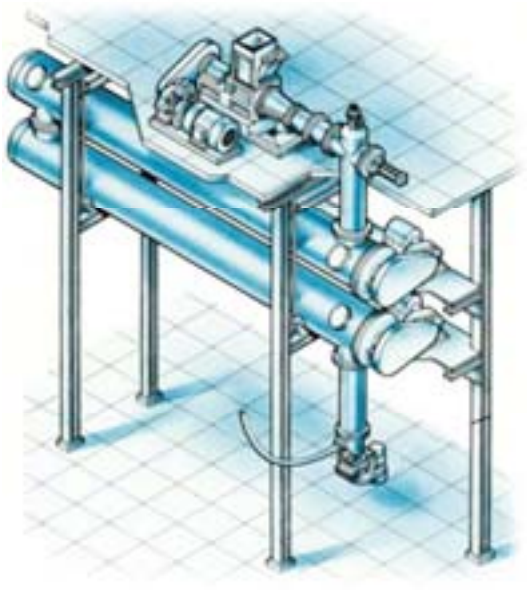
# Considerations for Nonwood Pulp Mills

## c) Pulping – Horizontal Tube Digester



### Digester

- horizontal tube type standard in larger mills
- typically 2 or more tubes depending on capacity
- 100,000 bdmt/y bleached wheat straw
  - 2 identical digesters
  - 20" screw feeder
  - 36" inlet chamber
  - three 72" dia x 40' long tubes
  - 48" discharge



# Considerations for Nonwood Pulp Mills

## c) Pulping – Extrusion Pulping



### Twin Screw Extruder

- co-rotating screws
- can have compression and expansion zones in the same unit
- may allow pulping and moderate bleaching in same unit
- better suited to smaller capacities



# Considerations for Nonwood Pulp Mills

## c) Pulping – Mechanical Pulping

- **100,000 admt/y whole stalk kenaf APMP**
- **Sugarcane bagasse mechanical pulping (BCTMP)**
  - **Used in several mills producing bagasse newsprint**
- **Use refiners & post refining bleaching**
- **High yield**
- **Chemistry depends on process selected**



# Considerations for Nonwood Pulp Mills

## d) Washing

### Washers

- straw, bagasse & corn stalks pulps slow draining
- require much larger washer surface areas than woodpulp for various types of vacuum and pressure washers
- may impact on molding equipment

### CAPACITIES OF VACUUM FILTERS ( mt / m<sup>2</sup> Single Washer Surface )

Chemical Pulp	Brown Stock	Bleached Pulp
Softwood	6.0 – 7.0	7.0 – 8.0
Hardwood	4.5 – 5.5	5.5 – 6.5
Bagasse	3.0 – 3.5	3.5 – 4.5
Cereal Straw	1.6 – 2.0	2.0 – 2.5
Rice Straw	1.4 – 1.8	1.8 – 2.2



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- 6) **Marketing**



# Marketing

- **all fiber raw materials – wood, nonwoods, wastepaper – will produce molded products that are:**
  - **compostable**
  - **sustainable**
- **molded products made from nonwoods may or may not be “greener” than wood or wastepaper based products**
- **peer reviewed LCA’s required to support claims**





# Nonwood Fibers & Molded Products

**Any Questions?**

