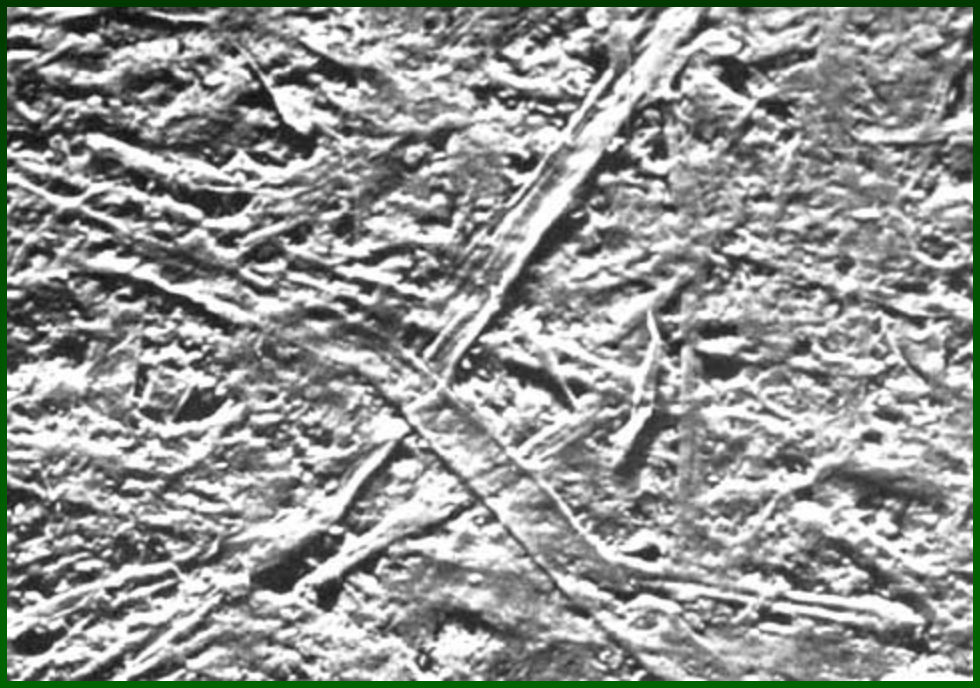
Lecture

Refining of Recovered Fibers

Several Slides Courtesy of Dr. Med Byrd.

What is Refining?

- Refining is a physical treatment performed on pulp fibers to improve their papermaking characteristics
- It is essential to the production of strong, smooth, useful paper



Several Slides Courtesy of Dr. Med Byrd.

Why do we need refining?

- Increasing bonding area by:
  - Collapsing hollow cell walls into flat ribbons
  - Fraying the fiber surface – “fibrillation”
- Making the fibers more flexible and conformable, delaminating the wall
- Cutting some of the longer fibers into smaller lengths to help formation

- *Courtesy of M. Hubbe*

Refining

- The effects of refining on freeness, density, tear index, and tensile index in virgin bleached kraft pulps

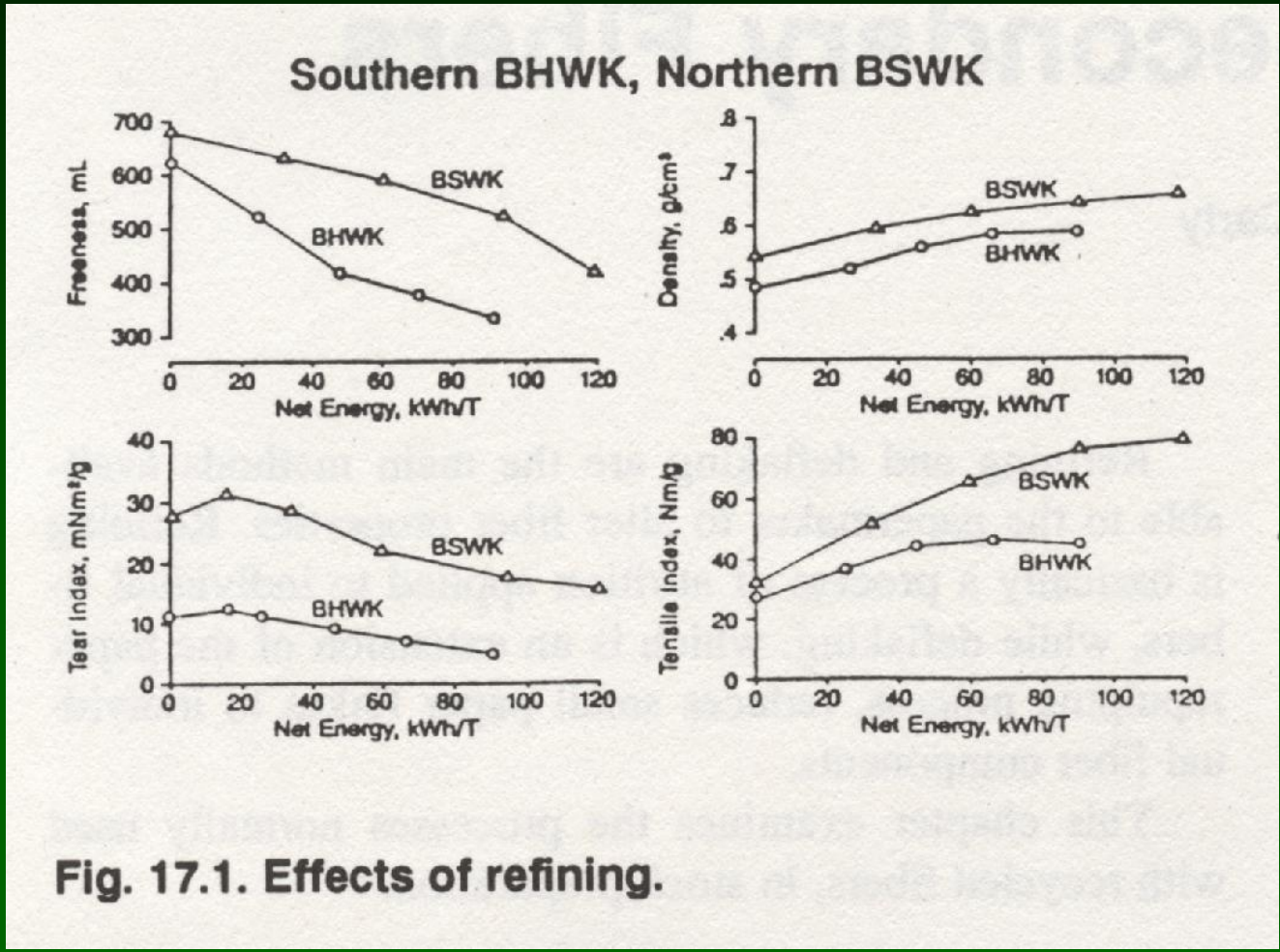


Fig. 17.1. Effects of refining.

Secondary Fibers, Tappi

Fiber Structure

- Thin primary wall (P), which is delicate and easily removed
- Secondary wall has three layers
  - S1 – thin and not easily wetted
  - S2 – 70-85% of total mass; easily wetted and swollen
  - S3 - thin, waxy, warty

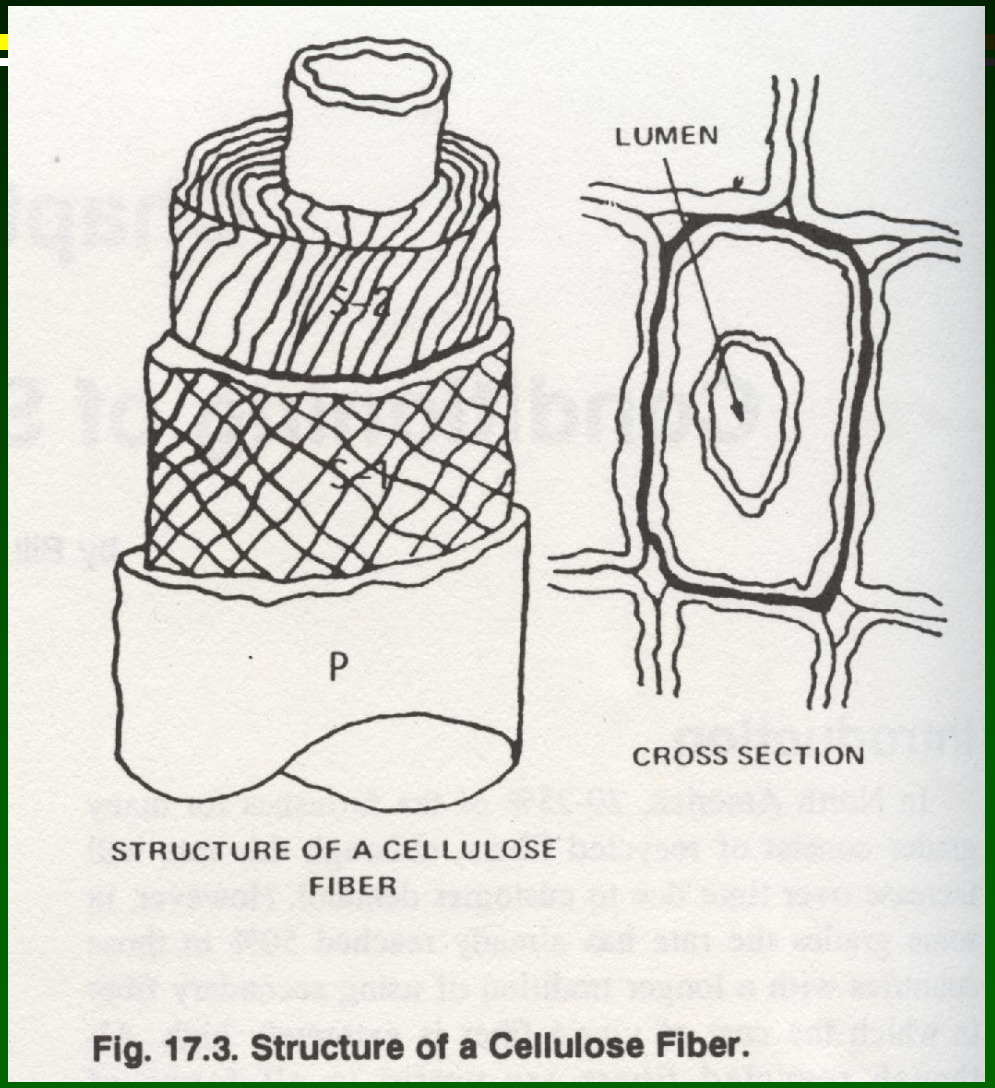


Fig. 17.3. Structure of a Cellulose Fiber.

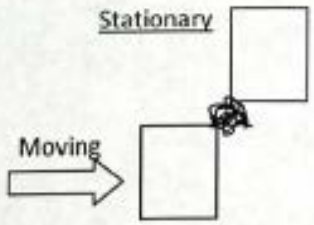
Secondary Fibers, Tappi

Fiber Structure

- Refining damages and removes the Primary and S1 wall layers, exposing the S2 layer
- Once the S2 layer is exposed and swollen, mechanical action causes the layer to delaminate and collapse
- Mechanical action also fibrillates the surface, cuts some fibers, and makes them less stiff and more conformable

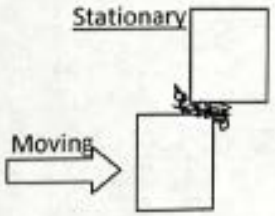
Photomicrograph showing a refined fiber with fibrillation on the surface

Refining: Subprocesses



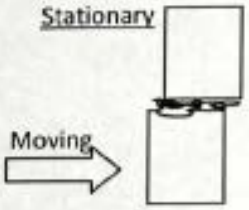
First Step

- Wad gathering and preliminary localized dewatering order of 15% to 30%



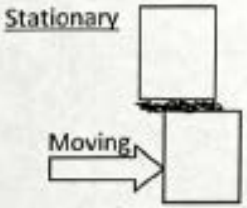
Second Step

- Mechanical pressure order of 1000 to 5000 psi
- Water expulsion order of 50 to 60%



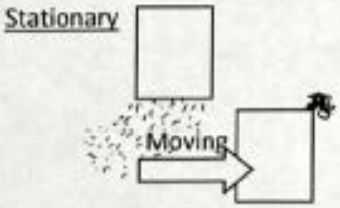
Third Step

- Sliding wads under pressure



Fourth Step

- Mechanical release
- Water reabsorption



Fifth Step

- Dispersion
- Wad gathering for next cycle

The Refining Action

- The mechanical action required for proper refining is not a simple brushing, cutting, grinding or pounding
- Rather, it is a more precise shearing of the fibers between two surfaces, both moving, or one moving and one stationary
- The cyclic shearing, compression, and release of fibers between moving surfaces causes the desired effect – “rolling friction”
- Refining equipment is designed to pass the stock slurry (2-5% consistency) between the moving surfaces, either in multiple passes or a single-pass

The Refining Action

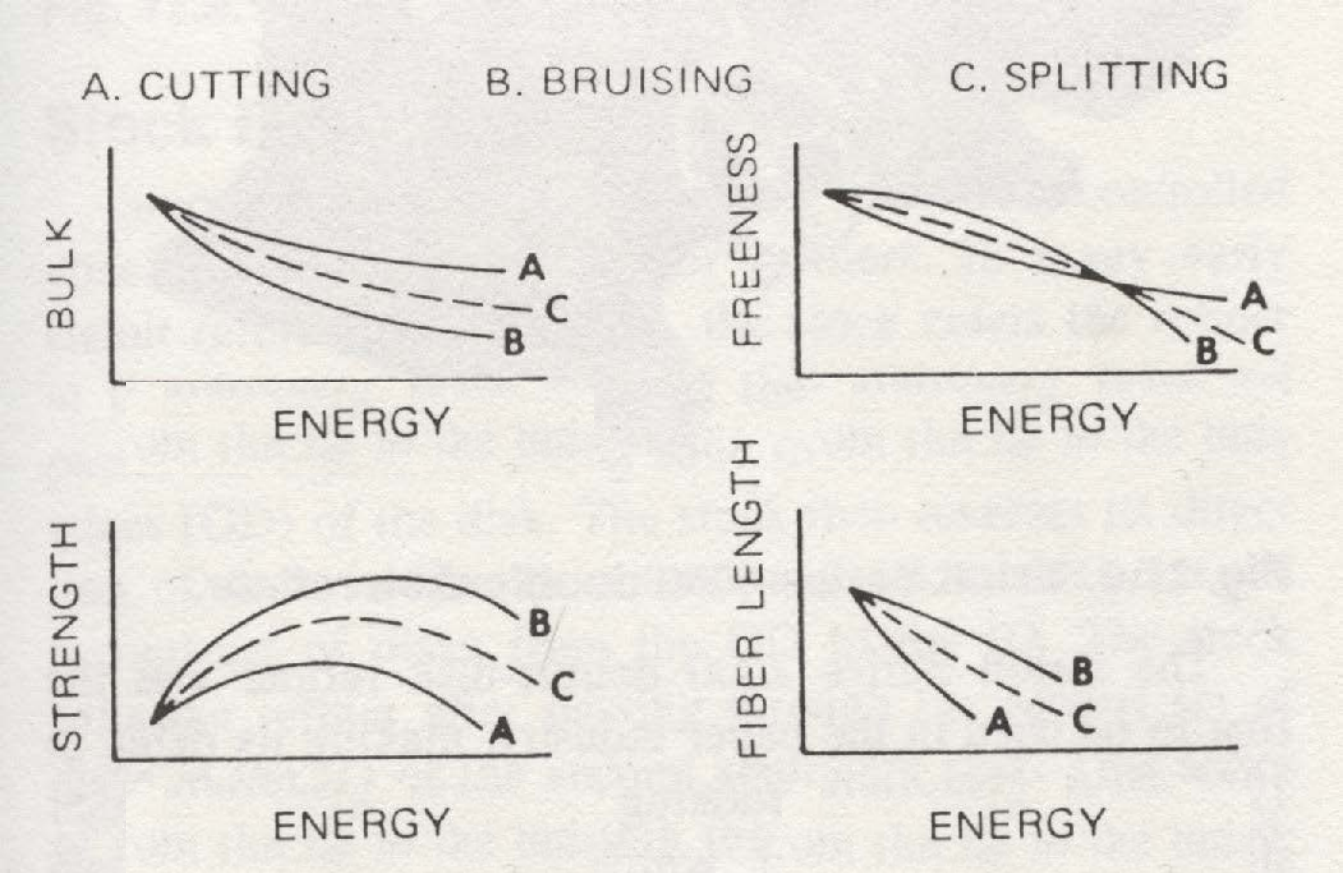
- Cutting
  - Reduces the average length of the fibers, producing short, stiff fibers that form a bulk sheet
  - Reduces the drainage rate (freeness)
- Bruising
  - Retains fiber length while developing flexible fibers that conform well to produce high strength and low bulk

The Refining Action

- Splitting
  - Combination of Cutting and Bruising
  - Paper properties fall between the two extremes
  - Most stock preparation involves splitting

The Refining Action

- The effect of different refining actions have on various properties



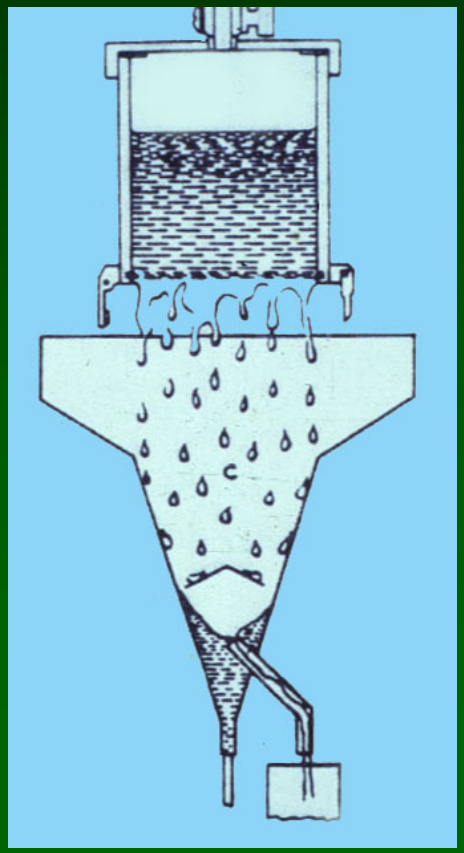
Secondary Fibers, Tappi

Fundamentals of Refining

- Freeness
  - Definition: how freely water drains from a fiber slurry
  - It is an indirect indication of amount of refining via generation of fines from the P and S1 layers (as well as cutting)
  - High Freeness = High Drainage Rate

Fundamentals of Refining

- Canadian Standard Freeness (CSF)
  - Most common test used in North America



Fundamentals of Refining

- Measuring Freeness
  - Freeness is very sensitive to several factors
    - Surface area – must fix the sample weight
    - Temperature of the stock – must fix or compensate
    - Fines content of the stock – varies with the degree of refining

Fundamentals of Refining

- Typical CSF Values
  - Unrefined chemical pulps – 700+
  - Chemical pulps after refining – 400-500
  - Refined mechanical pulps – 100-300
  - Groundwood pulp for newsprint – 40-100

Fundamentals of Refining

- Other types of Freeness Tests
  - Schopper-Riegler – used in Europe
  - Williams Slowness Tester
  - Drainage Resistance Analyzer
  - TAPPI Drainage

Secondary Fiber Refining

- LC refining used in deinking processing lines for Supercalendered (SC) paper.

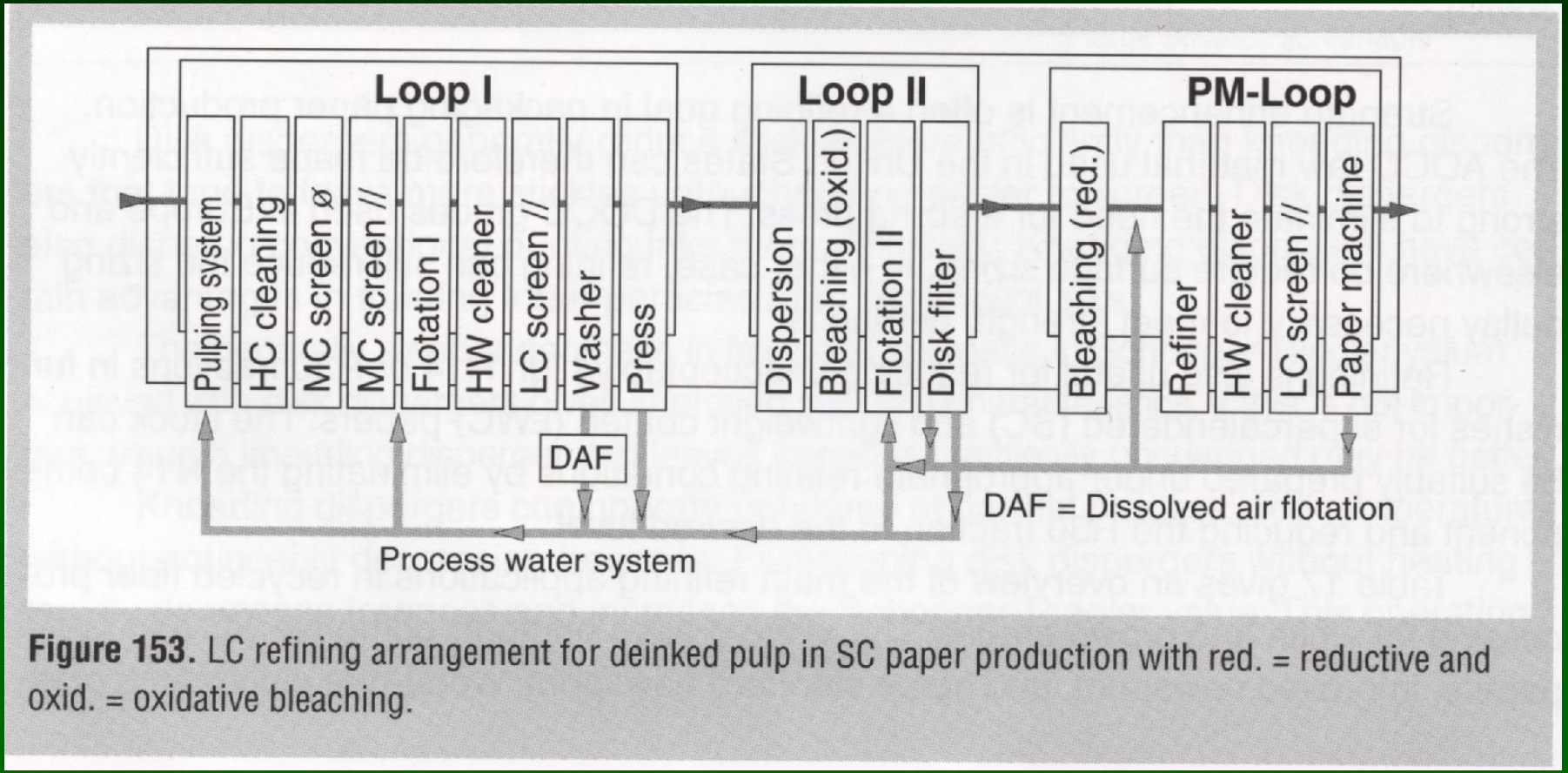


Figure 153. LC refining arrangement for deinked pulp in SC paper production with red. = reductive and oxid. = oxidative bleaching.

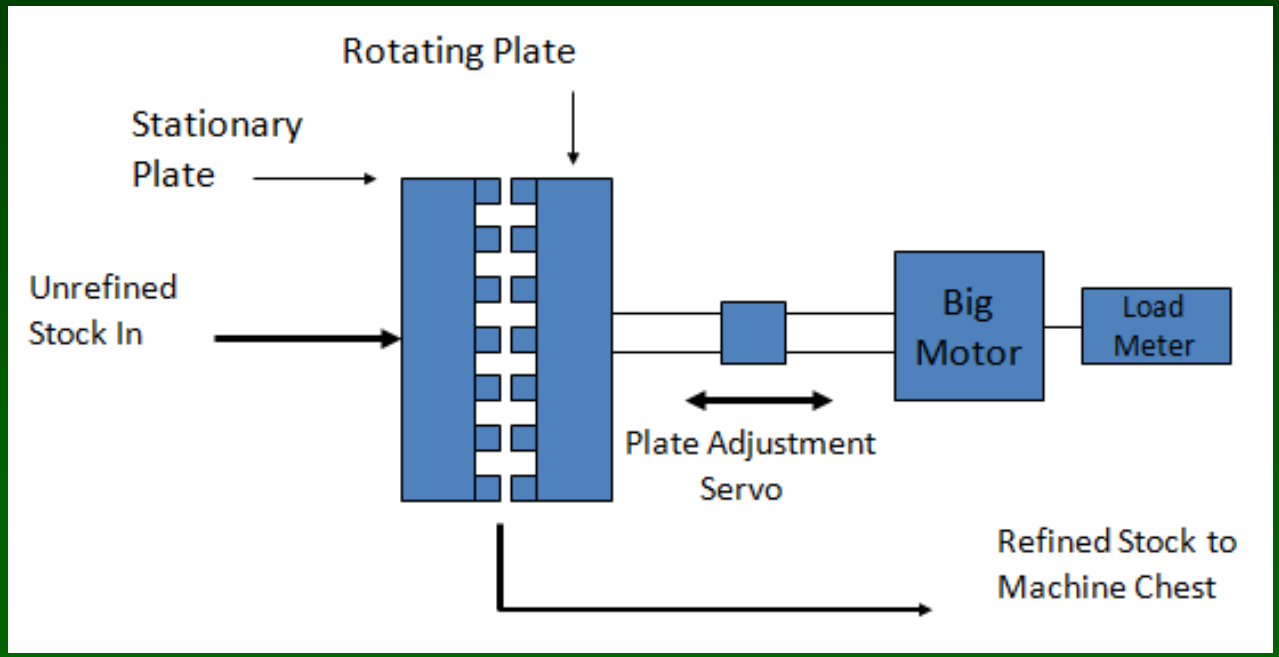
•Recycled Fiber and Deinking, Parkarinen

Refining Equipment

- Rotating Disk Refiners
  - Stock is pumped between two circular, bar-covered disks (plates)
    - Single-disk – one disk rotating, one stationary
    - Double-disk – one rotating disk with two sides plus two stationary disks = two refining chambers in one refiner
  - This configuration maximizes refining efficiency, reducing equipment size

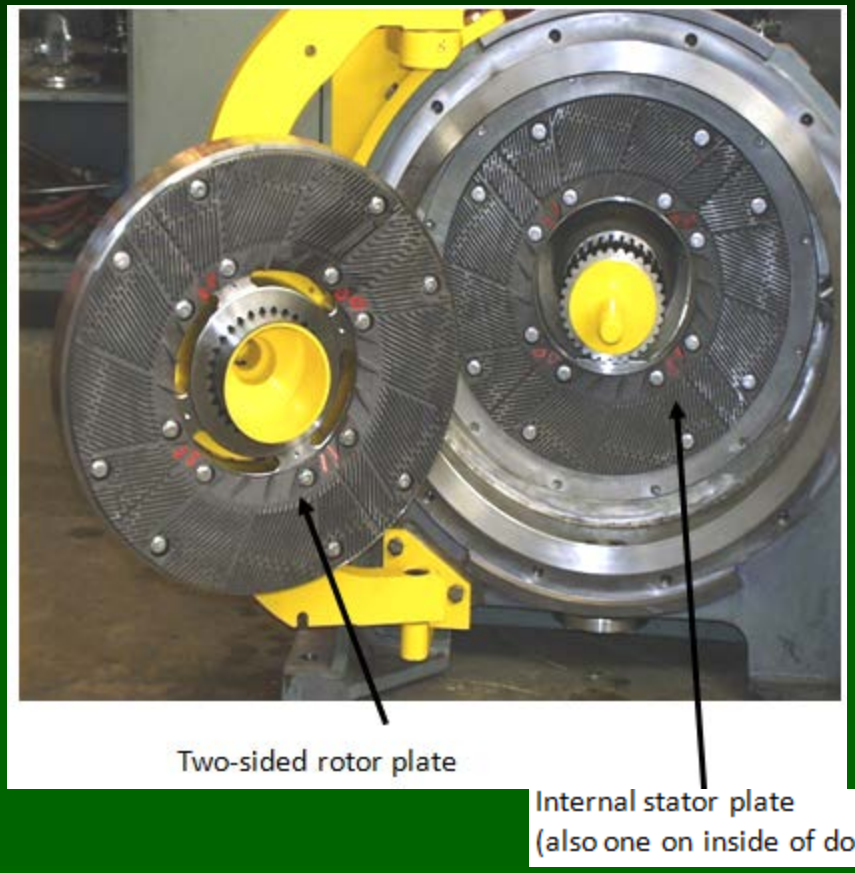
Refining Equipment

- Single Disk refiner



Refining Equipment

- Double-Disk Refiner



Refining Equipment

- Double-Disk refiners

Refining Equipment

- Example of a typical kind of refiner filling

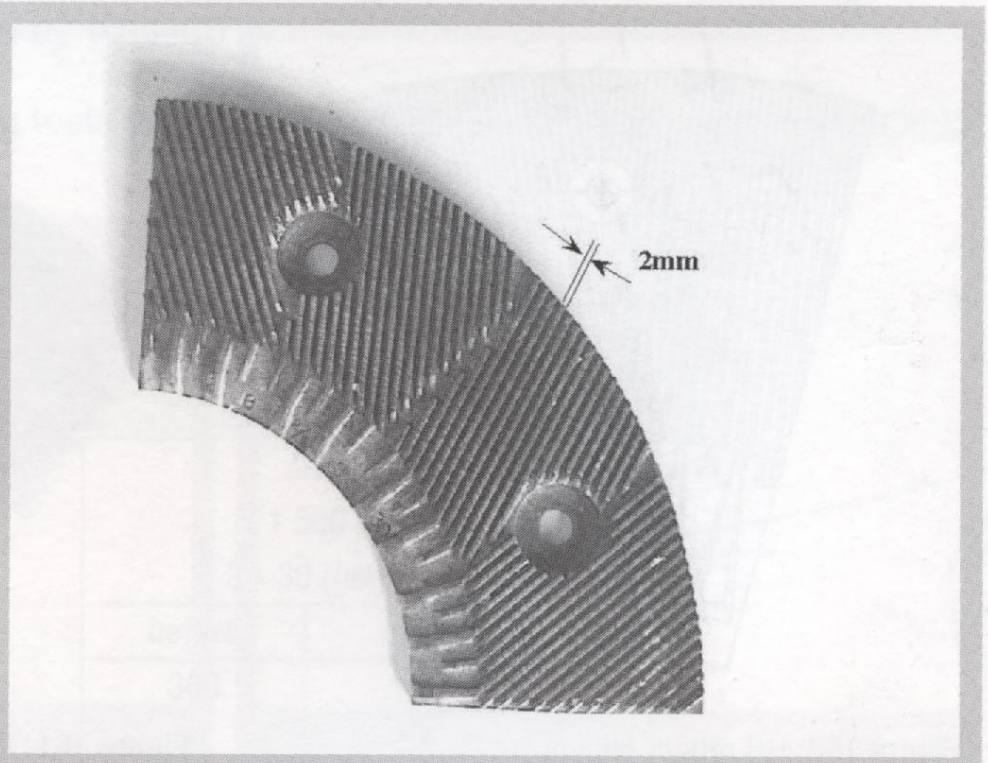


Figure 157. LC refiner fillings for low intensity refining.

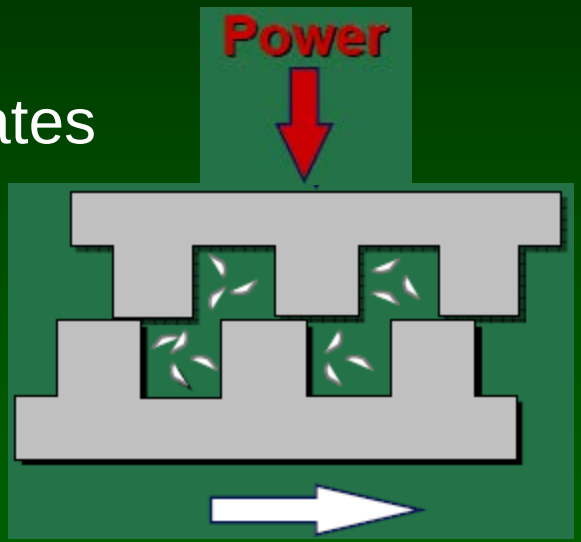
• Recycled Fiber and Deinking, Parkarinen

Refining Equipment

- Advantages of the disk refiner
  - Most energy efficient design
  - Higher stock consistencies can be used, maximizing fibrillation and strength
  - Can use higher loads and RPM
  - More compact, lower capital cost
  - Easy to maintain
  - Plate patterns can be customized

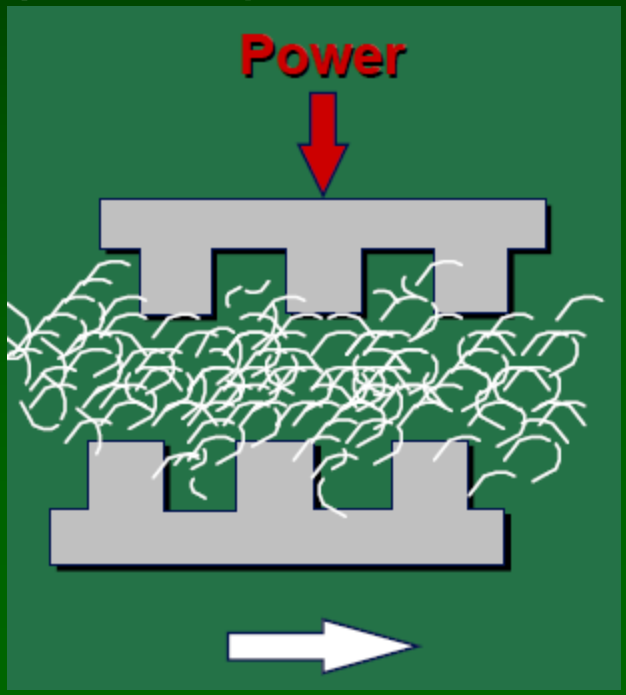
Fundamentals of Refining

- Flow
  - Problems with low flow
    - Little or no fiber mat between plates
    - Fiber channeling
    - High pressure rise (25-50psi)
    - Plate crashing
    - Short plate life
    - Inefficient refining (power vs fiber development)
    - Poor strength development
    - Increased fines generation



Fundamentals of Refining

- Problems with high flow
  - Inability to optimize plate design for maximum strength development (compromise)
  - Short plate life
  - High pressure drop
  - Motors maxed out



Fundamentals of Refining

- Why is the Proper Consistency Important to Refining?
  - Increases the Probability of Fiber Mat Formation
  - Fiber Strength Potential is Maximized
  - Plate Life Potential is Maximized
  - Variation is Minimized

Fundamentals of Refining

- Consistency

Consistency Guidelines for Various Fiber Types	
Fiber Type	Recommended Range of Refining Consistency
Unbleached Softwood Kraft	3.5 - 4.5%
Bleached Softwood Kraft	3.5 - 5%
Bleached Hardwood/Eucalyptus Kraft	4 - 6%
OCC	3.5 - 5%
Mechanical Pulps	4.5 - 6%
Unbleached Semi-Chem Hardwood	4.5 - 6%
Mixed Waste	4 - 6%

Fundamentals of Refining

- Effects of Operating outside Recommended Consistency
  - High Consistency
    - Plate Plugging
    - Poor Fiber Development
  - Low Consistency
    - Little to no fiber mat between plates
    - Inefficient refining
    - Poor fiber development
    - Fiber cutting
    - Plate clashing
    - Short plate life

Fundamentals of Refining

- Specific Refining Energy (SRE)
  - Definition: The amount of energy transferred from the refiner's motor to the fiber
    - SRE = kWh/t= $\frac{\text{Motor Load (kW) - No Load (kW)}}{\text{metric tonnes per Hour}}$
    - SRE = HPD/T= $\frac{\text{Motor Load(HP) – No Load(HP)}}{\text{Tons per Day}}$

Fundamentals of Refining

- No Load Energy
  - Definition: The energy required to spin the rotor in a pulp slurry.
    - No Load (kW) = (2.299x10^-13)(Diam^4.249)(RPM^3)
      - Diam = Plate diameter in inches
      - RPM = Refiner motor speed
  - The refiner is an inefficient pump!

Fundamentals of Refining

Specific Energy Guidelines

NET REFINING REQUIREMENTS FOR MAJOR GRADES

GRADE		HPD/UST	KWH/UST	KWH/MT
Linerboard	Base	5 - 7	89 - 125	99 - 138
	Top	10 - 12	179 - 215	197 - 237
Sack, Bag		12 - 14	215 - 250	237 - 276
Medium	Virgin HWD	6 - 10	107 - 179	118 - 197
	Waste	2 - 3	36 - 54	39 - 59
	Tickler	1.0 - 1.5	18 - 27	20 - 30
Fine Papers	Hardwood	4 - 6	72 - 107	79 - 118
	Softwood	6 - 8	107 - 143	118 - 158
	Tickler	1.0 - 1.5	18 - 27	20 - 30
Foodboard, Milk Carton	Hardwood	2 - 3	36 - 54	39 - 59
	Softwood	3 - 4	54 - 72	59 - 79
	Tickler	1. 0 - 1.5	18 - 27	20 - 30
News	SB Kraft	2 - 5	36 - 89	39 - 99
	Groundwood	2 - 3	36 - 54	39 - 59
Grades w/ OCC	OCC	2.5 - 5.0	81 - 117	50 - 100

Fundamentals of Refining

- Freeness Drop / HPD/T
  - Great measure to determine the refiner(s) efficiency and if it is operating correctly

$$-\Delta CSF / HPD/T = \frac{CSF_{in} - CSF_{out}}{HPD/T}$$

Fundamentals of Refining

- Freeness Drop / HPD/T Guidelines

FREENESS DROP / NET HPD/T

Various Furnishes

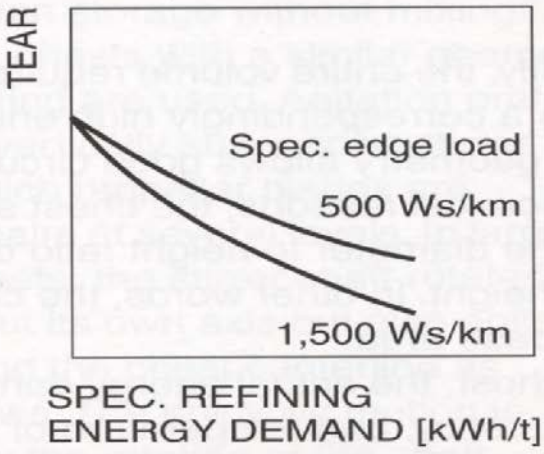
UNBLEACHED SOFTWOOD KRAFT	
NORTHERN U.S.	15 - 25 CSF / Net HPD/T
SOUTHERN U.S.	15 - 30 CSF / Net HPD/T
BLEACHED SOFTWOOD KRAFT	
NORTHERN U.S	25 - 50 CSF / Net HPD/T
SOUTHERN U.S.	25 - 60 CSF / Net HPD/T
BLEACHED HARDWOOD KRAFT	
MOST SPECIES	60 - 100 CSF / Net HPD/T
EUCALYPTUS	45 - 50 CSF / Net HPD/T
SECONDARY FIBER	
OCC	40 - 70 CSF / Net HPD/T
MIXED	50 - 70 CSF / Net HPD/T
NEWS	20 - 35 CSF / Net HPD/T

Note that these results are a combination of both fiber properties and conditions in which the refiner is operated.

Fundamentals of Refining

- Refining Intensity, Specific Edge Load (SEL)
  - Definition: The amount of energy expended per unit length of bar crossings
  - Describes the intensity of the refining impacts
    - Higher SEL = more shortened and cut fibers
    - Lower SEL = more pronounced fibrillation
  - Recycling requires lower SEL

Fundamentals of Refining



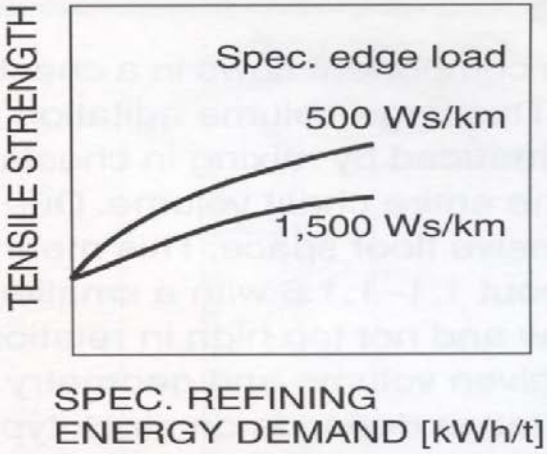


Figure 163. Effects of specific edge load in LC refining on characteristics of writing and printing papers.

Lower SEL provides better properties.

- **Recycled Fiber and Deinking, Parkarinen**

Fundamentals of Refining

- Effects of refining outside the recommended intensity range

Lower than recommended

- Potentially poor fiber development (all fibers require a certain intensity to break down their walls)
- Maintain fiber length
- Inefficient freeness drop

Higher than recommended

- Severe fiber cutting
- Plate clashing, exceed fiber threshold
- Short plate life
- Poor strength development

Secondary Fiber Refining

- OCC for Board Grades
  - The properties of mill-refined unbleached kraft pulp for linerboard to those of an OCC furnish developed for the same mill.

Table 17.1. Linerboard Base Sheet Properties

Property		Virgin Furnish Mill Refined 3.8% Cons. 54" DD, 450 RPM			OCC Furnish Lab Refined 3.6% Cons. 20" DD, 900 RPM		
		Before	After	Change	Before	After	Change
Gross Energy	kWh/t	- - -	130	- - -	- - -	53	- - -
Net Energy	kWh/t	- - -	110	- - -	- - -	30	- - -
Refining Intensity	Ws/m	- - -	3.6	- - -	- - -	1.6	- - -
Freeness	ml	745	655	-90 ml	610	530	-80 ml
Density	g/cc	.379	.468	+23.5%	.442	.468	+5.9%
Burst Index	-	2.48	4.68	+88.7%	1.68	2.71	+61.3%
Tear Index	-	20.8	13.5	-64.9%	15.0	13.2	-12.0%
Tensile Index	-	38.9	64.6	+66.1%	29.8	38.8	+30.2%
Fiber Length (Kajaani)	mm	2.36	2.32	-1.7%	1.79	1.73	-3.4%

Secondary Fibers, Tappi

Secondary Fiber Refining

- Deinked Ledger Grades for White Paper
  - Grades such as office waste or other white recovered papers made from wood-free chemical pulps
    - Main problem with regard to strength is the high ash content, which leads to low freeness after repulping

Secondary Fiber Refining

Table 17.2. Effects of Fines Removal on Handsheet Properties of Deinked Ledger Pulp Washed on 100-Mesh Screen

		Raw Pulp		"Refined Pulp"	
		Before	After	Before	After
Weight Loss	%	- -	6.4	- -	9.3
Freeness	ml	410	600	350	550
Fines (Kajaani FS-100)	%	29.9	16.7	31.2	17.1
Density	g/cc	.600	.581	.607	.580
Burst Index	–	3.04	2.55	3.47	3.20
Tear Index	–	10.2	12.9	9.5	9.9
Tensile Index	–	48.1	39.9	56.3	49.9

Washing DI pulp increases freeness but have low tensile.
Refining DI pulp increases tensile but low freeness.
Refining and then washing DI pulp gives good tensile and freeness.

Secondary Fibers, Tappi

Fundamentals of Refining

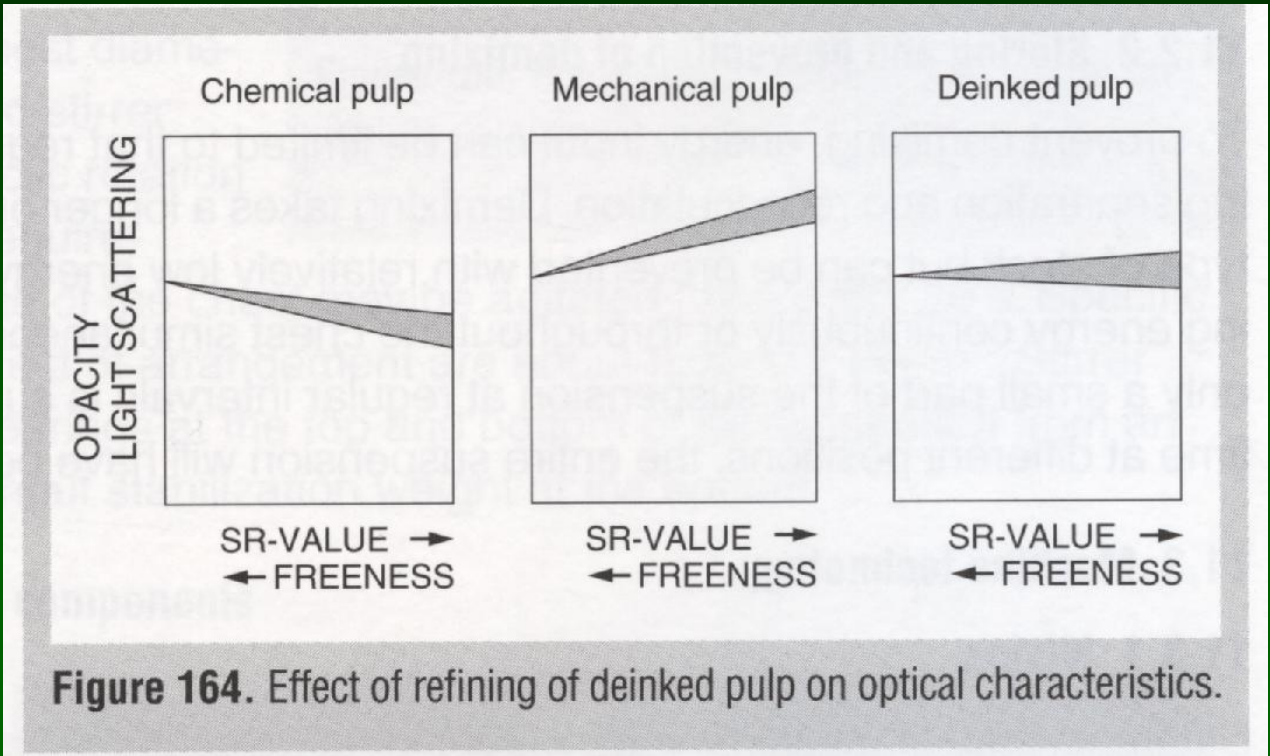


Figure 164. Effect of refining of deinked pulp on optical characteristics.

- **Recycled Fiber and Deinking, Parkarinen**

Combined effects of densification of sheet and fines generation
Note mechanical pulps generate fines mostly.

Lecture

Fiber Fractionation

Several Slides Courtesy of Terry Bliss.

Fractionation

- Definition: Separation of a heterogenous mixture of fibers into two or more streams of different properties
  - At least one stream has properties more suitable for some end use than the original mixture

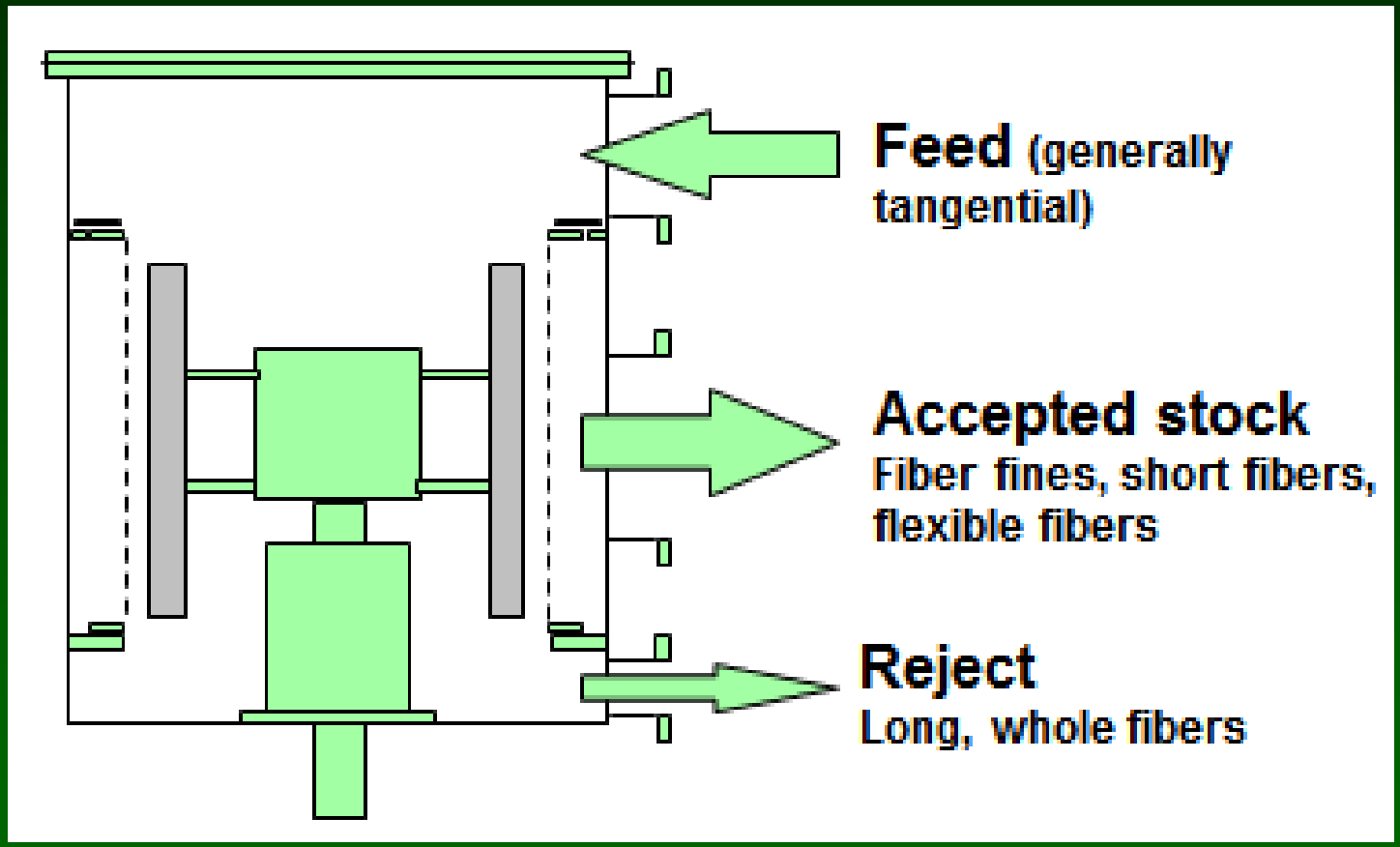
Basis of Separation

- Fiber length
- Fiber diameter
- Fiber flexibility (fiber wall thickness, degree of hydration, degree of refining)
- Fiber specific surface area
- Springwood/ / Summerwood
- Hardwood / Softwood
- Lignin content (wettability)
- Brightness or color (optical means)
- Kappa number

Fractionation Hardware

- Pressure screens (fiber length, flexibility, fines removal)
- Washers (fines, ash, ink removal)
  - Gravity screens
  - Deckers
  - High speed belt washers
- Centrifugal cleaners (fiber specific surface area, coarseness in milligram/meter)
- Rarely used methods
  - Froth flotation (fiber length, lignin content)
  - Spinning disc (wettability, fiber length)
  - Dry sorting

Pressure Screens

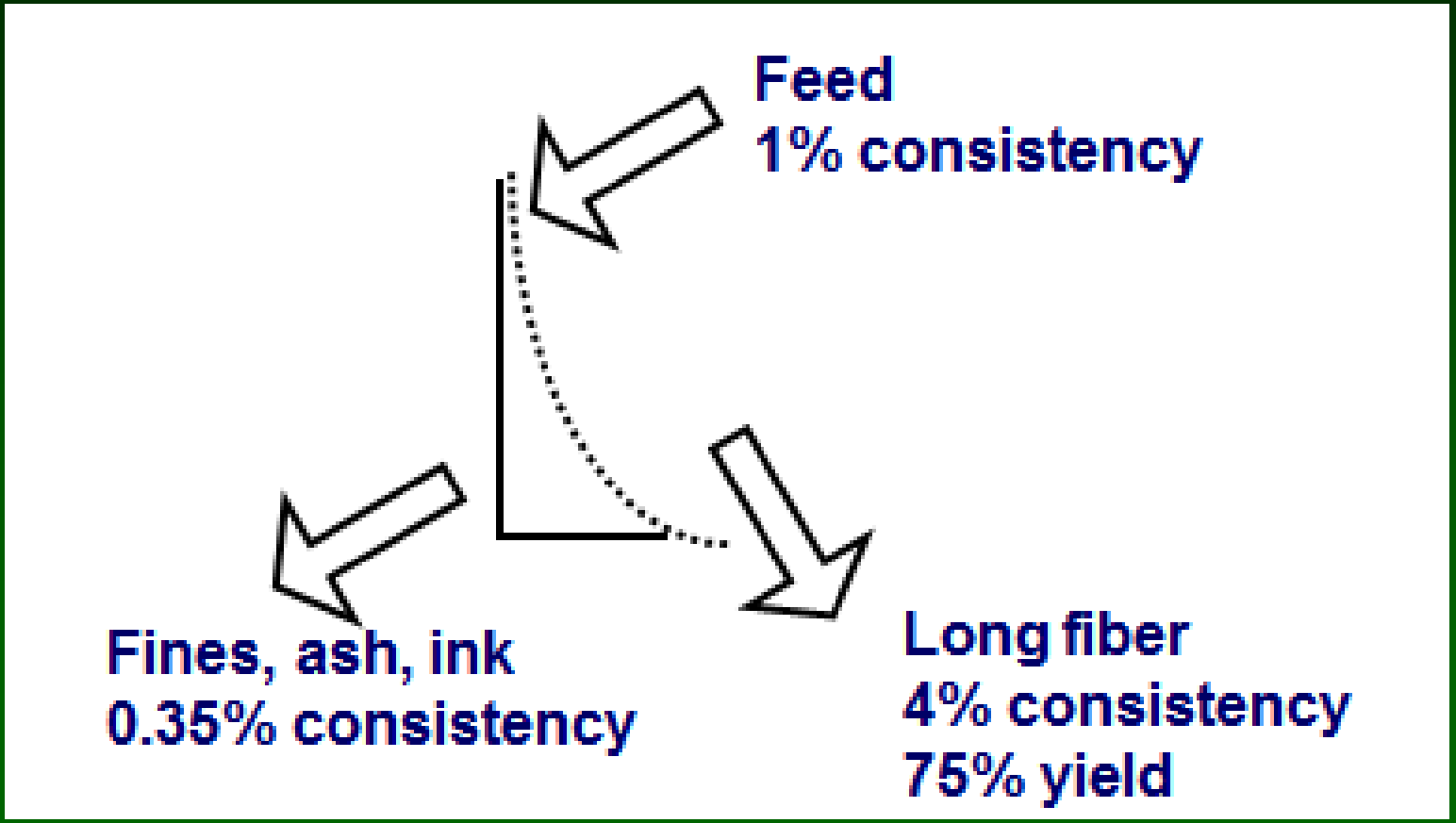


Typical Pressure Screen Fractionation Data

- Furnish: Groundwood, second stage screen rejects

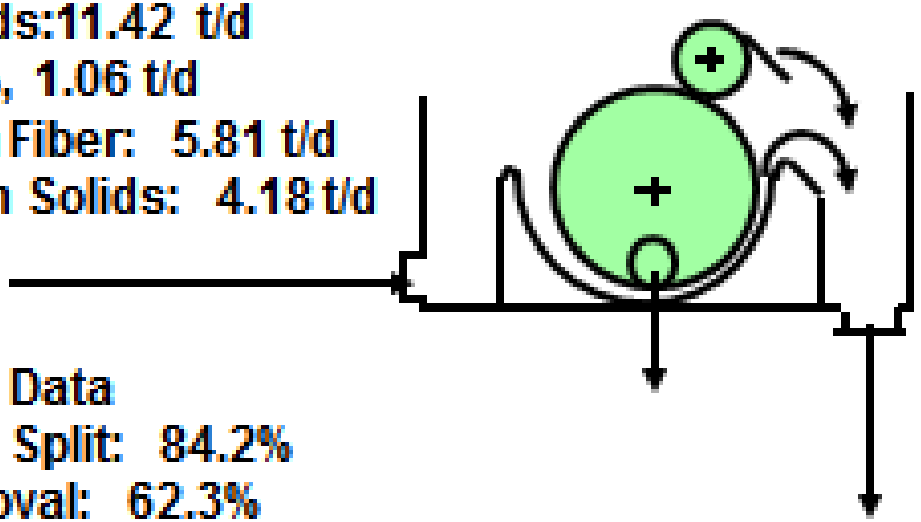
Property	Feed	Long	Short
Consistency	1.61	2.71	0.75
Shives,%	10.9	16.19	2.45
Burst Index	8.18	7.10	11.5
Tear Index	65.1	68.4	52.3
Breaking length	2.6	2.4	3.1
Bulk	3.47	3.5	3.01
+14 mesh	16.1	24.8	3.6
-200 mesh	13.7	3.5	17.9

Washing: Gravity Screens



Washers: Gravity Deckers

Feed (793 l/min)
Total Solids:11.42 t/d
Ash: 9.3%, 1.06 t/d
+65 mesh Fiber: 5.81 t/d
-200 mesh Solids: 4.18 t/d



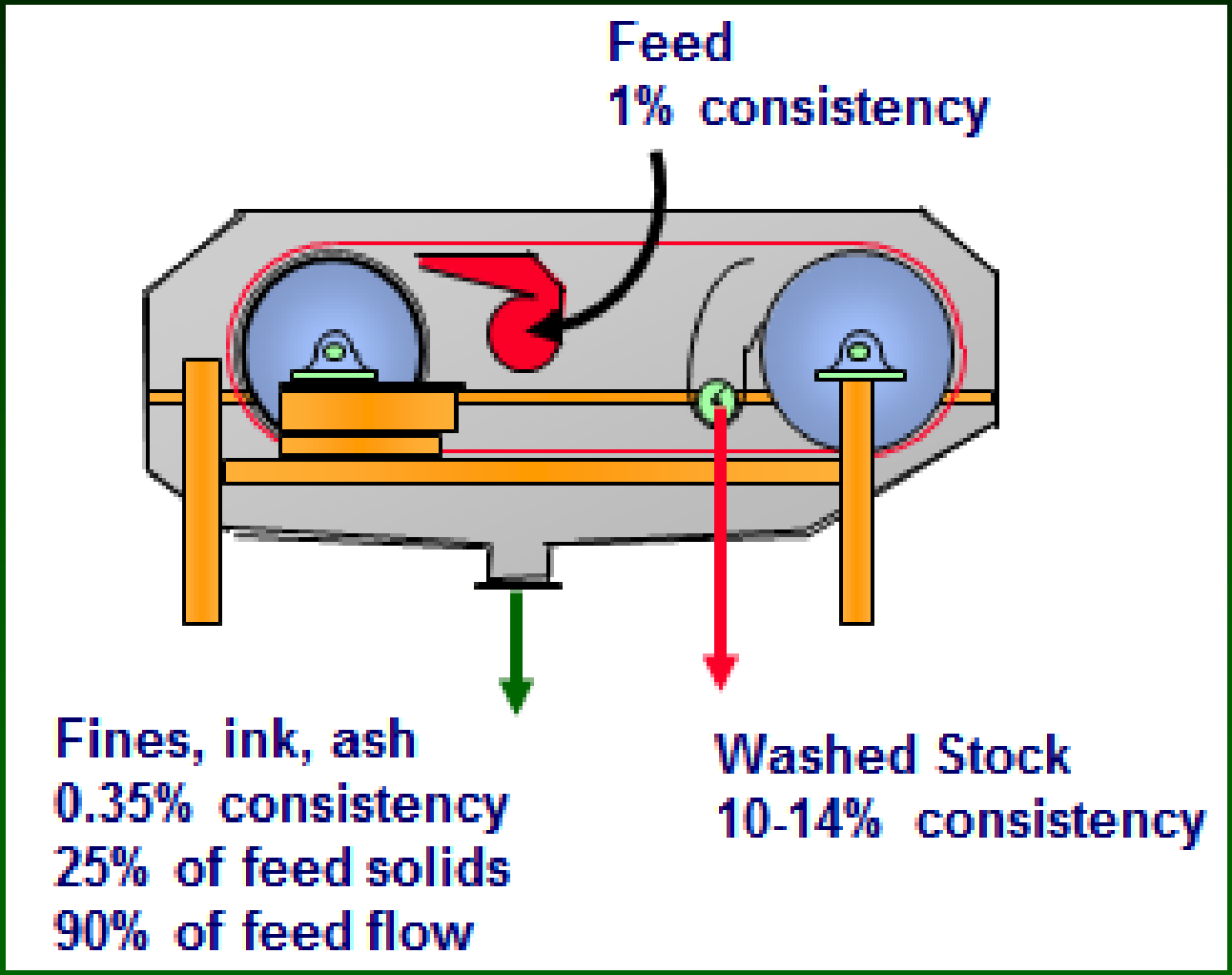
Thick Stock (125 l/min)
Total Solids: 9.06 t/d
Ash: 4.5%, 0.40 t/d
+65 mesh Fiber: 5.71 t/d
-200 mesh Solids: 2.06 t/d

Summary Data
Hydraulic Split: 84.2%
Ash Removal: 62.3%
+65 mesh Fiber Loss: 1.7%
-200 mesh Solids Loss: 50.7%
Total Solids Loss: 20.7%

White Water (668 l/min)
Total Solids: 2.36 t/d
Ash: 27.9%, 0.66 t/d
+65 mesh Fiber: 0.10 t/d
-200 mesh Solids: 2.12 t/d

A "+" before the sieve mesh indicates the particles are retained by the sieve, while a "-" before the sieve mesh indicates the particles pass through the sieve.

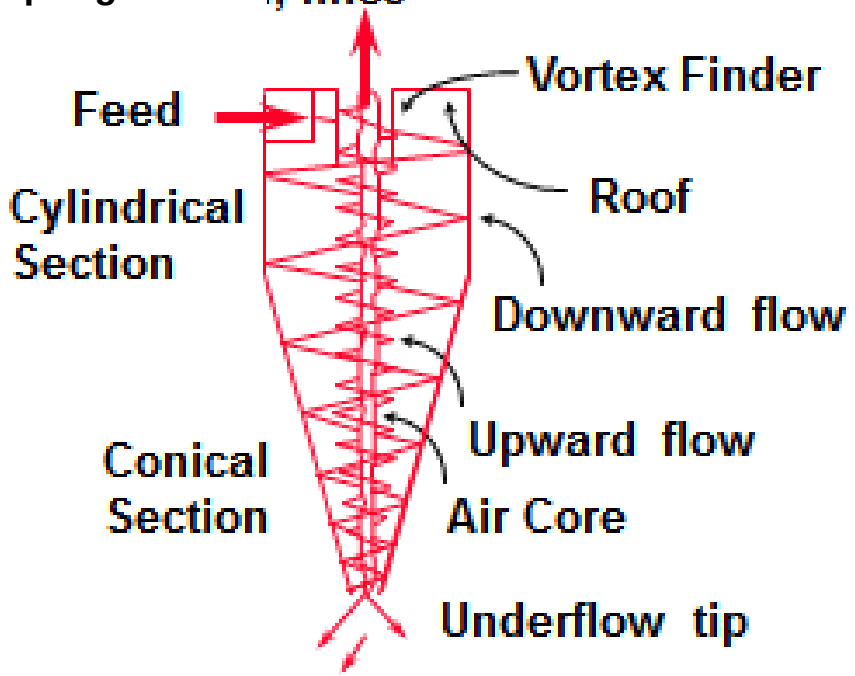
Washers: High Speed Belts



Fiber Fractioination, Bliss

Centrifugal Cleaner Fractionation

Overflow- lower consistency and freeness, light debris, flexible, well refined fibers, spring wood |, fines



Centrifugal Cleaner Fractionation

Underflow- higher consistency and freeness, heavy debris, coarse, stiff, whole, unrefined fibers, summerwood

Centrifugal Cleaner Fractionation:
accepts=over flow, rejects=underflow

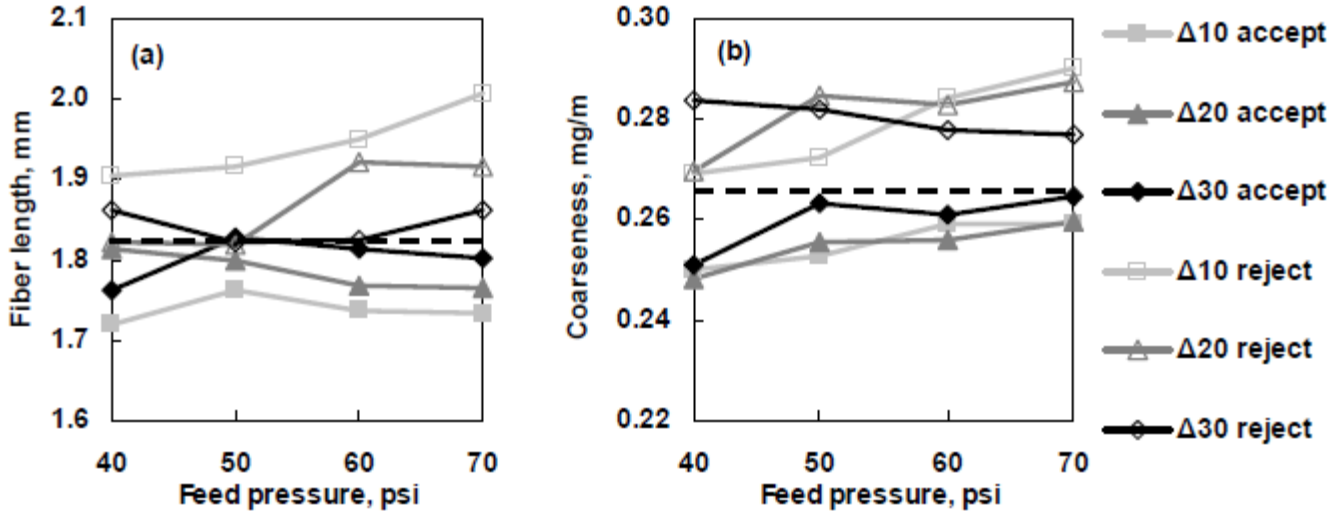
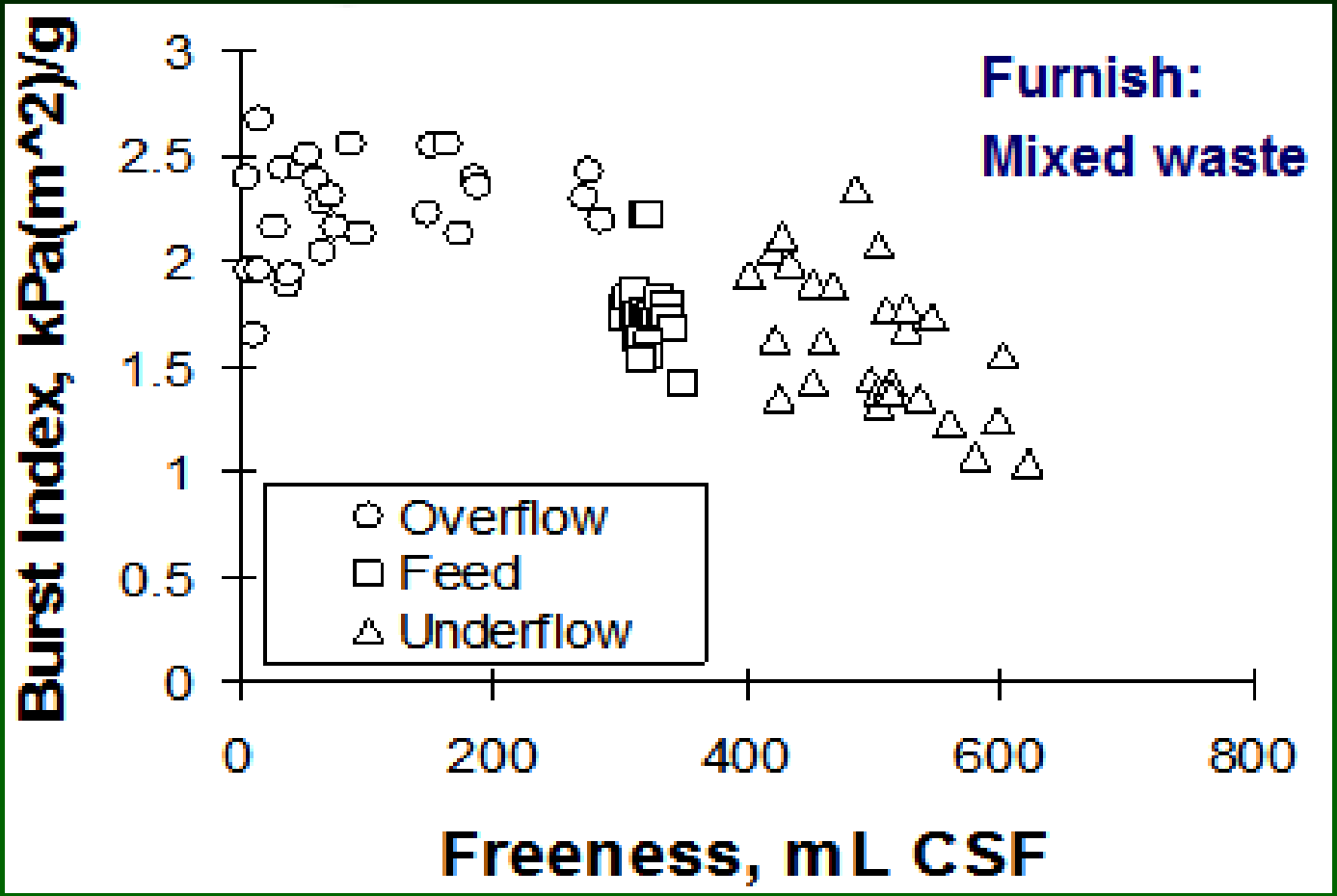


Fig. 3. Average fiber length (a) and coarseness (b) versus pressure variables for the mixture of unbeaten and beaten pulps. The feed pulp had an average fiber length of 1.82 mm (dashed line) and coarseness of 0.264 mg/m (dashed line).

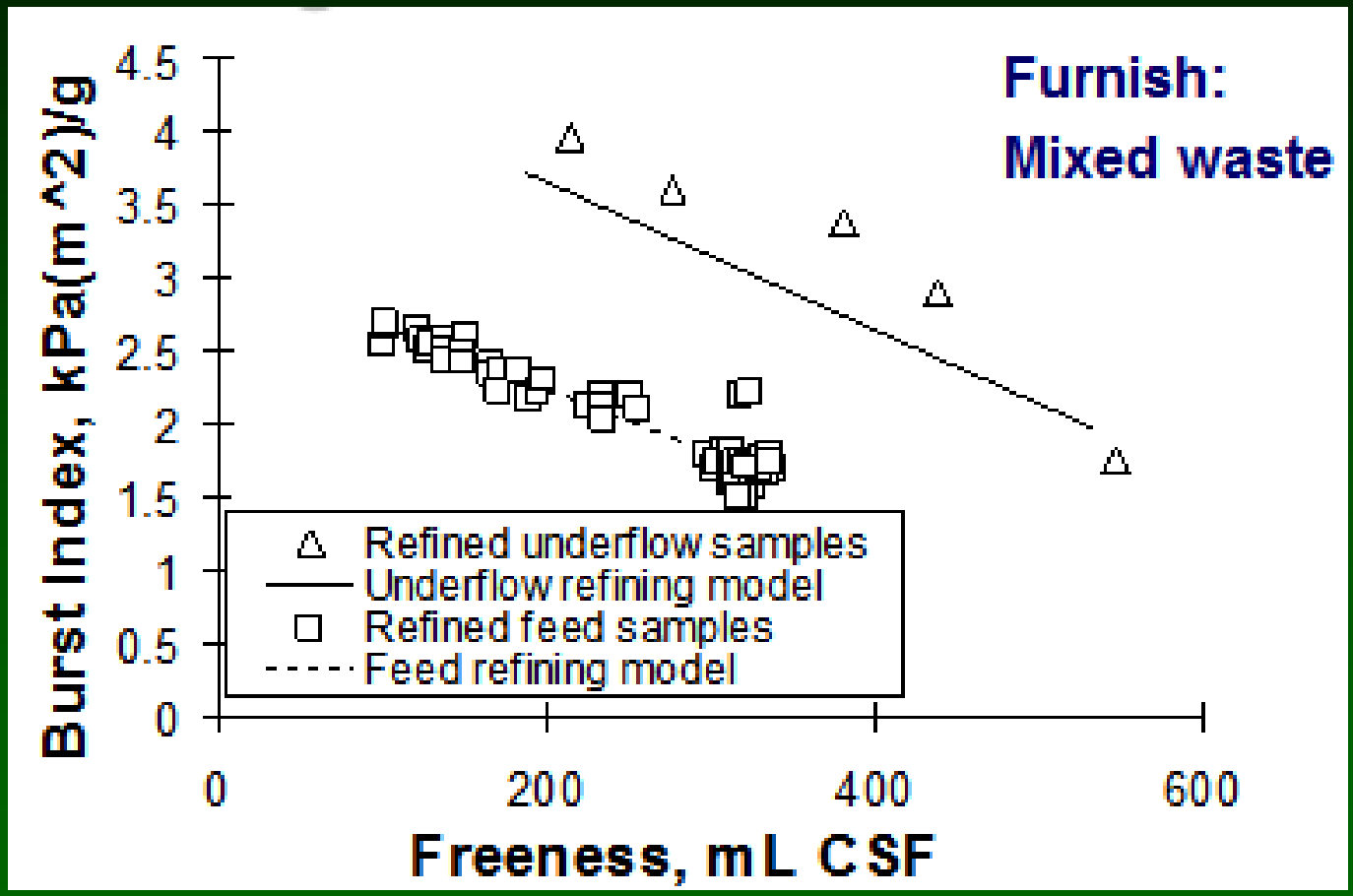
"The Effect of Fiber Properties on Fiber Fractionation Using a Hydrocyclone" S. Park, R. A. Venditti, H. Jameel, and J. Pawlak, Journal of Pulp and Paper Science, 31(3), pp. 132-137, 2005.

Centrifugal Cleaner Fractionation



Fiber Fractioination, Bliss

Centrifugal Cleaner Fractionation



Fractionation by Automated “Dry” Sorting

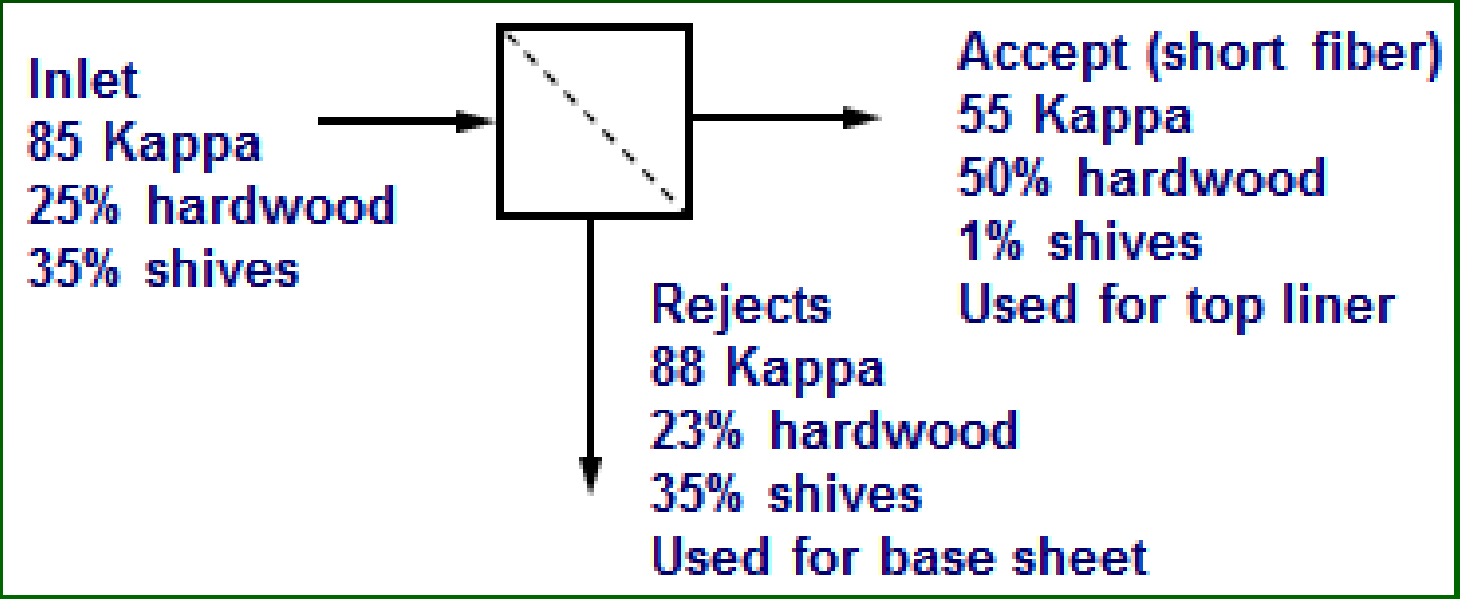
- Detect fundamental differences by optical or other non-contact means
  - Color or brightness
  - Lignin conent
- Separate with air jets or other means at very high speeds
- Technology is in its infancy, but is operating commercially
- Manual sorting very common

Fractionation Goals and Applications

- Reduce furnish cost by using lower cost fiber
  - Highly mixed fibers usually sell for a lower price
- Improved strength
- Produce sheets with unique properties
- Reduced processing cost
  - Reduced refining energy
  - Reduced screening or cleaning

Hot Stock Fractionation

- Unwashed brown stock can be fractionated with a pressure screen into a high hardwood, low Kappa stock suitable for top liner, and a softwood-rich stock suitable for base stock for linerboard
- Now common practice in virgin linerboard mills



Fiber Fractioination, Bliss

Fractionation Screening with Recovered /Fibers

- Fractionation is often combined with screening systems
- Typically, pressure screen fractionated short fiber is very clean- it usually does not need additional fine screening –top liner
- The long fiber fraction is more difficult to fine screen, but sometimes the end use (base sheet) does not need to be as clean

“Engineered” Sheets

- Separate long fibers from short fibers:
  - Long fibers have higher bulk
  - Short fibers have higher stiffness
- Make a three layer sheet with short fibers on the outside, long fibers on the inside
- Result: A stiffer composite sheet than an equal weight sheet of uniform composition

Top Liner and Back Liner for Cylinder board from single Stock

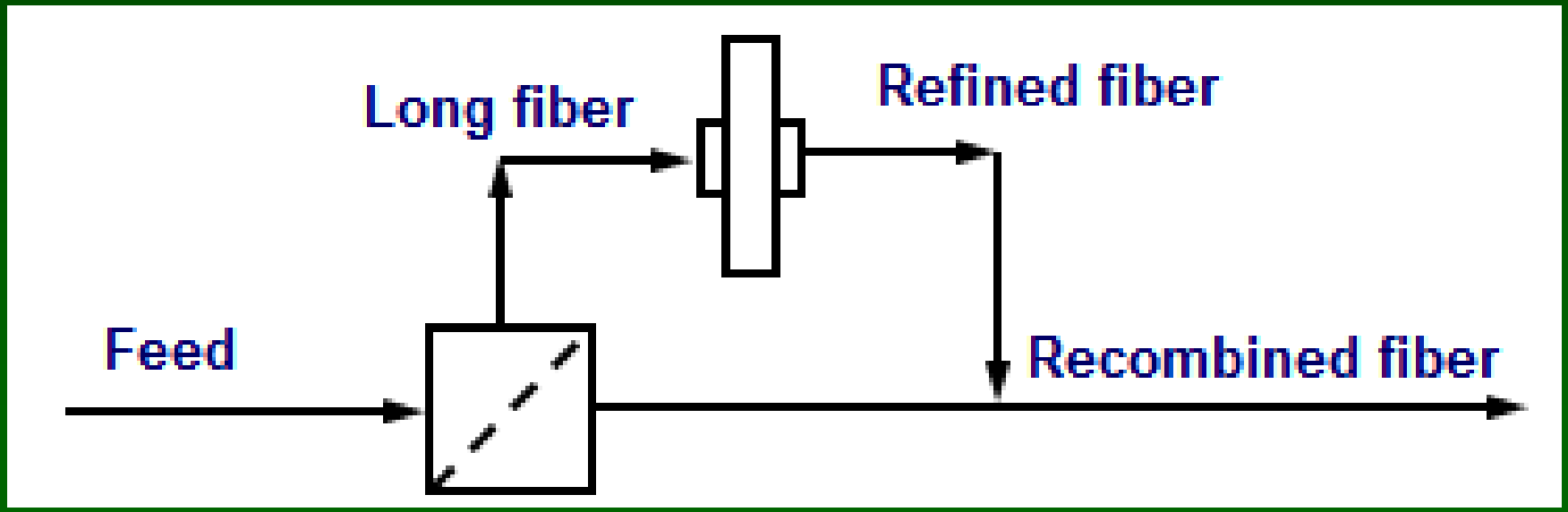
- Multi-layer cylinder paperboard is generally produced from
  - 2 layers of top liner (smooth, bright surface for printing or coating),
  - 4-6 layers of filler (low cost, high bulk),
  - and sometimes 2 layers of back liner (intermediate properties).
- Fractionation can be used to direct fibers to different layers
- Filler can be upgraded by fractionation, but great care must be taken to produce stocks of suitable properties (cleanliness, smoothness, and freeness)
- Some commercial success

Separate Grades Produced on Separate Paper Machines

- Pressure screens or cleaners can be used to separate a heterogeneous stock into streams suitable for production of different grades of paper;
- The paper is made on different paper machines
- Example: Linerboard and corrugating medium from OCC
- Generally not feasible due to lack of compatible grades and production rates at the same mill site

Selective Refining / Recombination

- Fractionated long fibers can be refined, and then recombined with the short fibers to improve strength, save energy, and reduce the generation of fines



Fiber Fractioination, Bliss

Selective vs Joint Refining

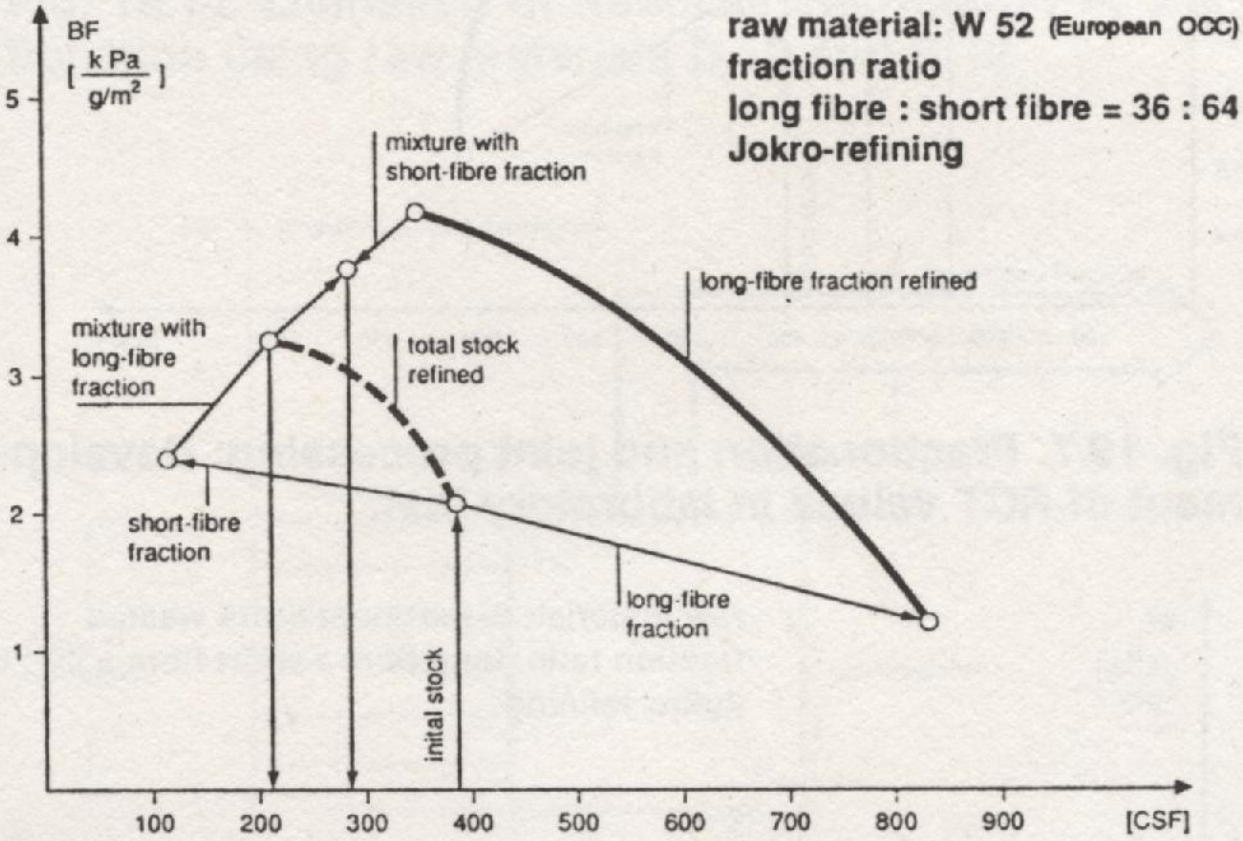
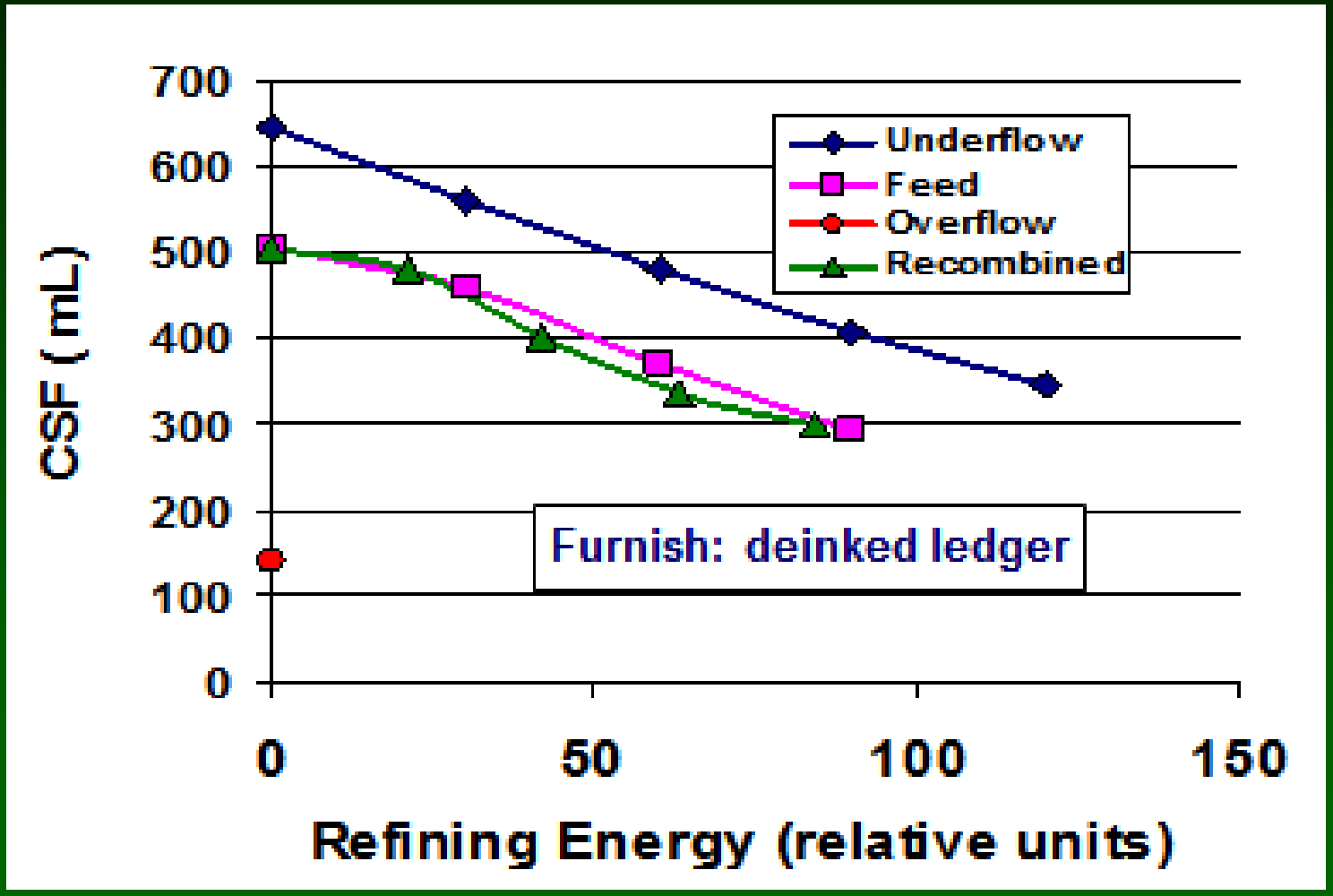


Fig. 19.5. Fractionation and joint processing: Development of burst strength in laboratory test.

Secondary Fiber, Tappi

Selective Refining / Recombination Data



Fiber Fractioination, Bliss

The Curse of Fractionation

What to do with the "other" fraction

- The short fiber fraction is much lower consistency and freeness than the long fiber fraction
  - Pressure screens: shorts = 1-2%, 150-300 CSF;
  - Centrifugal cleaners: shorts <0.5%, 20-300 CSF;
  - Flotation: shorts <1%, high ash content;
  - Washing devices: shorts <0.3%, high ash content
- Yield loss, disposal of fiber fines and ash is very costly
  - Deink systems typically must have a yield of 70-85%
  - OCC or mixed waste yields must be much higher
  - No yield loss, no fractionation, no property improvement

Where is the Greatest Potential for Fiber Fractionation

- Multilayer papermaking from a common furnish
- Upgrading of sludge from pulp mills and fine paper mills for use in packaging and building papers
- Making multiple grades of market pulp from highly mixed recycled paper
- Automated dry sorting
- Finding new uses for low freeness, high fines, high ash pulps
  - High density construction board?
  - Fuel source?

Demands on a Fractionation System

- A primary requirement of any fractionation system is high selectivity
  - Other requirements include:
    - Adaptability to changing raw materials and to various characteristics
    - High feed stock consistency to save pump energy and chest capacity and to avoid intermediate thickening
    - Low specific energy consumption
    - Low specific floor space needs
    - Low overall capital and maintenance costs
    - Lack of environmental problems
    - High operational reliability and low manpower requirements

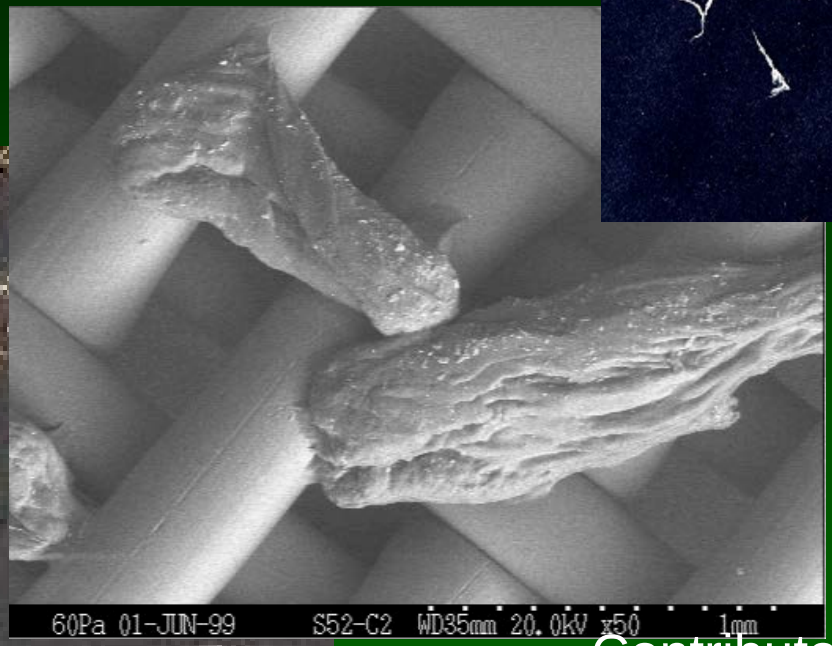
Conclusions

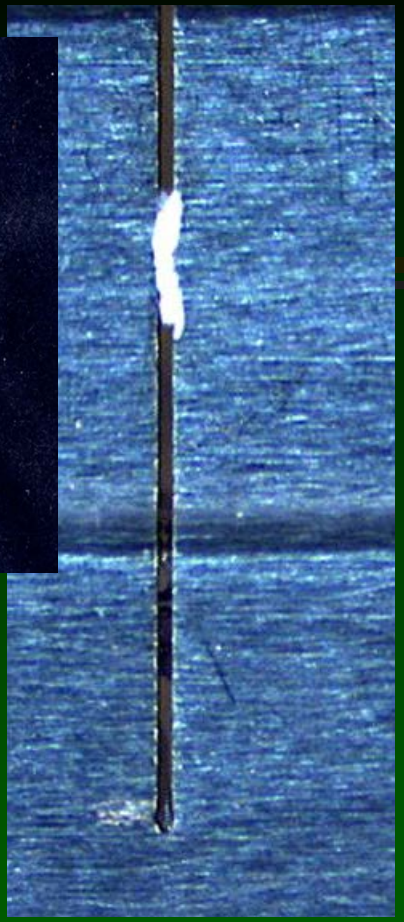
- In selected cases fractionation has been used in stock preparation systems as an economically viable method of improving quality, cutting costs, and stabilizing the properties of the end product, especially with multi-layered boards

Lecture

Stickies: Tacky Contaminants

Stickies





Contributors

Richard A. Venditti(1), Mahendra Doshi(2)

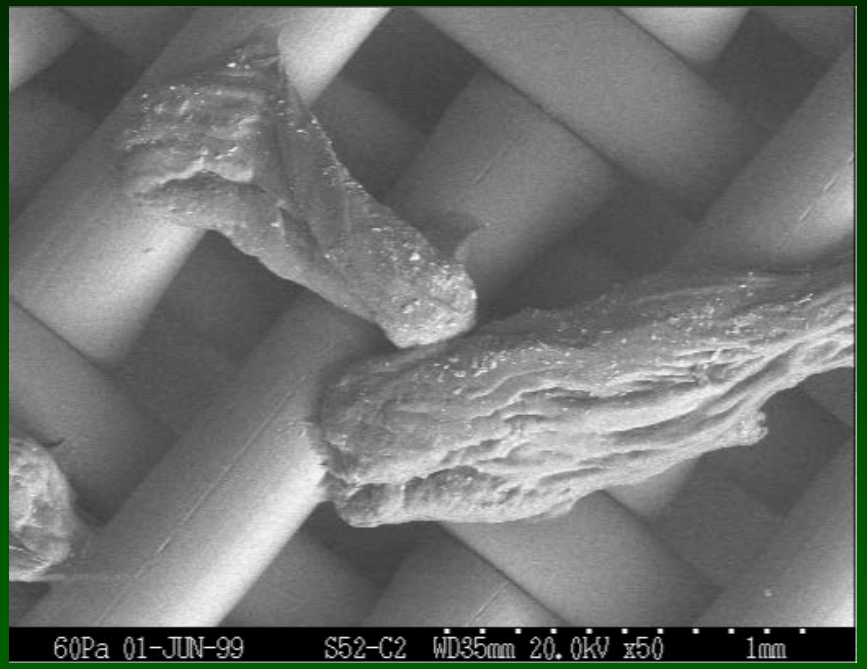
(1)North Carolina State University
Dept. of Wood and Paper Science

(2) Progress in Paper Recycling

Sticky Contaminants (Stickies)

A sticky particle:

- is typically hydrophobic
- is tacky and depositable
- often DEPOSITS ON EQUIPMENT
- Often adsorbs particulates/dissolved species on its surface



- Examples of adsorbed species might include talc, Calcium Carbonate, Inks, Toners, polymers …

What are stickies?

Stickies in paper recycling are believed to be a mixture of

----Hot melts adhesives

----Pressure-sensitive adhesives (PSA's)

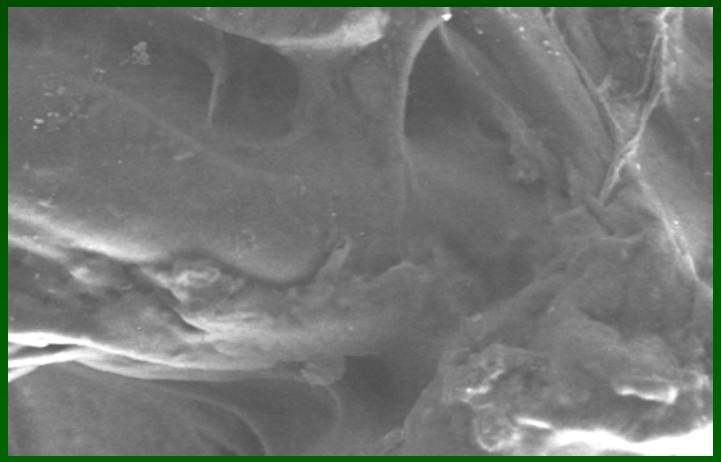
----Glues

----Wax

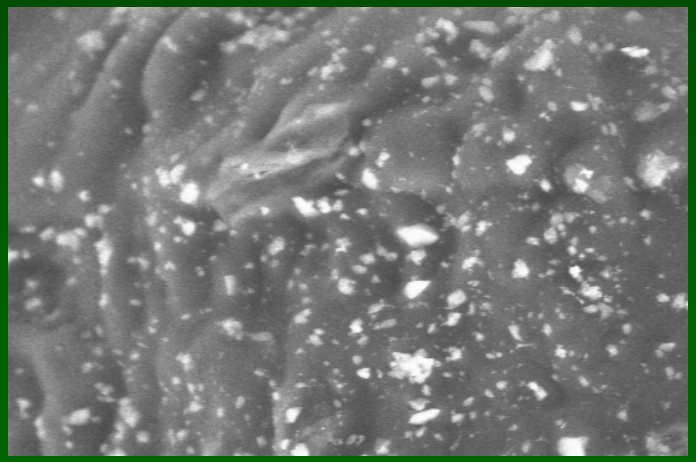
----Inks, Paper additives, Coatings

----Wood derived extractives…

*The actual surface behavior of stickies depends on the adsorbed species.



PSA Surface



PSA Surface with $CaCO_3$

Composition of Hot Melts

- Vinyl Acetate Polymers and Copolymers
- Tackifiers
- Wax

Properties of Hot Melts

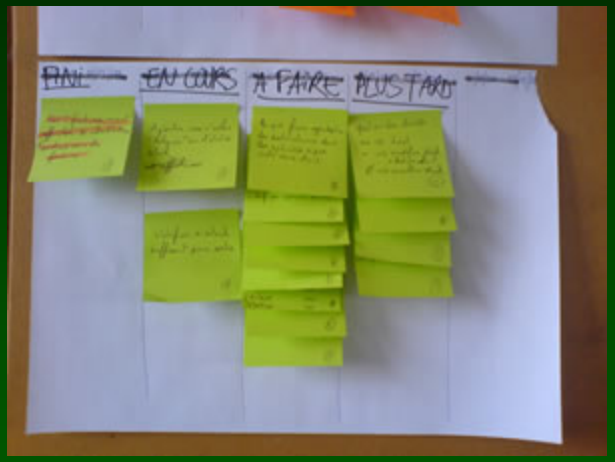
- 100 % Solid Formulations
- Soften at 150^{O}F to 250^{O}F
- Insoluble in Aqueous Media
- Soluble in Many Organic Solvents
- Density 0.9 to 1.0 g/cc

Composition of PSA

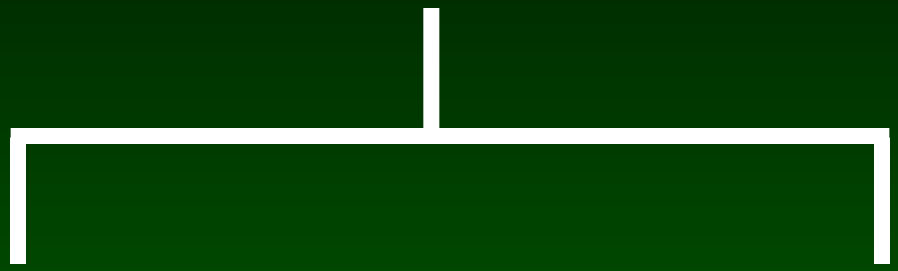
- Rubber Elastomer
  (e.g. Styrene-butadiene or poly-acrylate)
- Tackifiers
- Fillers (MgO. ZnO, etc.)

Properties of PSA

- Tacky at room temperature
- Insoluble in Aqueous Media
- Soluble in Many Organic Solvents
- Density 0.9 to 1.1 g/cc
- Often (but not always) precipitate with drops in pH



CLASSIFICATION OF STICKIES



PRIMARY

(Formed in pulper)

SECONDARY

(Change in environment, pH, temp., etc.)

Micro versus Macro Stickies

Macrostickies

Retained on 6-cut

6 cut = 0.006 inches

(0.15 mm)

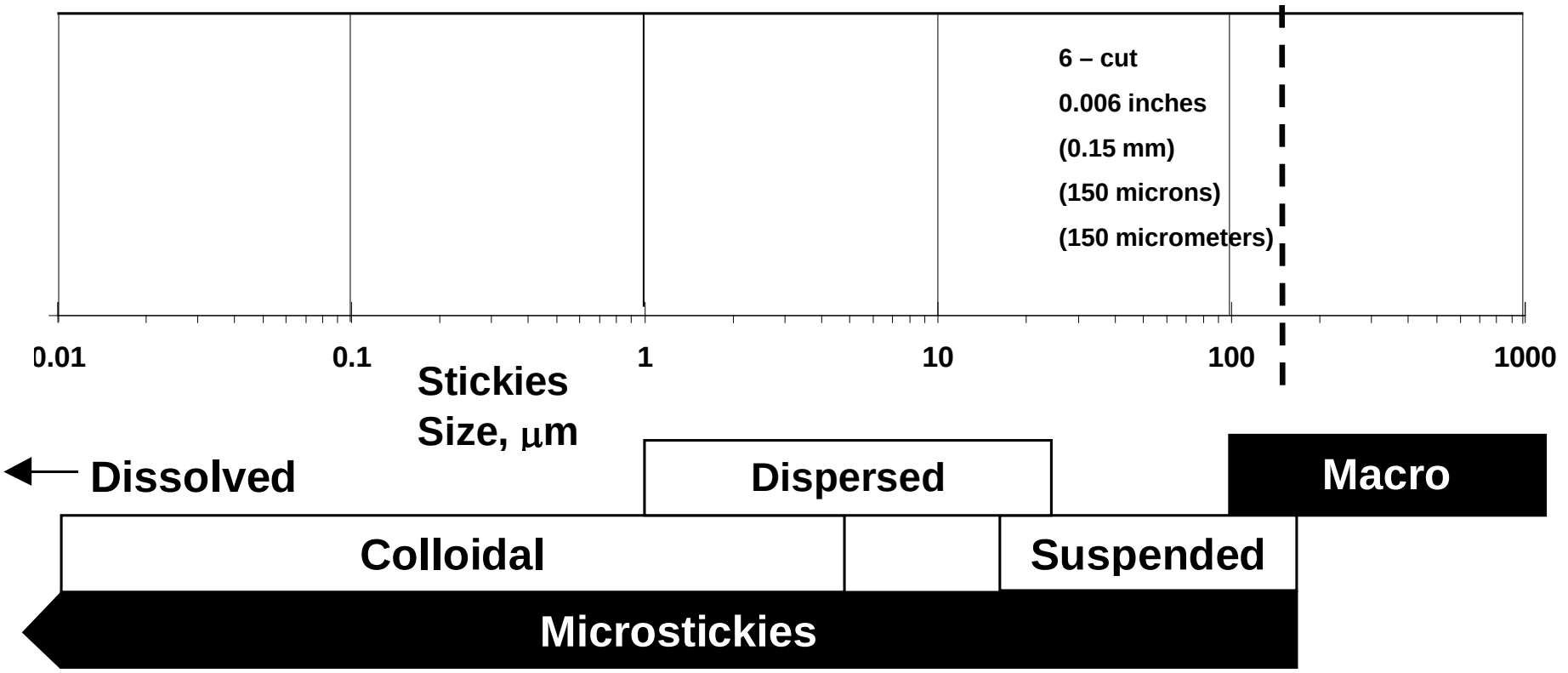
(150 micrometers)

slotted screen

Microstickies

Pass thru a 6-cut slotted screen

Stickies Size Classifications:

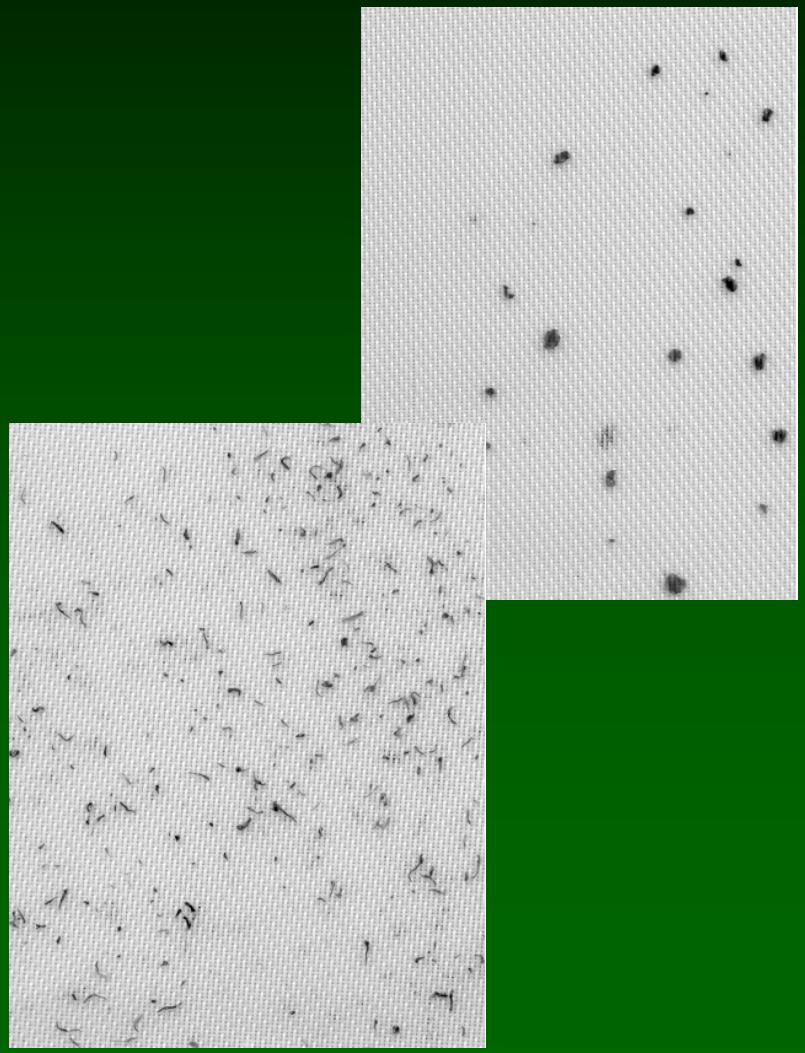


Micro vs Macro Sticky:

- Macro stickies
  - Are large, can be screened
  - Are visible and offensive in products
- Micro stickies
  - Are small, are carried along with water, can not be screened
  - Are very chemistry sensitive, can agglomerate and precipitate
  - Water clarification can be effective
  - Often must dump water or be retained in product to deal with
  - Can not generally be seen in a product

Stickies-Related Problems

- Product quality
  - Dirty spots in paper
  - Holes in the paper
  - Picks in the paper
  - Converting issues
    - Coating
    - Printing
    - Folding, scoring, cutting
- Operational problems
  - Deposition on machine
  - Breaking web
  - Down time for cleaning



Control and Removal Methods for Stickies

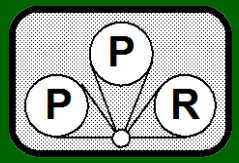
- Use of environmentally benign adhesive (recyclable adhesive)
- Avoidance: Control of recovered paper quality
- Mechanical removal: screening and cleaning
- Water clarification
- Chemical control: polymers surfactants, others
- Passivation with inorganic particles
- Enzyme hydrolysis
- Physical adsorption to paper fibers: retention
- Dispersion
- Protection: treatment of equipment to limit deposits
- Continuous cleaning of papermaking clothing
- Water dumping
- Mill shut down for clean-up

Lecture

Stickies: Control and Removal

Control and Removal Methods for Stickies

- Use of environmentally benign adhesive (EBA, recyclable adhesive)
- Avoidance: Control of recovered paper quality
- Mechanical removal: screening, cleaning and water clarification
- Chemical control: polymers surfactants, others
- Passivation with inorganics
- Enzyme hydrolysis
- Physical adsorption to paper fibers: retention
- Dispersion
- Protection: treatment of equipment to limit deposits
- Mill shut down for clean-up



Richard A. Venditti, Mahendra Doshi

Governmental efforts to promote benign adhesives

- US Postal Service, USPS P1238-F, qualifies products,
  - all stamps are EBA
- Document E.O. 13148, “Greening the Government Through Leadership in Environmental Management”, was signed on April 21, 2000.
  - Mandates use of EBA’s for government purchases
  - Not all tapes and labels are EBA
- Cost circa $100,000,000 in United States

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Recovered Paper Quality Control

- •Stickies
- - Dirt
- -Groundwood
- -Strength
- -Coated
- - Plastic films
- - Brightness
- - Glass, Metal
- -Municipal trash
- - Uniformity

What to measure in bales if stickies are the concern?

1. Visually inspect outside of bales for stickers….
2. Visually inspect bale after opening.
3. Can supplier/location/grade be identified with high stickies content: keep track?
4. Reject bales with justification or simply discuss needs with supplier.

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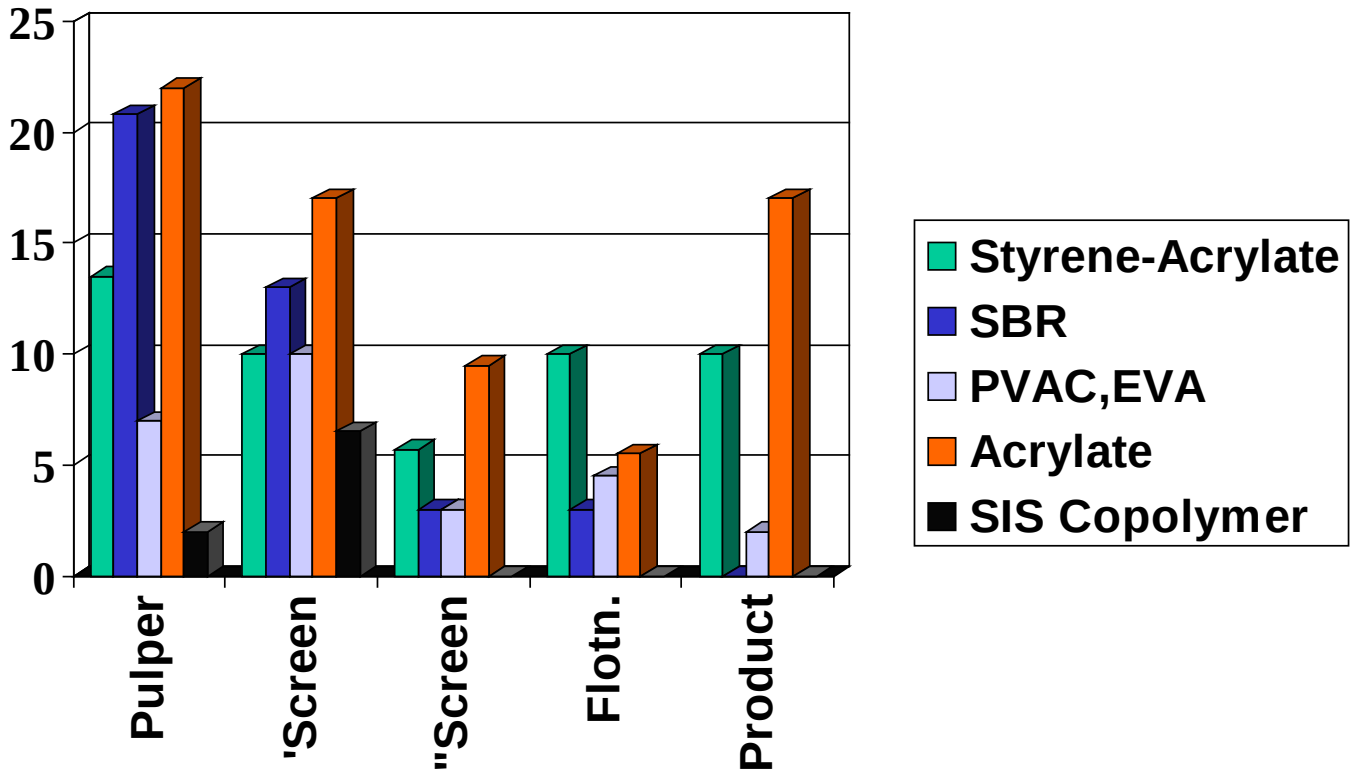
Pulper Performance

- **Often can not change parameters**

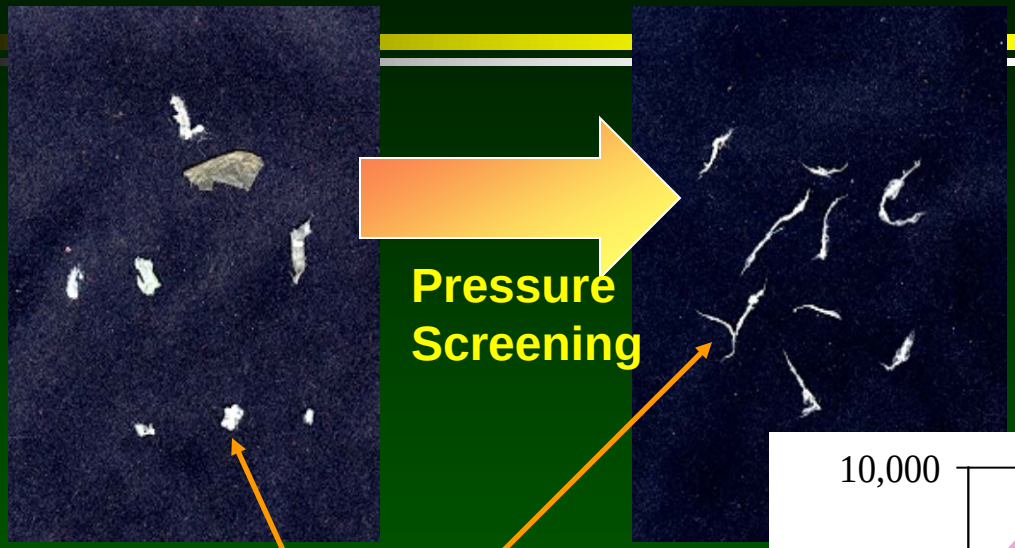
- **Gentle pulping**
- **Drum pulping**
- **Pre soaking**
- **Short pulping time**
- **Low temperature**
- Low pH

Analysis of Macro Stickies - SOW

M. A. Pikulin, AF&PA and USPS Joint Conference to Address PSA Issues, June 1996



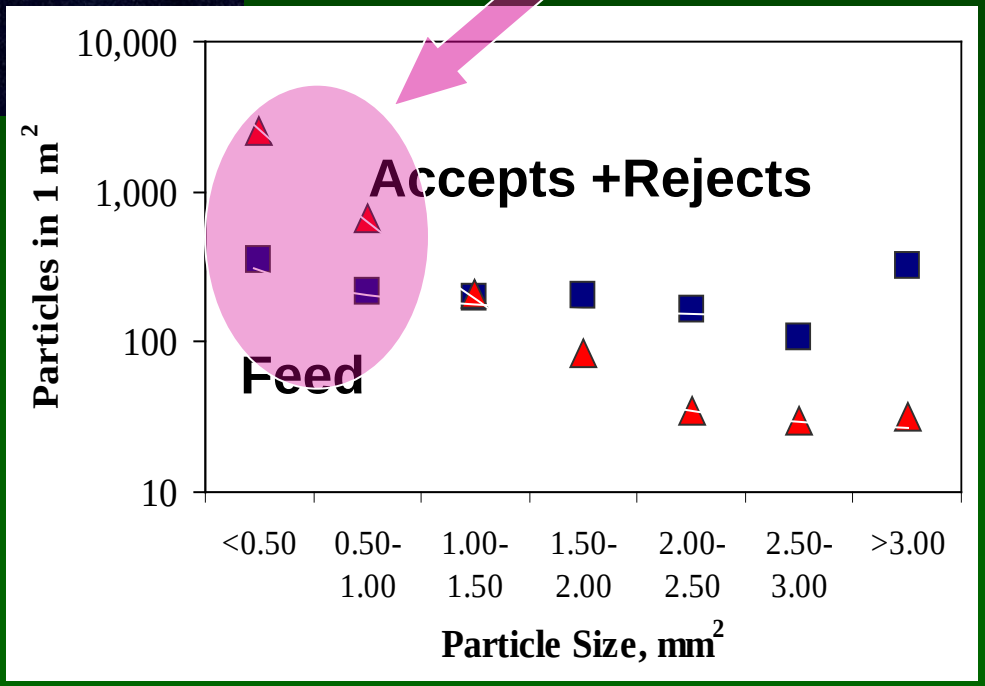
Intense Forces in a Pressure Screen Break/Deform Adhesives: Decreases Screening Efficiency



Pressure Screening

Shredding makes particles more 1-dimensional

"Thousands of small particles generated"



Improved screening efficiency:

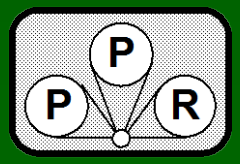
- **Lower consistency**
- **Lower pressure drop**
- **Lower temperature**
- **Lower passing velocity**
- **Feed forward versus cascade arrangement**

SCREENING SYSTEM

Simple Common Sense Principles

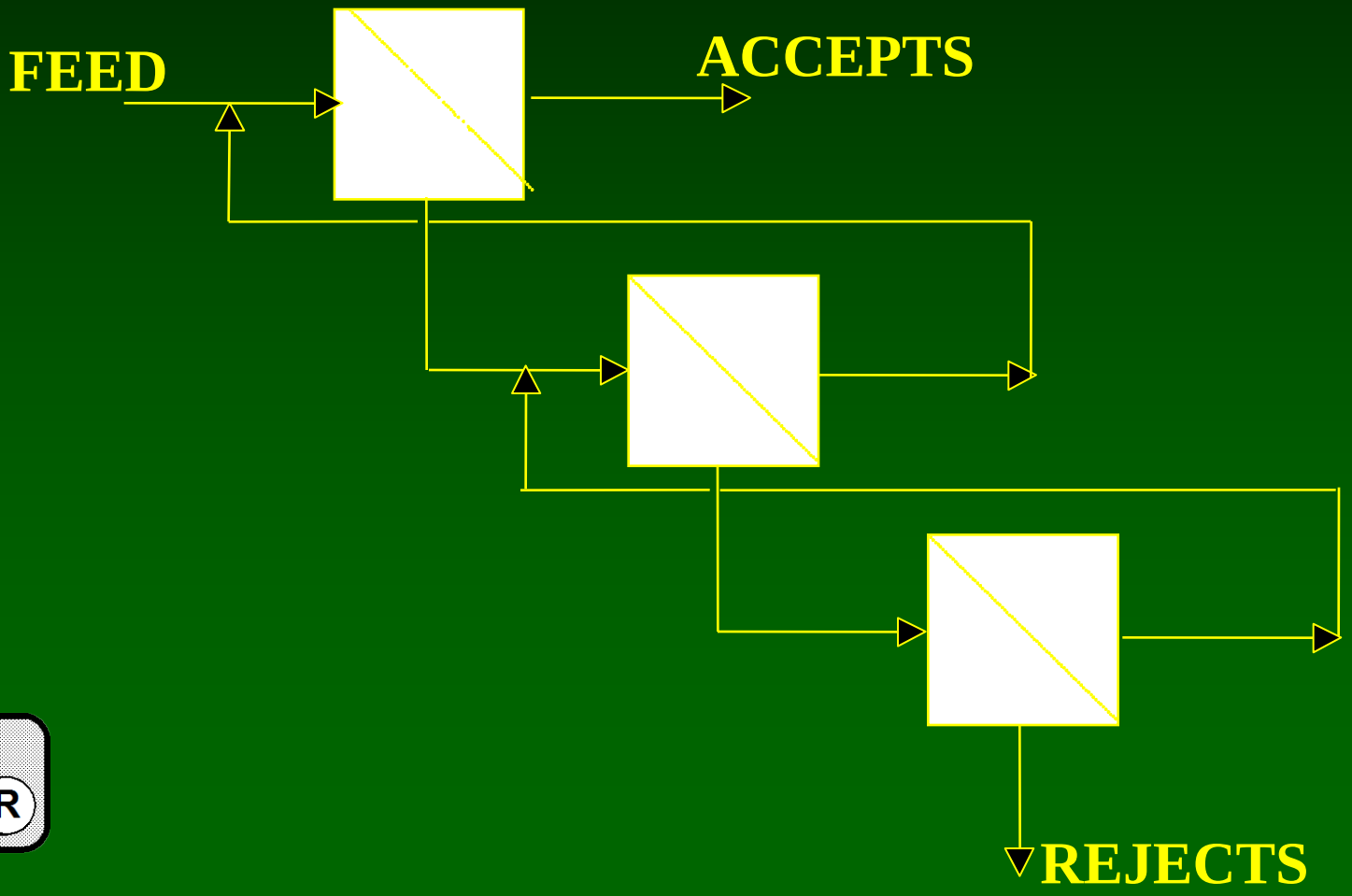
1. Do not mix a clean stream with a dirty stream.

2. Avoid recirculation of contaminants.

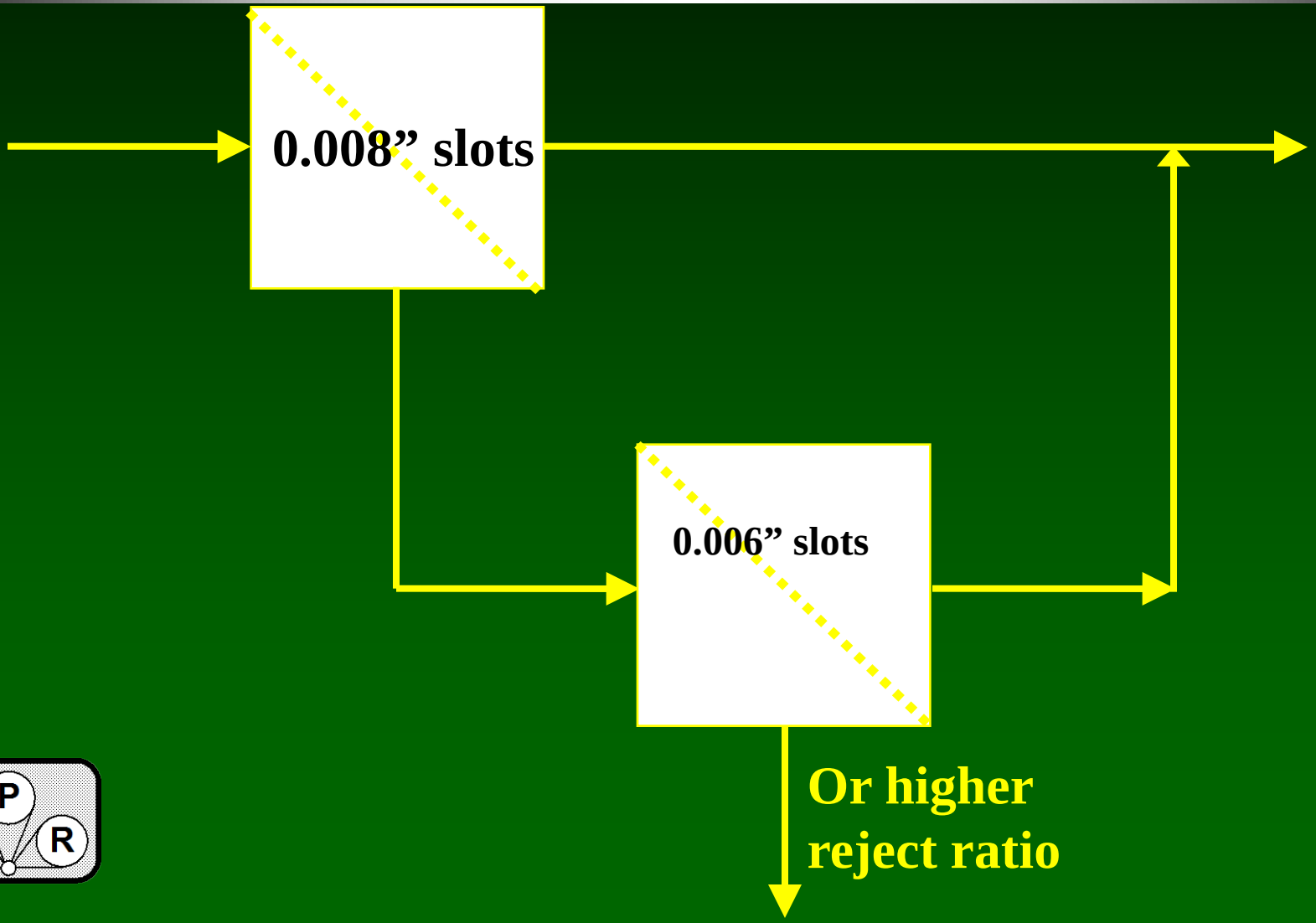


SCREENING SYSTEMS

Conventional Cascade Arrangement

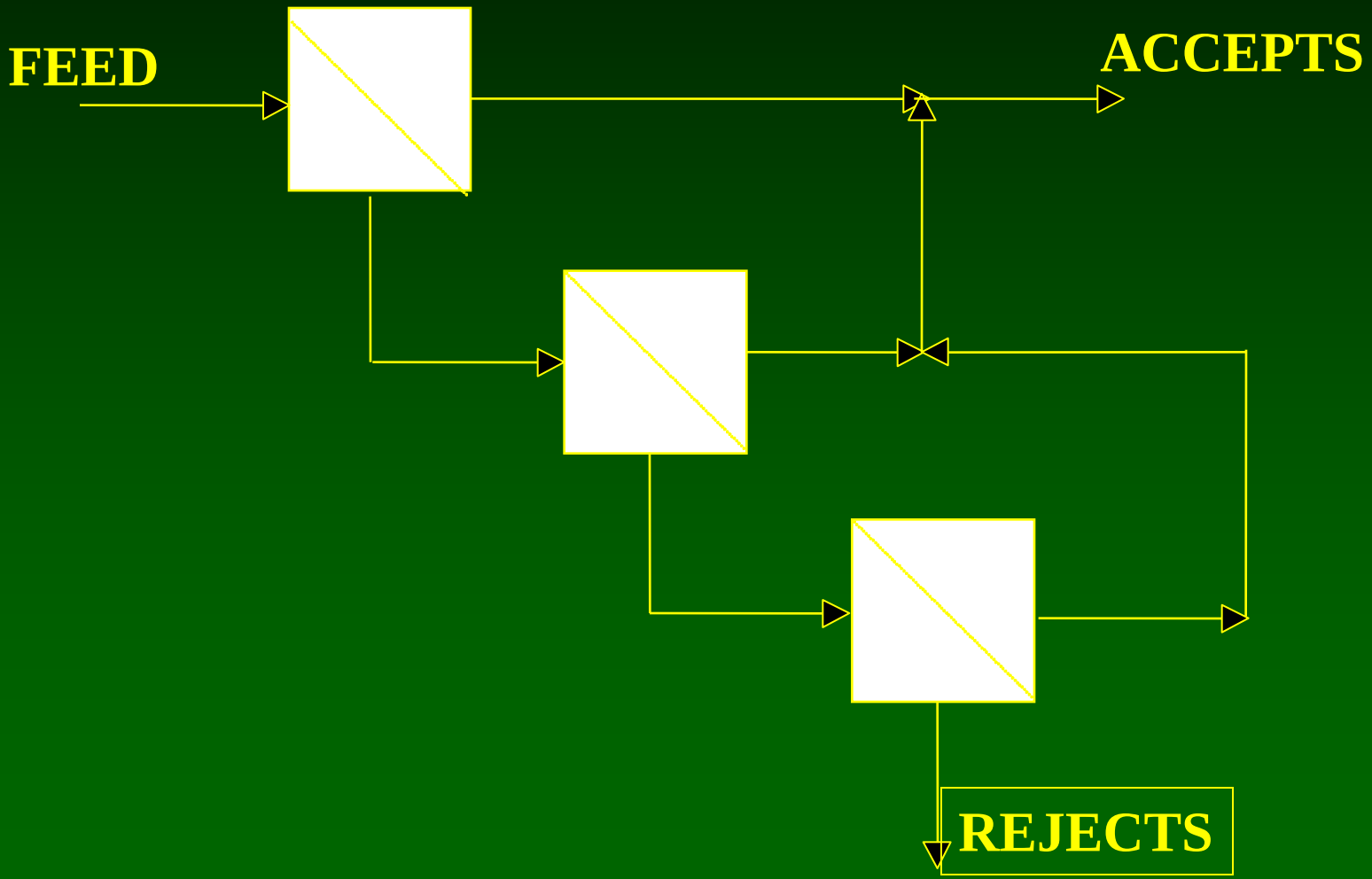


SCREENING SYSTEMS
Forward Flow Arrangement



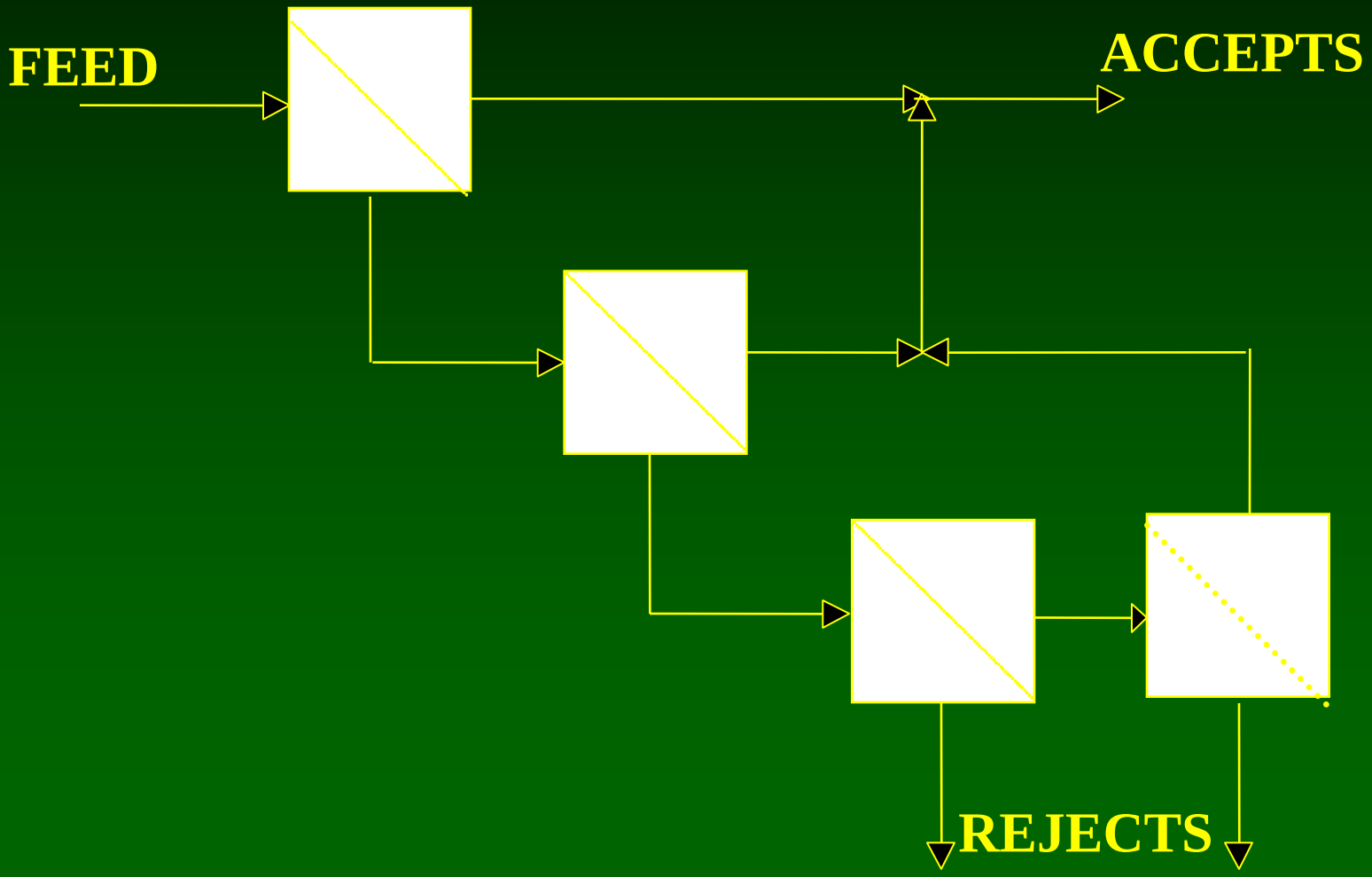
SCREENING SYSTEMS

Forward Flow Arrangement

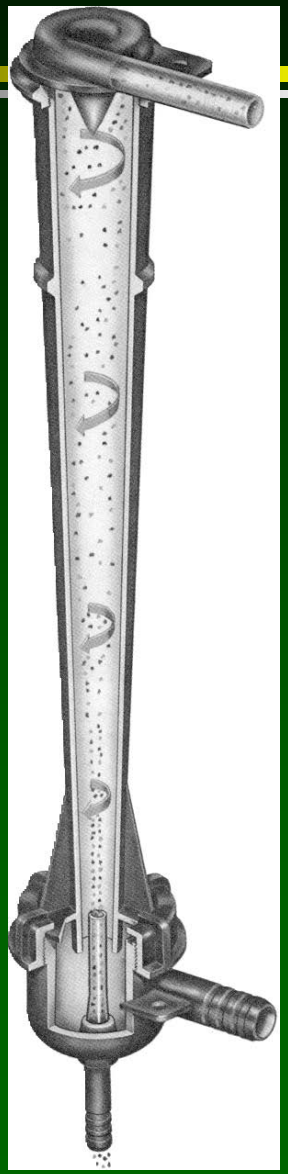


SCREENING SYSTEMS

Forward Flow Arrangement



Through Flow Cleaner: removes low density contaminants



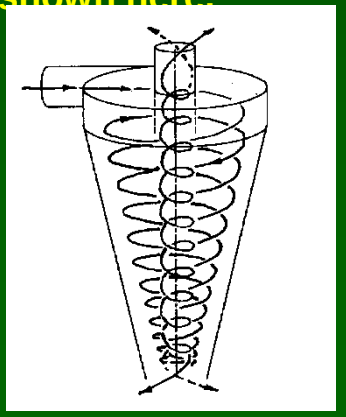
Feed

Rejects

Accepts

Also note, that reverse cleaners are another type of cleaner used to remove low density contaminants.

Reverse cleaners look like a forward cleaner except the top middle port is the rejects (and is smaller) and the bottom cone tip is the accepts (but is wider), picture not shown here.



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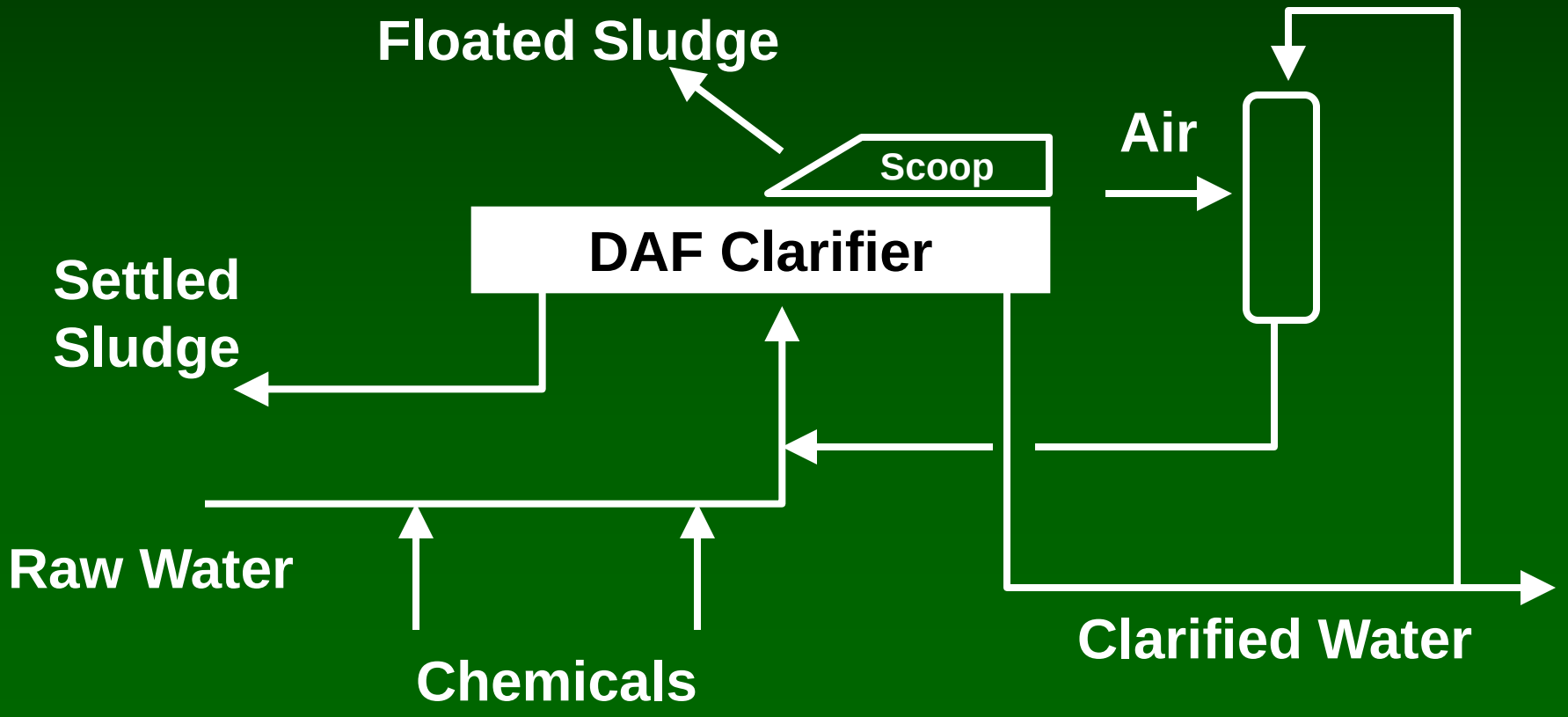
- Mill shut down for clean-up

Water Treatment

- Re-use filtrates (often from thickening or washing process) to conserve water
- Clarifier objective: take filtrate and make a sludge and a filtrate
- Filtrate to Clarifier: 2000 ppm suspended solids
- Clarified water: 100 ppm suspended solids
- Sludge: 3-7% solids
- No change in colloidal or dissolved species

DAF Clarifier



Improved **micro** stickies removal efficiency:

- **Improvement to the water clarification process.**
- **Maximum air addition and retention time.**
- **Proper type/dosage/mixing of chemicals.**
- **Routine testing of suspended solids removal.**
- **Additional clarifier capacity**

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Additives to Combat Stickies

- Solids/Slurry
  - Inorganic (Talc)
- Liquids/Emulsions
  - Inorganic (Zirconium Compounds)
  - Organic
    - Cationic fixatives to fibers
    - Anionic (Negative Charge)
    - Nonionic (Surfactant)—stabilize adhesive particles
    - Starch
- Enzymes: hydrolyze ester groups making stickies more stable in water

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Physical adsorption to paper fibers: retention

- Cationic polymers with high charge density and low MW used to fix anionic stickies to anionic fibers
- Starch, proteins, alum and others…
- Needs good mixing in stock prep area
- Requires passivation of papermaking equipment

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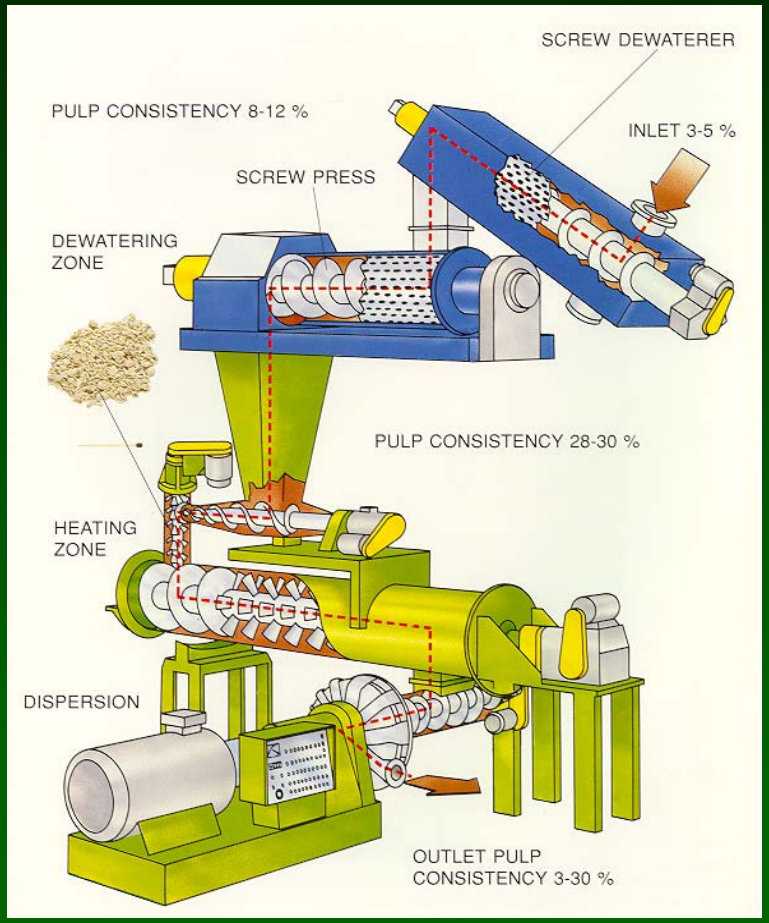
Dispersion

- Dispersing System:
  - Process stock is dewatered to 30%K
  - Clods of stock are broken in the breaker screw
  - Steam introduced into a heating screw to increase temperature to 185-245 C
  - Stock fed to dispersing unit
  - Stock is diluted and agitated for further processing



Dispersion

- Must have excellent washing and water clarification directly after dispersion
- Should use an additive to pacify the particles
- Otherwise, the problem will worsen for papermachine
- Not recommended, energy intensive and harm to the fibers

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If a clean-up is needed:

- The amount of residual cleaner in the paper machine water loop should be minimized if not reduced to zero concentration before start up
- Basically, cleaners are dispersants for stickies, any residual cleaning material can actually interact with stickies and possibly cause increased stickies deposits
- Follow the instructions of the cleaner manufacturer carefully

Lecture

Stickies: Measurement

How to detect a sticky?

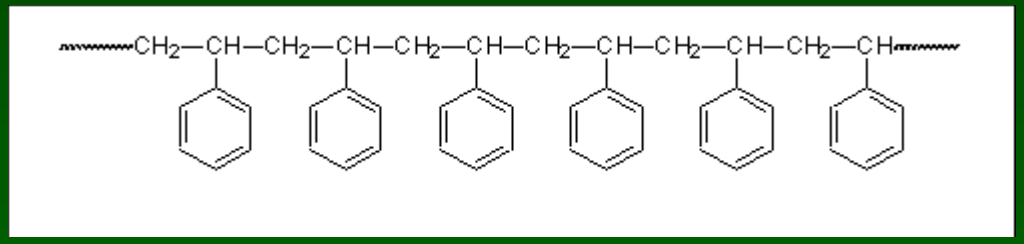
- **Sticky detection is incredibly difficult**
  - **Must detect the particles and also make sure they are tacky**
  - **Low concentrations of stickies**
  - **Intermittent concentration of stickies**
  - **Sometimes the stickies exist, but are in a pacified state and might not be detectable**
  - **Statistical significance often impossible**
  - **Testing methods tedious**

How to detect a sticky?

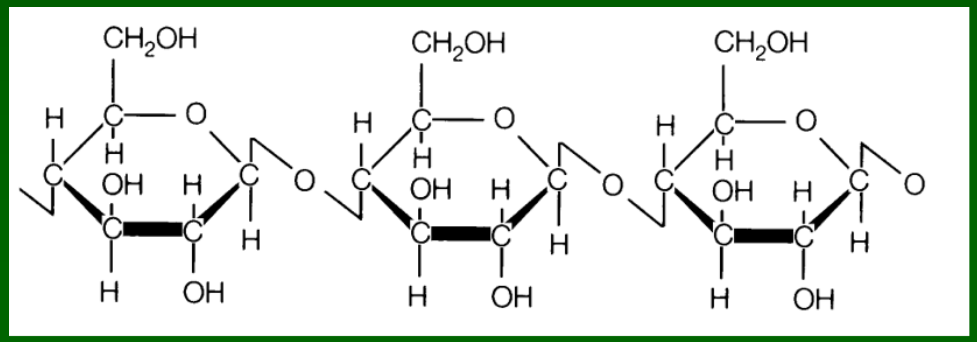
- **Stickies: typically a synthetic polymer (hydrophobic)**
- **Papermaking Fiber Furnish: Lignocellulosic materials (hydrophillic)**
  - **Hydrophobicity**
  - **May be dyed differently a different color**
  - **Screening plus…..**
  - **Deposition on a surface**
  - **Melt versus decompose**
  - **Tack**
  - **Solubility in organic solvents**
  - **Others**

How to detect a sticky?

- **Stickies: typically a synthetic polymer (hydrophobic)**
- **Papermaking Fiber Furnish: Lignocellulosic materials (hydrophillic)**



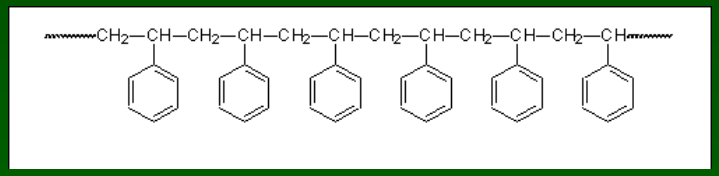
Poly(styrene)



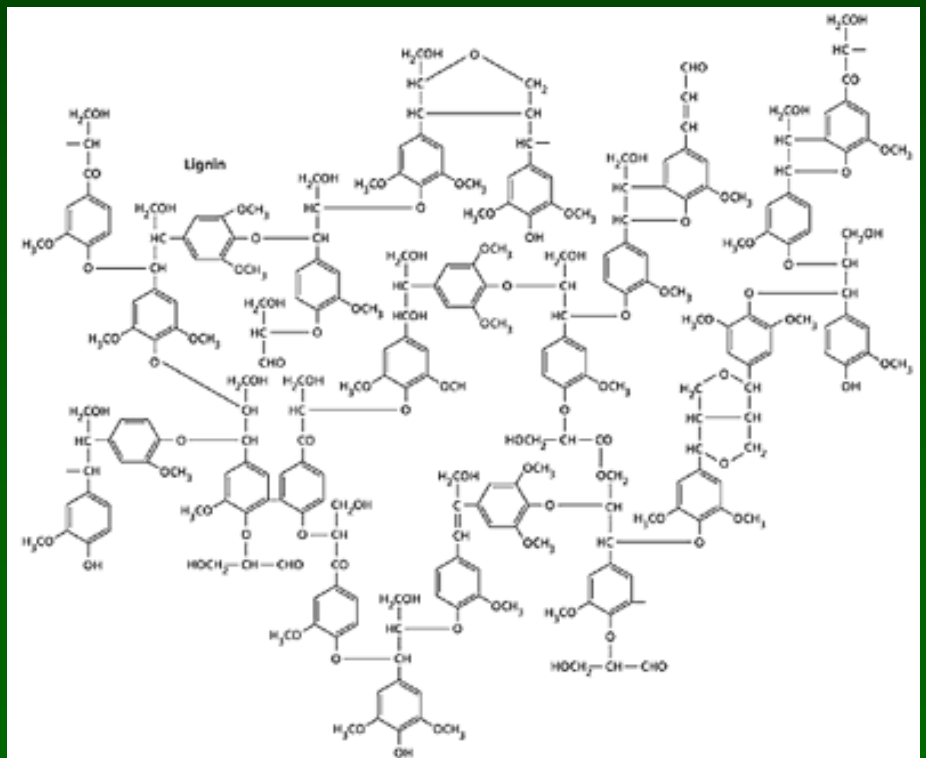
Cellulose

How to detect a sticky?

- **Stickies: typically a synthetic polymer (hydrophobic)**
- **Papermaking Fiber Furnish: Lignocellulosic materials (hydrophillic)**



Poly(styrene)

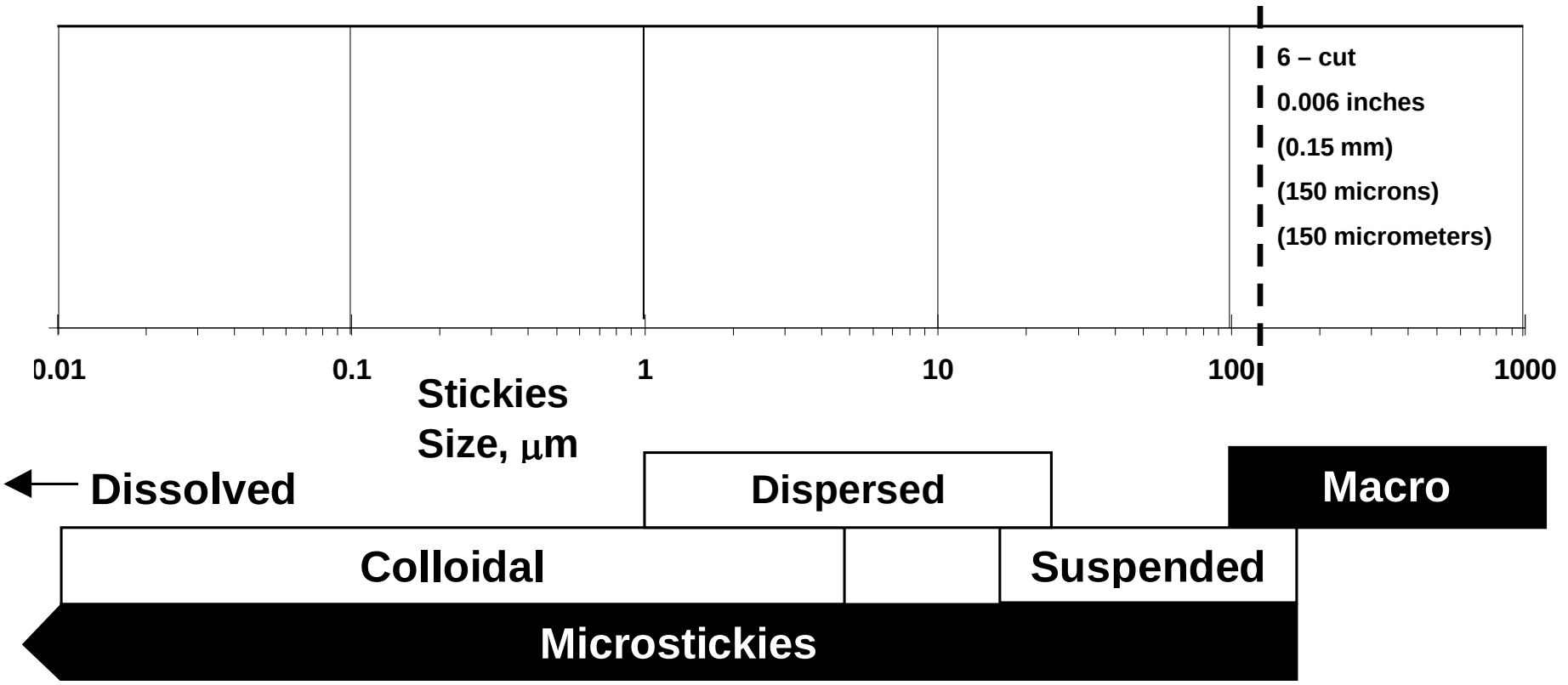


Lignin

Categories of Methods for Stickies Detection

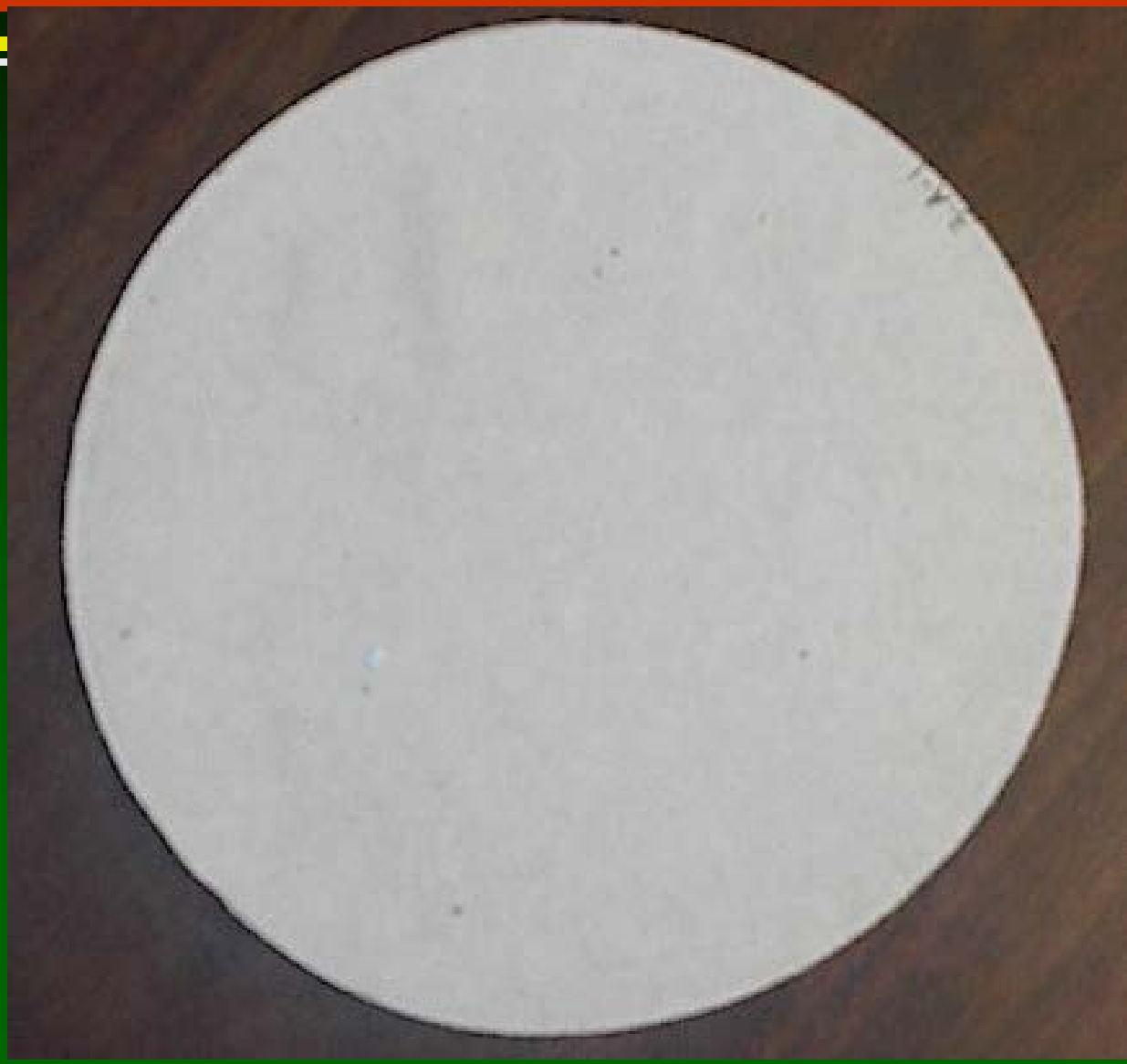
- **Macro (large) stickies methods**
- **Micro (small) stickies methods**
- **Dissolved and colloidal methods**

Stickies Size Classifications:



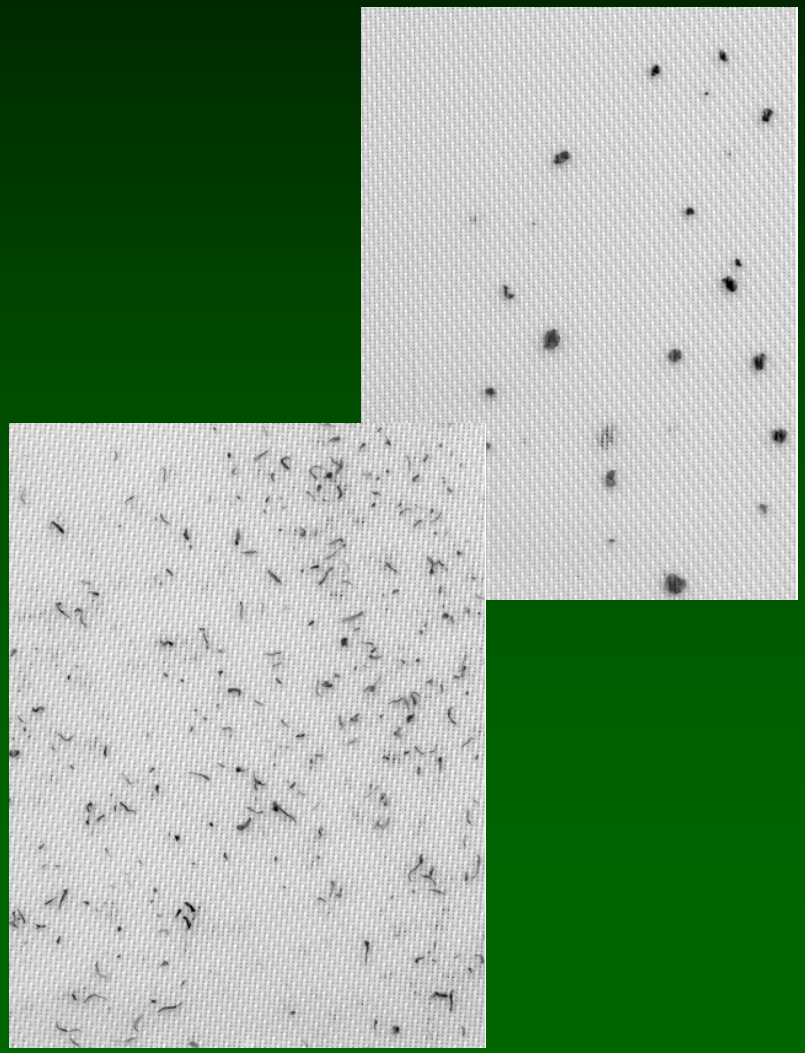
Macro-stickies Detection Methods Studied

- **Bleaching and dyeing**
  - Bleach with Chlorite and make Handsheets
  - Perform Image Analysis
  - Dye with Morplas Blue
  - Perform Image Analysis

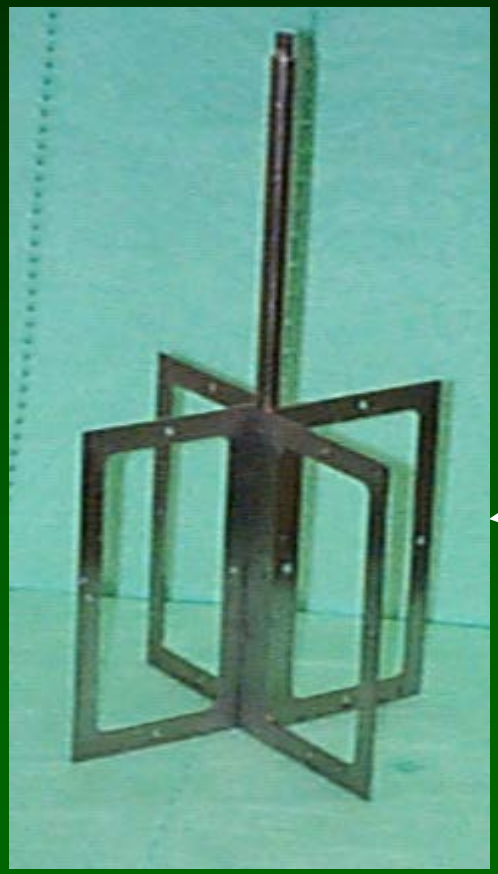


Macro-stickies Detection Methods Studied

- **Deposition:**
  - Low Consistency pulp slurry exposed to counter rotating paper machine wires
  - Determine Gravimetrically the Deposits
  - Dye deposits and perform Image analysis



Stickies Deposition Tester



Motor

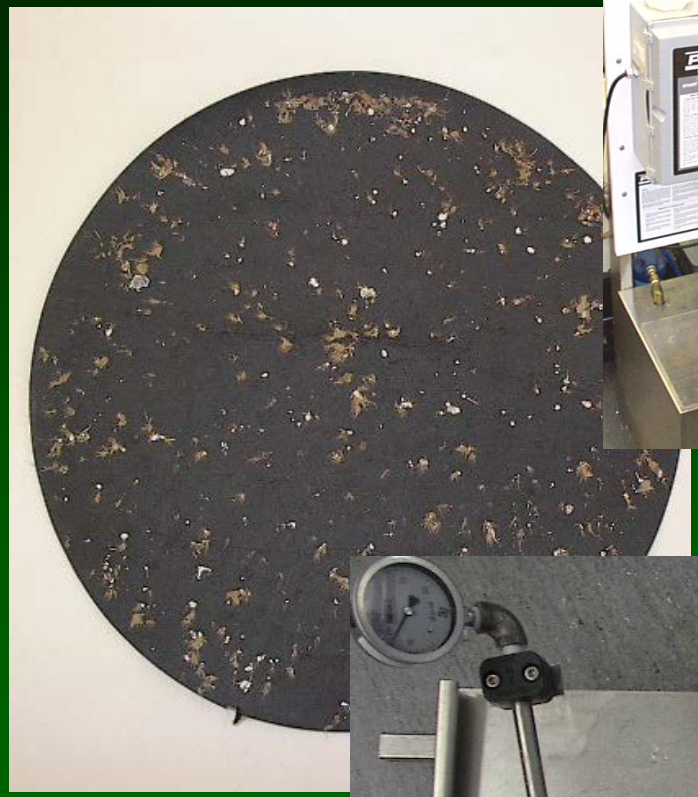
Gears

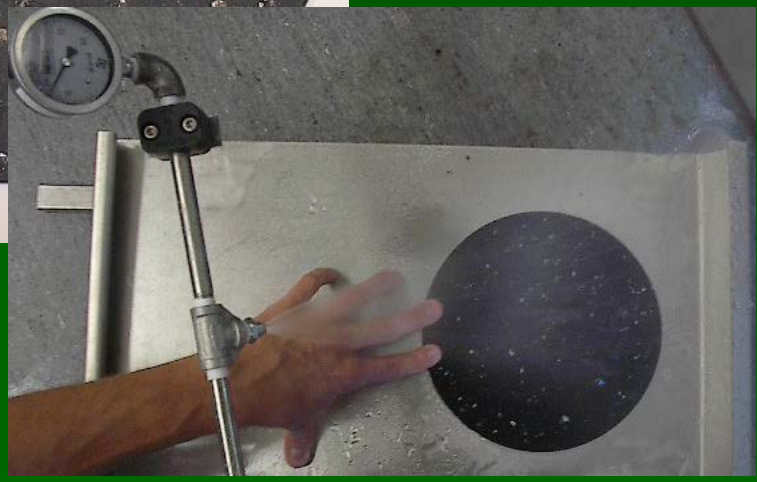
Paddle

Water Bath

Macro-stickies Detection Methods

- **Tappi Test Method T-277:**
  - Screen pulp with Pulmac Masterscreen (0.006 inch slots)
  - Collect rejects on black filter paper
  - Press against white coated paper : adhesives pick-up white coating
  - Use black marker to darken brown fiber
  - Image Analysis





Macro-stickies Detection Methods

- **Port Townsend Method 1: Handsheets (Steve Nordwell)**
  - Make Handsheets
  - Dye with black ink, stickies do not pick-up ink
  - Perform Image Analysis

Macro-stickies Detection Methods

- **Port Townsend Method 2: Screening**
  - Screen pulp with Pulmac Masterscreen (0.006 inch slots)
  - Dye rejects with black ink, stickies do not pick-up ink
  - Perform Image Analysis

Effort Required for Test Methods

Macro-stickies Test Methods:	Effort Needed:
Bleaching and Dyeing Method	4 hrs
Deposition Testing	
– gravimetric	2 hrs
– image analysis	3 hrs
Tappi T277 pm-99	1.5 hrs
Port Townsend 1: Handsheets	1.5 hrs
Port Townsend 2: Screening	2 hrs

Summary of Macro-Stickies Tests

Weyerhaeuser Mill Samples			
	Avg. 95%CI	SPAN	100%* Avg CI / SPAN
Bleaching and Dyeing	3900	1330	300
PT Method 1	6060	5800	104
PT Method 2	8920	17360	52
T277	12540	7690	164
Inland Mill Samples			
Bleaching and Dyeing	1720	100	1710
PT Method 1	1940	3830	50
PT Method 2	5100	21000	24
T277	21930	128330	17

OTHER MACROSTICKIES QUANTIFICATION

- Fluorescent Speck Counting Method
- Sulzer Escher Wyss Method
- Southeast Paper Method
- Dye Method
- Manual Method

Manual Method

- Screen 100 g stock through 6-cut (0.150 mm) slotted screen Collect rejects on filter paper
- Dry and press against clean sheet, stickies transfer
- Manually probe under microscope with pin all spots
- Count sticky spots/100g pulp
- This is tedious but can be very dependable compared to other methods!!!

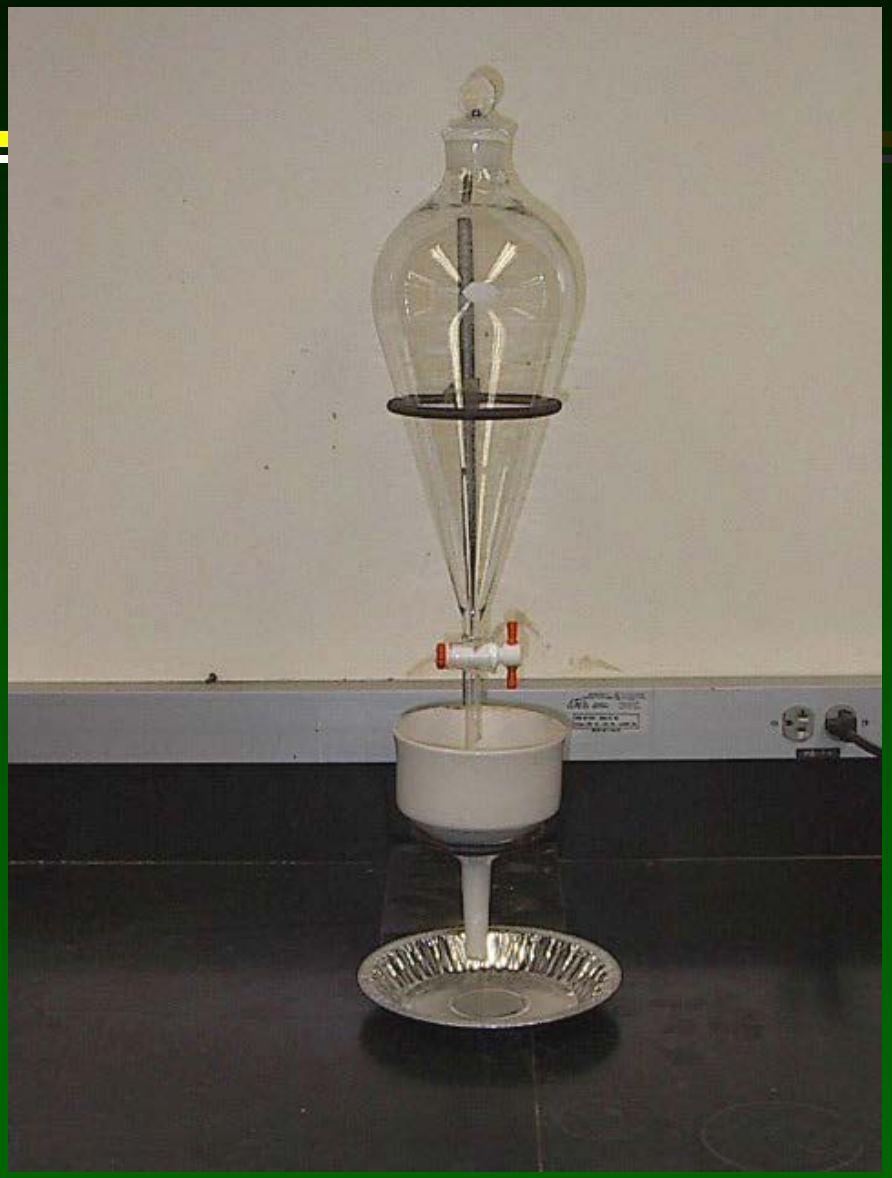
Micro-stickies Research Methods (Tests):

- Deposition: polyethylene bottle
- Deposition: polyethylene film
- Solvent Extraction (requires screening)
- Pulmac Macro and Micro method, United States Patent 7674355

PE Bottle Deposition Method

PE Film Deposition Method

Solvent Extraction



Method of measuring macro and micro stickies in a recycled sample containing pulp fibers United States Patent 7674355

- Screen the macrostickies with the Pulmac and weigh the macrostickies
- Retain the material that passed through the screen, agglomerating the micro stickies to form agglomerated micro stickies.
- Screen the agglomerated micro stickies.
- The agglomerated micro stickies are removed separation device and weighed.

Lecture

Manufacture of packaging grades
from recovered paper

Introduction

- Recovered paper began being used in packaging grades during WWI
- It was used more in fiber deficient countries like the UK
- differences between fiber deficient countries and fiber rich countries, like the USA and Canada

Table 8.1 Wastepaper use in the production of packaging grades in the UK, in 1992

Grade	Total production (Mt)	Total wastepaper use (Mt)	Utilisation rate (%)
Corrugated case materials	1.381	1.510	109
Packaging board	0.670	0.461	41
Packaging papers	0.092	0.038	69
Total	2.143	2.009	94

Table 8.2 Wastepaper use in containerboard production, in the USA, in 1992

Grade	Total production (Mt)	Total wastepaper use (Mt)	Utilisation rate (%)
Containerboard	27.7	15.1	35

Technology of Paper Recycling, McKinney

Introduction

- The USA and Canada had considerable government pressure to increase recovered paper use due to the significant contribution of paper and board packaging to domestic and solid waste steams

Table 8.3 Contribution of fibrous packaging grades to solid wastes (% of total)

	Commercial waste	Domestic waste	Municipal solid waste
UK	13.9[a]	6.5[b]	–
USA [1]	19.2	7.7	13.5

[a]Average of surveys in City of London [2], City of Westminster [2] and West Midlands [3]
[b]Average of Mole Valley [4], Ealing [5] and Richmond [6] surveys.

Introduction: Packaging Grades from Recovered paper

- Components of corrugated containers – liner grades, jute or test liner, and waste-based corrugating medium.
  - In white-top liner grades the white layer can be deinked fiber from wood free wastepapers or bleached virgin fibers
- Solid board- called folding box-board, containerboard, and paper board.
  - Solid board grades may also have a white layer and may be coated as in white lined chipboard
- Packaging Papers – paper bags, wrapping papers, etc.

Introduction: Corrugated Containers

- Stiffness is the most important criterion for corrugating, which is why hardwood fibers are used
- The structure of combined board, medium, and liner is illustrated in Figure 8.1

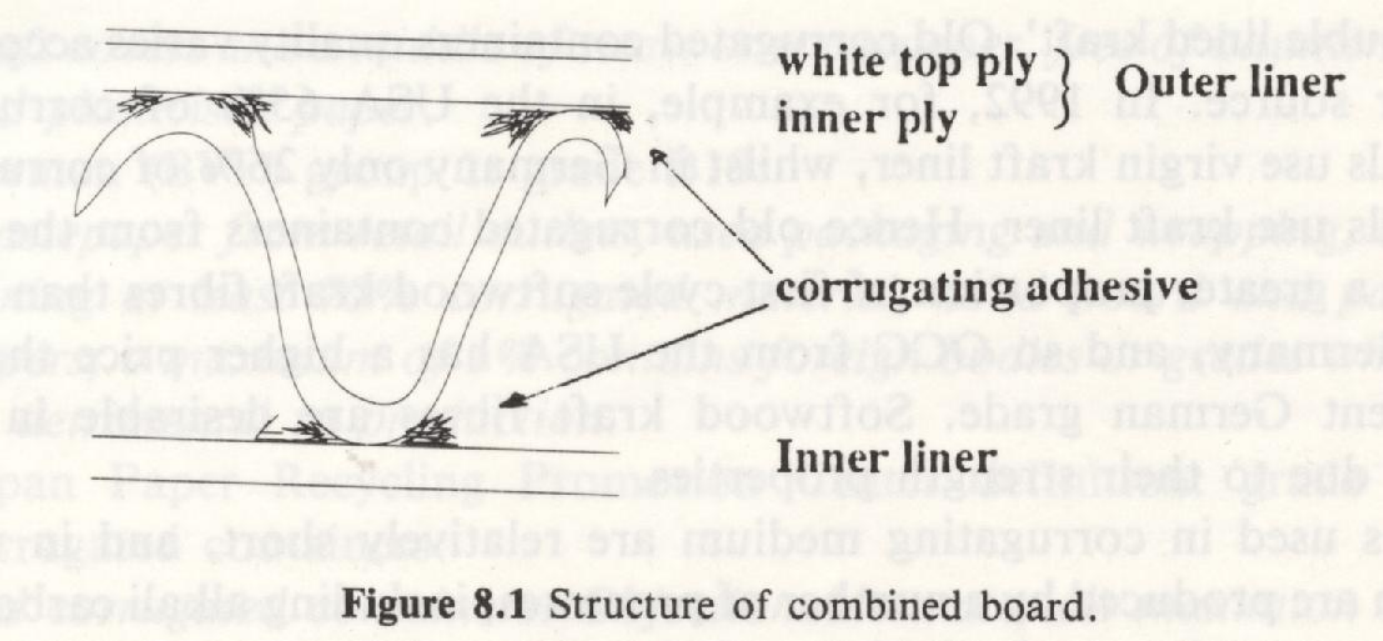


Figure 8.1 Structure of combined board.

Properties of Recycled Fiber Grades

- Corrugating medium or fluting
  - Medium is hidden: appearance not important
  - Mechanical properties and runnability issues on the corrugator are major performance criteria
  - Compressive strength is the single most important requirement for corrugated boxes, related to the edgewise compressive strength (ECT)
    - ECT is largely dependent on the compressive properties of the components of combined board (liners and corrugated fluting)
  - Various tests are used to measure properties related to strength and stiffness:
    - Concora medium test (CMT)
    - Ring crush test (RCT)
    - STFI (short span compression test, or index)
    - Edgewise compression test (ECT)

Introduction: Corrugated Containers

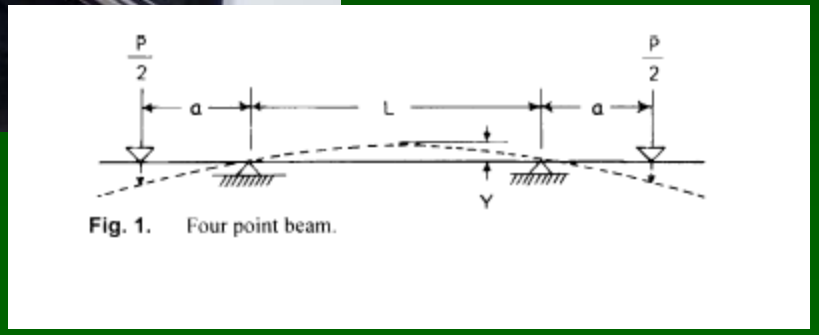
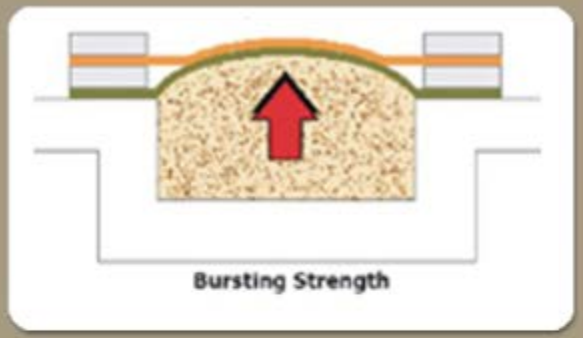


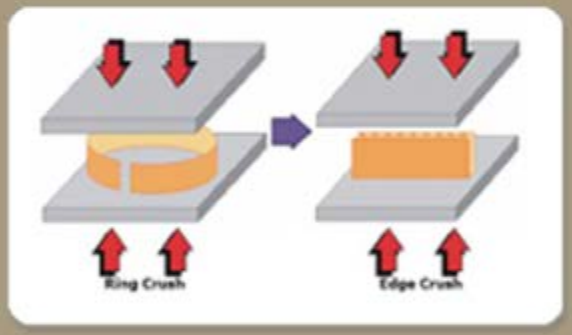
Fig. 1. Four point beam.

Technology of Paper Recycling, McKinney



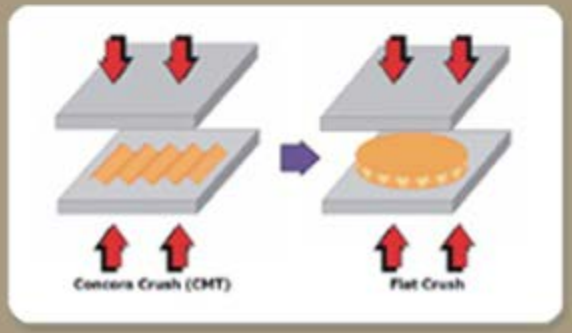
Bursting Strength :

The combined tensile strength and stretch of a material as measured by the ability of the material to resist rupture when pressure is applied under specified conditions to one of its sides by an instrument used for testing the property. Testing for the bursting stength of paper is a very common procedure, although its value in determining the potential permanence or durability of paper is suspect.



Ring Crush Test :

Ring Crush is a traditional test of linerboard and corrugating medium strength. Ring crush measures compression resistance, and this compression strength is considered to relate to the eventual compression strength of combined board made from the component. Linerboard called high strength or high performance linerboard is board that is able to achieve a specified minimum ring crush at basis weights that are lower than traditional basis weights.



Concora Crush Test :

The Concora Crush Tester performs a series of tests to determine the rigidity and crush resistance of corrugated material. It is used in conjunction with the Concora Liner Tester. The first test measures the flat crushing resistance of a laboratory-fluted corrugated material. The second test determines the edgewise strength, parallel to the flutes, of a short column of single-, double-, or triple-wall corrugated board. The third test evaluates the ability of corrugated material to contribute to the compression strength of a corrugated box by measuring the edgewise compression strength of a laboratory-fluted strip of corrugated material in a direction parallel to the fluted tips.

http://www.uccbox.com/page/standard_testing-eng.html

Recovered paper use in Liner Grades

- In virgin kraft liner production, filler fibers can be used, up to about 15-20%, without adversely affecting strength properties.
- Frequently, old news print (ONP) or similar grades are used, without deinking, though centrifugal cleaning and screening may be necessary to remove contaminants such as grit and stickies
- Up to 20% wastepaper use still permits the linerboard to be classified as virgin liner board in the USA
- Test, jute, or bogus liner is usually made from 100% waste, but from grades which contain some softwood kraft fibers

Recovered paper use in Liner Grades

- White top liner can be produced from 100% wastepaper.
  - The white ply is made from deinked woodfree grades made to have a clean, bright layer with good printing properties
  - Because the top ply needs to be so clean, there must be two separate fiber prep systems, including water, although backwater from the white prep may feed to the brown prep, but not vice versa.

Introduction: Folding Box-Board Grade

- Heavyweight grades of solid board are normally produced on multi-ply machines

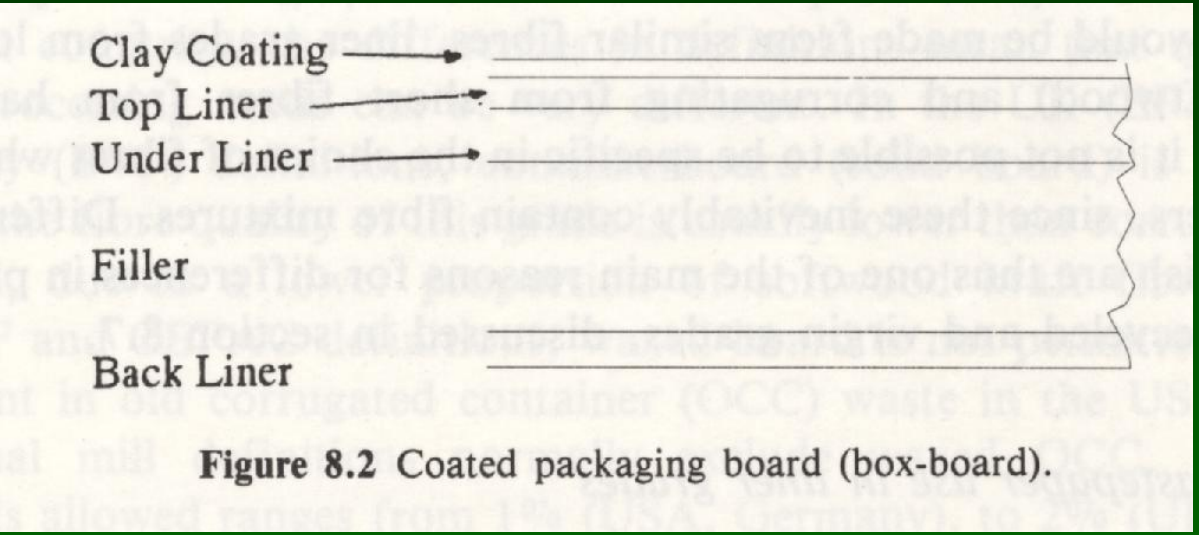


Figure 8.2 Coated packaging board (box-board).

Recovered paper use in Folding Box-Board Grade

- This grade has be to stiff, able to fold and scores, and usually has to have good printing properties
- Short fibers enhance stiffness but long fibers give strength and runnability properties
- Short fibers in the top ply provide good printing properties, which are improved by coating

Recovered paper use in Folding Box-Board Grade

- Inner or filler plies tend to be produced from low-quality grades while outer plies (top liner and back liner) are made from higher quality grades
- If white-top or coated board is produced, a news ply can be added between the white top and the brown grade, called the under liner ply, to reduce the weight of the white ply needed to cover the brown

Machine Runnability with Recycled Grades

- Major problem is stickies
  - contamination of board machine clothing,
  - holes and tears in the product and
  - contamination of printing blankets
- Another runnability problem is the slower drainage of recycled fibers
  - the concentration of fines higher for recycled than virgin
  - Must take a reduction in yield to remove fines
  - Since board grades have very high basis weights, drainage limitations can considerably reduce machine productivity

Machine Runnability with Recycled Grades

- Box-board
  - Machine configurations are similar for virgin or recycled grades but vary appreciably according to the type of product
  - White lined chip and box-board machines usually use vat formers
    - A major disadvantage of the vat former with respect to recycled-fiber grades is a problem with poor ply bonding
    - Fines help form strong ply bonds
    - Fines from recycled pulp are inert and do not form inter-fiber bonds, thus acting as a hindrance to good ply bonding
    - Inert fines removal reduces yield, but helps improve ply bonding

Machine Runnability with Recycled Grades

- Liner board and medium
  - Liner board machines are fourdriniers
  - Newer machines tend to produce two (or more) ply liner, which is achieved by the use of , for example, a secondary headbox, two wires, or a multilayer headbox
  - Twin wire gap formers are being used due to their potential for higher speed operation and good formation, among other things

Effect of the Use of Recycled Fibers on Product Properties

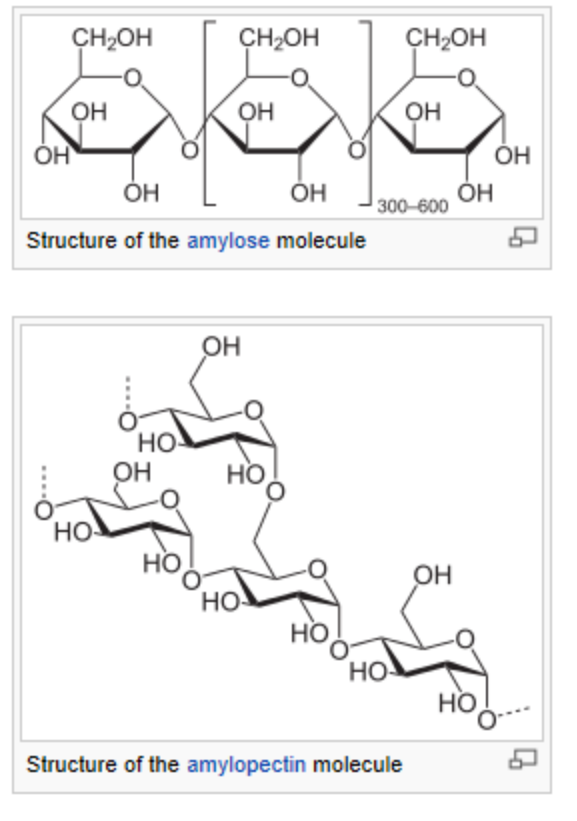
- **When recycled fibers are used, it is inevitable that strengths are lower, since inter-fiber bonding is reduced by a combination of mechanisms, including:**
  - fines build-up that don't bond well and interfere with fiber-fiber bonding
  - Hornification of the cell wall, stiff fibers, preventing bonding
  - Hornification at the surface of the fiber, which increases stiffness, less inter-fiber bonds will be formed
  - Non-fibrous contaminants accumulate – clay, ink particles, stickies, etc.
    - Prevent inter-fiber bond formation
    - result in localized weak points in the sheet, leading to erratic sheet properties
  - Some multivalent cations and salts may bond to carboxyl groups of fibers, preventing inter-fiber bond formation
  - Due to freeness considerations, recycled fibers may not be refined to their full strength potential

Effect of the Use of Recycled Fibers on Product Properties

- There is a constant compromise between cleanliness, yield of wastepaper, and strength development
- Other means to improve strength properties are:
  - Increased basis weight to give equivalent performance to virgin grades
  - Use of strength aids, such as starch, which is very widely used in Europe, but less so in the USA
  - Use of higher grades of fiber,

Effect of the Use of Recycled Fibers on Product Properties

- Starch use in recycled papers
  - Starch is the most important dry strength additive used in brown grades, and can be >5% of the final sheet weight, excluding starch used as a corrugating adhesive.
  - Starch improves inter-fiber bonding through adsorption and the creation of new bonding sites on fiber surfaces, with stronger than original fiber-to-fiber bonds
  - Despite the disadvantages, starch is widely used since it provides a low-cost method by which recycled grades can reach necessary strength properties
  - Starch addition also improves surface strength, pick resistance, and inter-ply bonding.



Effect of the Use of Recycled Fibers on Product Properties

- Starch use in recycled grades
  - Several disadvantages:
    - Addition increasing drying requirements,
      - especially via a size press, which can reduce machine speed, given a fixed drying capacity
    - Organic strength of effluents is much higher
    - Machines tend to run ‘dirtier’
    - Must make up and store properly or else use is inefficient and performance variable
    - Dependent on the type of starch used, control of wet end chemistry can become more difficult
    - Internal sizing can be impaired, together with formation

Improving the Properties of Recycled Fiber Grades

- Solid fiberboard, box-board
  - Finished boxes must have stacking strength, to avoid collapse or excessive bulge, and are frequently printed, so that the appearance and printability may be as important as protection
  - Stiffness is the most important mechanical property
  - Stiffness can be increased
    - with refining, which improves fiber bonding
    - with the use of starch or other chemical additives

Improving the Properties of Recycled Fiber Grades

- Solid fiberboard, box-board
  - Strong surfaces are needed with the ability to accept high printing and converting speeds
    - – Smoothness can be achieved by calendering, but it also reduces caliper, which decreases stiffness and compressive strength
  - A specky top ply is unattractive and difficult to print on
    - – Tools to improve appearance
      - Recovered paper type for top ply
      - Contamaninant removal system
      - Separation of stock and water for top ply
      - Good machine cleanliness

Improving the Properties of Recycled Fiber Grades

- Corrugating medium or fluting
  - To improve strength or stiffness the options are
    - to use starch, normally applied at the size press,
    - or to increase wet pressing, making a more dense sheet
  - Where starch is used to improve strength, porosity is an indicator of starch uptake
    - If the porosity is low, it may not be able to absorb sufficient starch
  - Starch viscosity can also be changed to improve starch absorption, but reducing viscosity may mean reducing machine speeds

Improving the Properties of Recycled Fiber Grades

- Liner board, test liner
  - Due to its lower strength properties, but lower cost, test liners were first used as the inner liner, to give cost savings in box production.
  - Since then, developments have allowed test liner to substitute for kraft over a much wider range of applications
    - Techniques which have been adopted to improve mechanical properties of test liner include:
      - Starch or other chemical additives or treatment
      - Increased basis weight
      - Increased mechanical pressing
      - Wastepaper processing techniques, such as fractionation
      - Wastepaper grade selection

Lecture

Manufacture of newsprint from recovered paper

Introduction

- Historically, the majority of newsprint producers who used recycled fibers were in the fiber limited regions
  - Fiber limitations, in regions such as the Far East and western Europe, will continue to contribute to the growth of recycled fibers in newsprint production
  - However, other factors, such as legislative requirements, strict energy usage requirements, and technological advances in both processing of wastepaper as well as paper making has resulted in sustained use of recycled fibers in newsprint

Recovered Grades Used

- Old newspapers (ONP)
  - Generally speaking, ONP has a high percentage of mechanical fiber, groundwood, or thermochemical pulp
    - Chemical pulp (kraft or sulphite pulp) can be as much as 30% by weight of the furnish
  - ONP includes additives such as starch, inorganic fillers and dyes for color control
    - ONP is relatively low in these additives, with ash ranging from 3-12 wt%
  - Ink makes up 1-2 wt% of the ONP furnish

Recovered Grades Used

- Magazine: A generic term which generally refers to coated paper that is bound with stables or glue
  - Highly variable raw material
    - Fiber content can range from 100% kraft pulp to 100% groundwood
    - An individual magazine may have several different grades of paper included in its production
    - In addition to fiber variablility, the additives are also highly variable
      - In magazine stock, the inorganic portion of the furnish can range from 10 wt% in the uncoated sheets to as high as 50 wt% in a sheet coated on both sides
    - Contaminants associated with magazine grades are introducted in the converting process
      - Adhesives associated with bindings, thermal plastics, and hot melts can all contribute to stickies
      - Ink printed on coated paper can present a removal challege in the deinking stages
        - Ink can range from 1-7 wt%

Recycled Fiber Processing

- Process flow sheets
  - Deinking technology varies for different reasons including quality requirements, resource availability, wastepaper characteristics, per cent of recycled fiber in furnish, and environmental regulations

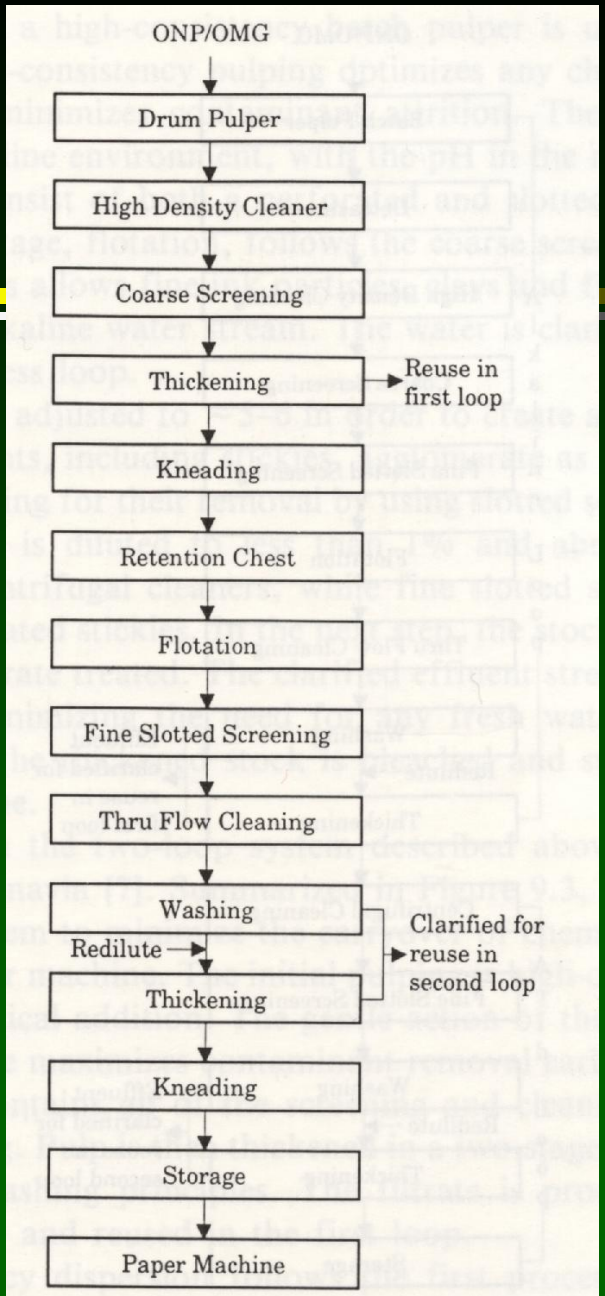


Figure 9.1 Asian deink process flow sheet.

Quality and Performance of Recycled Newsprint

- In general terms newsprint produced from recycled fibers relative to virgin newsprint has
  - a higher density,
  - lower caliper,
  - is more absorbent
  - has a lower coefficient of friction
  - Has a potentially better smoothness and porosity,
  - Strength properties are generally equivalent
  - Optical properties, such as scattering coefficient and opacity are generally improved
  - Brightness tends to be lower and shade variability increases
  -

Quality and Performance of Recycled Newsprint

- Pulp from deinking operations uses slightly more raw material and significantly less electricity
- Variable manufacturing costs excluding raw materials and energy are larger for the deinked pulp

ADMT = air dry metric tonnes

Table 9.4 Comparison of units of consumption for virgin and recycled fibres

		Unit/ADMT[a] finished pulp	
Variable	Unit	TMP	Deink
Raw material	ADMT	1.042	1.176
Energy			
Electricity	kWh	2200	600
Steam	MJ	1.00	1.00

[a] ADMT, air dry metric tonnes

Table 9.5 Comparison variable manufacturing costs for virgin and recycled fibres

		$/ADMT[a] finished pulp	
Variable	Unit	TMP	Deink
Labour (fully loaded)	$25/effort hour		
Pulp process		9.00	10.25
Maintenance		2.25	1.75
Chemicals	$/ADMT	10.00	25.00
Supplies	$/ADMT		
Pulp process		3.00	3.00
Maintenance		5.50	2.50
Miscellaneous operating expense	$/ADMT	15.00	10.00
Overhead	$/ADMT	5.00	5.00
Solid-waste disposal	$/ADMT	0	8.75
Total (excluding raw material and energy)		49.75	66.25

[a] ADMT, air dry metric tonnes

Quality and Performance of Recycled Newsprint

- Overall variable cost of deinked pulp versus virgin pulp is lower in general
  - a constant wood chip price of $75/ADMT.
  - Case 1: low wastepaper cost - $50/ADMT
    low energy cost - $0.02/kWh
  - Case 2: high wastepaper cost - $100/ADMT high energy cost - $0.05/kWh
  - Case 3: low wastepaper cost - $50/ADMT
    high energy cost - $0.05/kWh
  - Case 4: high wastepaper cost - $100/ADMT
    low energy cost - $0.02/kWh

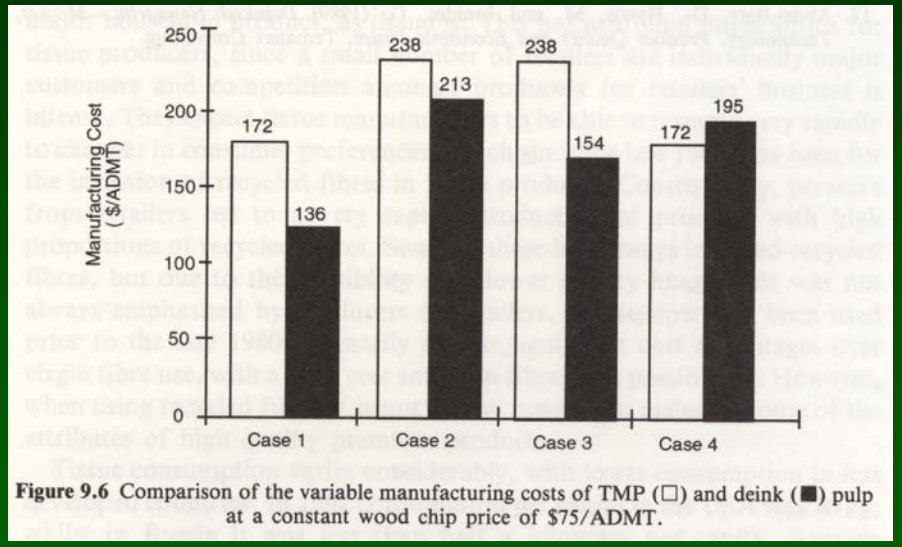


Figure 9.6 Comparison of the variable manufacturing costs of TMP (□) and deink (■) pulp at a constant wood chip price of $75/ADMT.

Technology of Paper Recycling, McKinney

Lecture

Manufacture of tissue from recovered paper

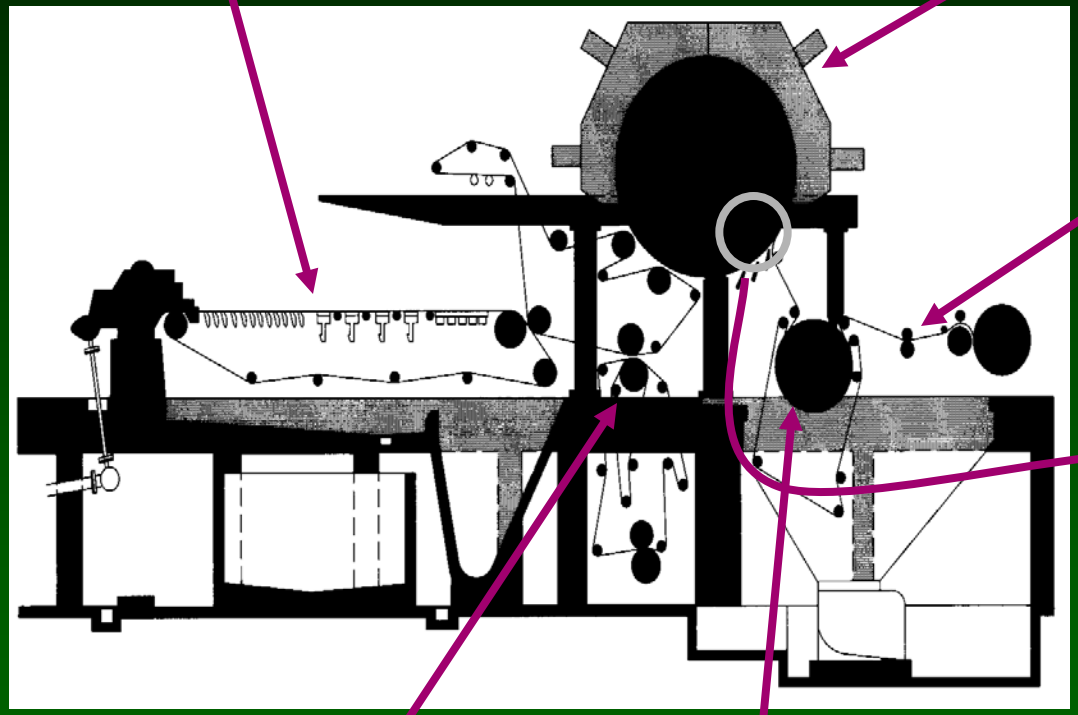
Introduction: Tissue

- Tissue is a light weight paper
- Can be made from virgin or recycled pulps
- Grammage can be as low as 5 g/m2
  - Reference: (copy paper is about 75 g/m2)
- Requirements
  - Strong
    - Product
    - Runnability
  - Absorbant
  - Soft
  - Clean

Tissue Machine

Fourdrinier

Yankee Dryer

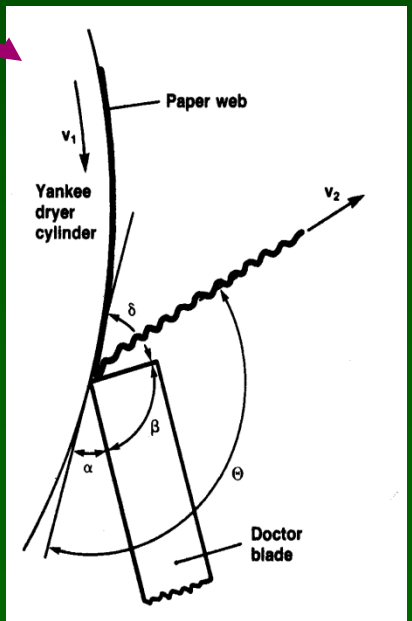


Calender

Wet Press

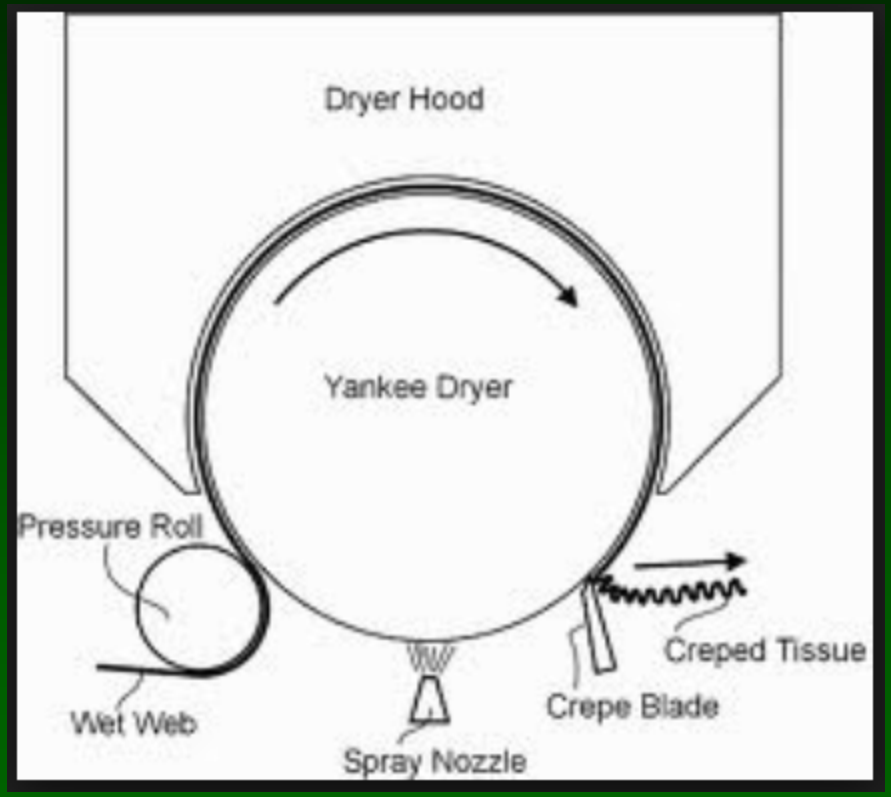
After Dryer

Detail of Creping Action

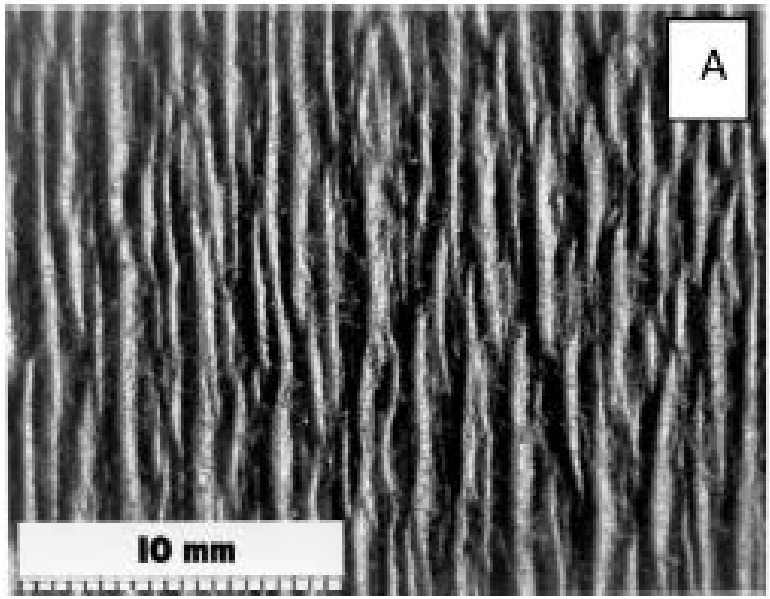


Introduction: Tissue

- Produced on a a single large steam heated drying cylinder (yankee dryer) fitted with a hot air hood.
- Creping is done by the yankee's *doctor blade* that is scraping the dry paper off the cylinder surface.



Introduction: Tissue



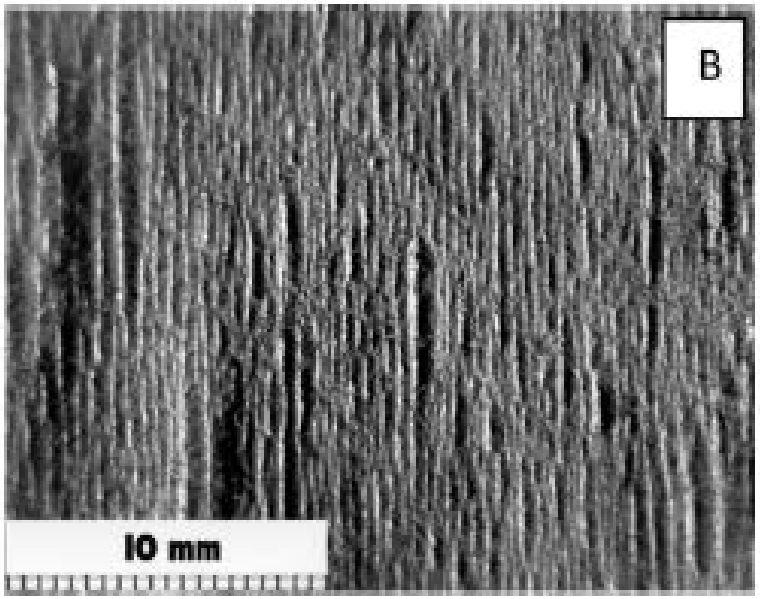


Fig. 3. Creped sheet of paper for a creping angle of (*A*) and (*B*), in which the creping direction is horizontal [2]

Creping

- Doctor blades are “consumables”.
- Wear rates can be high!
- The wear changes the contact geometry which can change performance during the run.
- Courtesy Joel Pawlak, NCSU

Introduction: Tissue

- Tissue is unique in the pulp and paper industry in that the product which leaves an integrated converting facility is ready for use by the final consumer
- Because of this, competition amongst producers for retailers' business is intense, and retailers respond very rapidly to changes in customer preferences
  - Example. Inclusion of recycled fibers

Introduction

- Recovered paper had been used prior to the late 1980s due to significant cost advantages over virgin fiber use
  - May be up to 50% less expensive
- When using recycled fiber, however, it is not always possible to maintain some attributes of high quality premium products

Grade Structure

- In the US about 30% is away from home grades (low quality) and 70% is at home
- This is a large growth sector of the paper industry
- The final product has a very high profit margin
  - Recovered paper $100/ton
  - Virgin pulp $600/ton
  - Finished tissue product $30,000/ton

Table 10.1 Typical wastepaper utilisation rates and grades used in toilet paper production

	USA		UK		Continental Europe	
	Wastepaper grades	(%)	Wastepaper grades	(%)	Wastepaper grades	(%)
Premium quality brands	White, unprinted	0–10	White ledger	0–50	Mixed printed[a]	50–100
Private label; quality	White ledger	0–40	White ledger	50–100	Mixed printed	50–100
Private label; budget	Mixed woodfree[b]	0–50	Mixed printed	0–100	Mixed, news magazines	50–100
Commercial and industrial	Mixed printed	100	Mixed printed	100	News and magazines	100

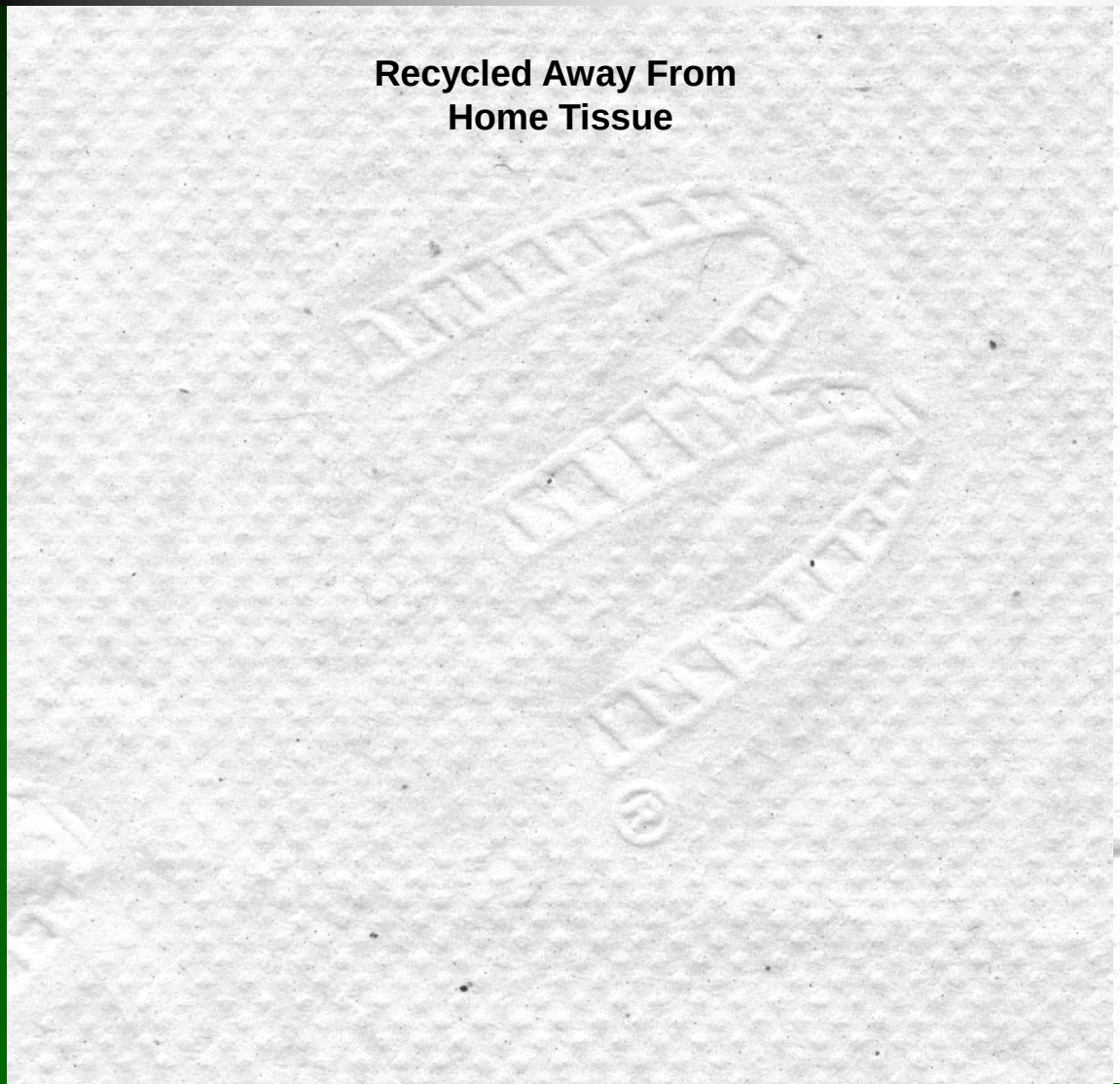
[a] Mixed printed – mixed woodfree and wood-containing. [b] Mixed woodfree – printed and coloured woodfree

Technology of Paper Recycling, McKinney

Grade Structure

- In the US about 30% is away from home grades (low quality)
- In the US about 70% is at home grades (high quality)

Recycled Away From Home Tissue



Virgin Premium Tissue

Grade Structure

- In the US about 30% is away from home grades (low quality)
- In the US about 70% is at home grades (high quality)

Recycled Away From Home Tissue

Virgin Premium Tissue

Specifications of recycled fiber for tissue production

- Some specs are related to product quality, others to tissue machine runnability, and some to both
- Low ash is required to protect the creping blade
- Some vary based on the type of product being produced
  - Premium quality tissue requires a minimum brightness of 75-80 ISO
  - Industrial toilet tissue requires a minimum brightness of 60-70 ISO

Table 10.4 Quality criteria for recycled bathroom tissue production

Quality parameter	Typical range	
	Woodfree, high quality	Wood-containing, budget
Ash (%)	1–3	3–6
Brightness (ISO)	75–80	60–65
Ink/Dirt (Tappi ppm)	30–60	30–100
Stickies Content (#/100 g bdf)	10–50	10–50
Freeness (CSF, ml)	min. 350	min. 200
Burst strength (kPa m^2 g^{-1})	min. 2.5	min. 1.5
Tear index (mN m^2 g^{-1})	min. 7.0	min. 5.0
Breaking length (km)	min. 3.5	min. 3.0

Technology of Paper Recycling, McKinney

Amount of Rejects and Sludges for Production of Paper Grades

Produced paper	Recovered paper grade	Amount of total waste	Amount of waste [% by dry weight]			
			Rejects		Sludges	
		[% by dry weight]	Heavy-weight & coarse	Light-weight & fine	Flotation deinking	White water clarification
Graphic paper	News, magazines	15–20	1–2	3–5	8–13	2–5
	Superior grades	10–25	< 1	≤ 3	7–16	1–5
Hygienic paper	Files, office paper, ordinary, medium grades	28–40	1–2	3–5	8–13	15–25
Market DIP	Office paper	32–40	< 1	4–5	12–15	15–25
Liner, fluting	Sorted mixed recov. paper, supermarket waste	4–9	1–2	3–6	–	0–(1)
Board	Sorted mixed recov. paper, supermarket waste	4–9	1–2	3–6	–	0–(1)

Example tissue production process

- A schematic outline of a wastepaper processing system, to produce good quality fiber from medium and low-quality wastepaper grades
- A compromise between recycled fiber quality and fiber yield
- Must have low ash, causes low yield, see two significant washing processes

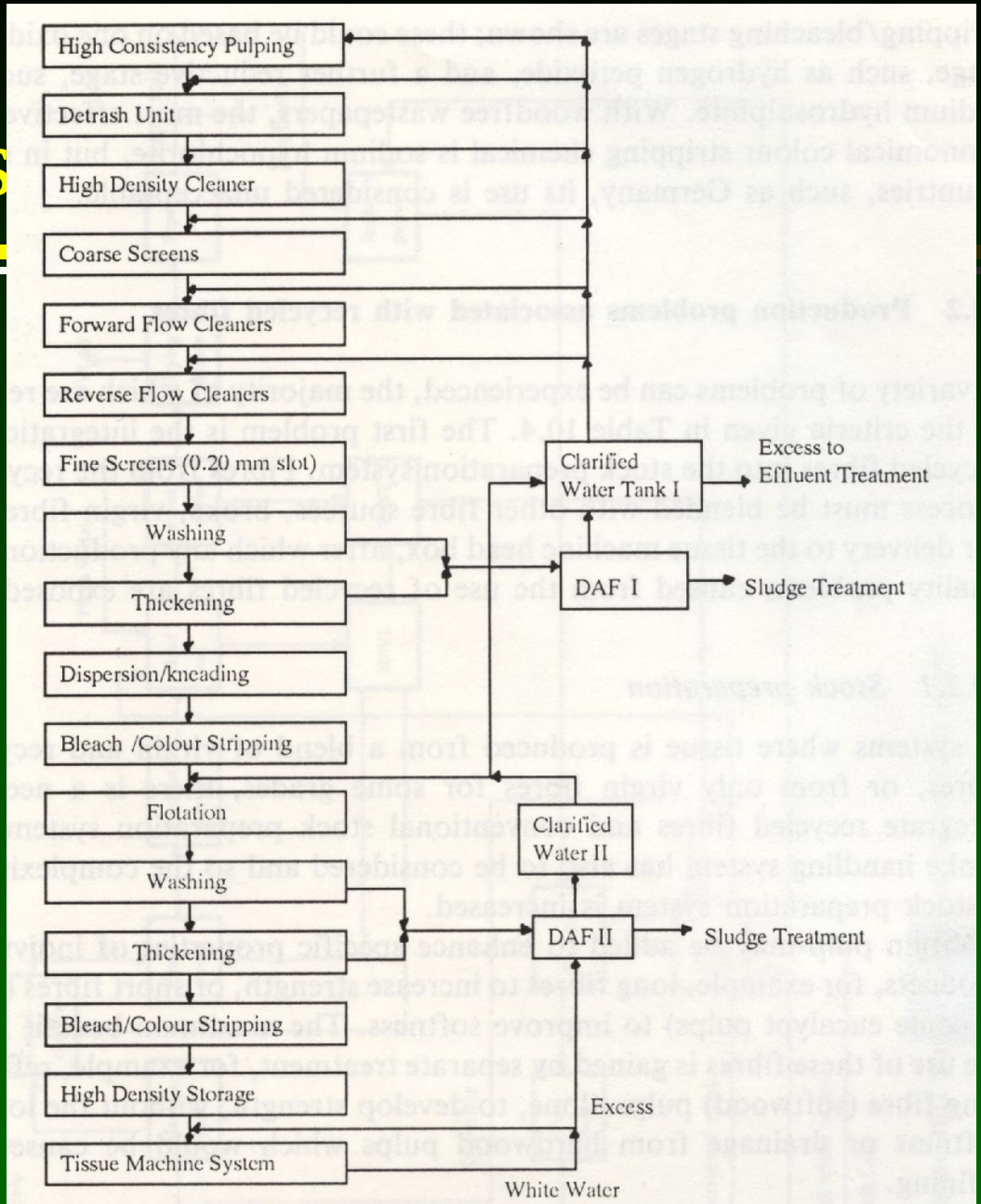


Figure 10.1 Schematic wastepaper processing system suitable for tissue.

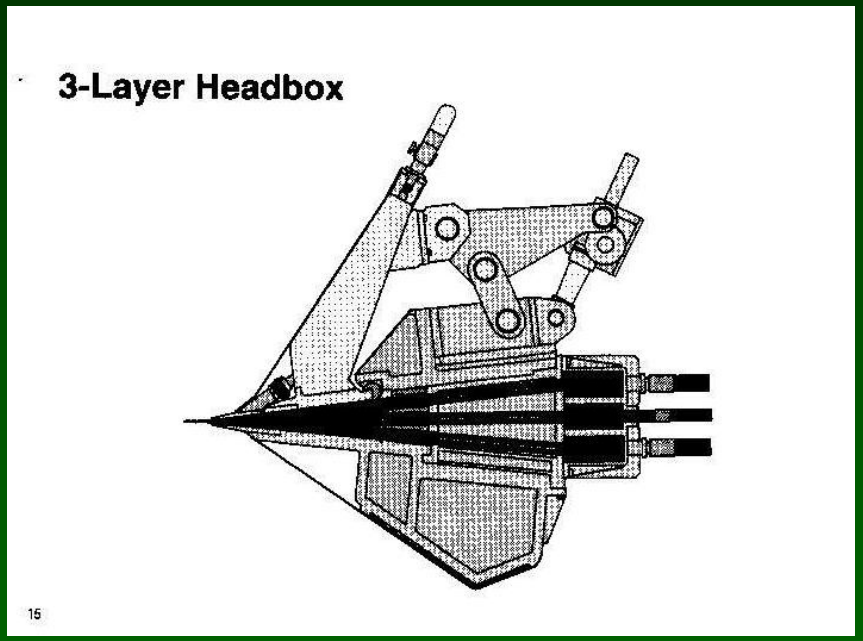
Technology of Paper Recycling, McKinney

Production Problems Associated with Recycled Fibers

- Issues arising from the use of recycled fibers:
  - Separate treatments of virgin and recycled fibers in stock prep
  - High Ash
  - Stickies
  - Cleanliness
  - Brightness

Production Problems Associated with Recycled Fibers

- Stock Prep
  - The use of a small amount of virgin pulp to mainly recycled pulp can improve strength (long fibers) or softness (short fibers)
  - To best exploit the virgin fibers separate stock prep lines must be used
  - Also a multi-layered headbox should be used
  - Adds extra equipment but better properties



Production Problems Associated with Recycled Fibers

- Stock Prep
  - a schematic of a single layered stock prep option

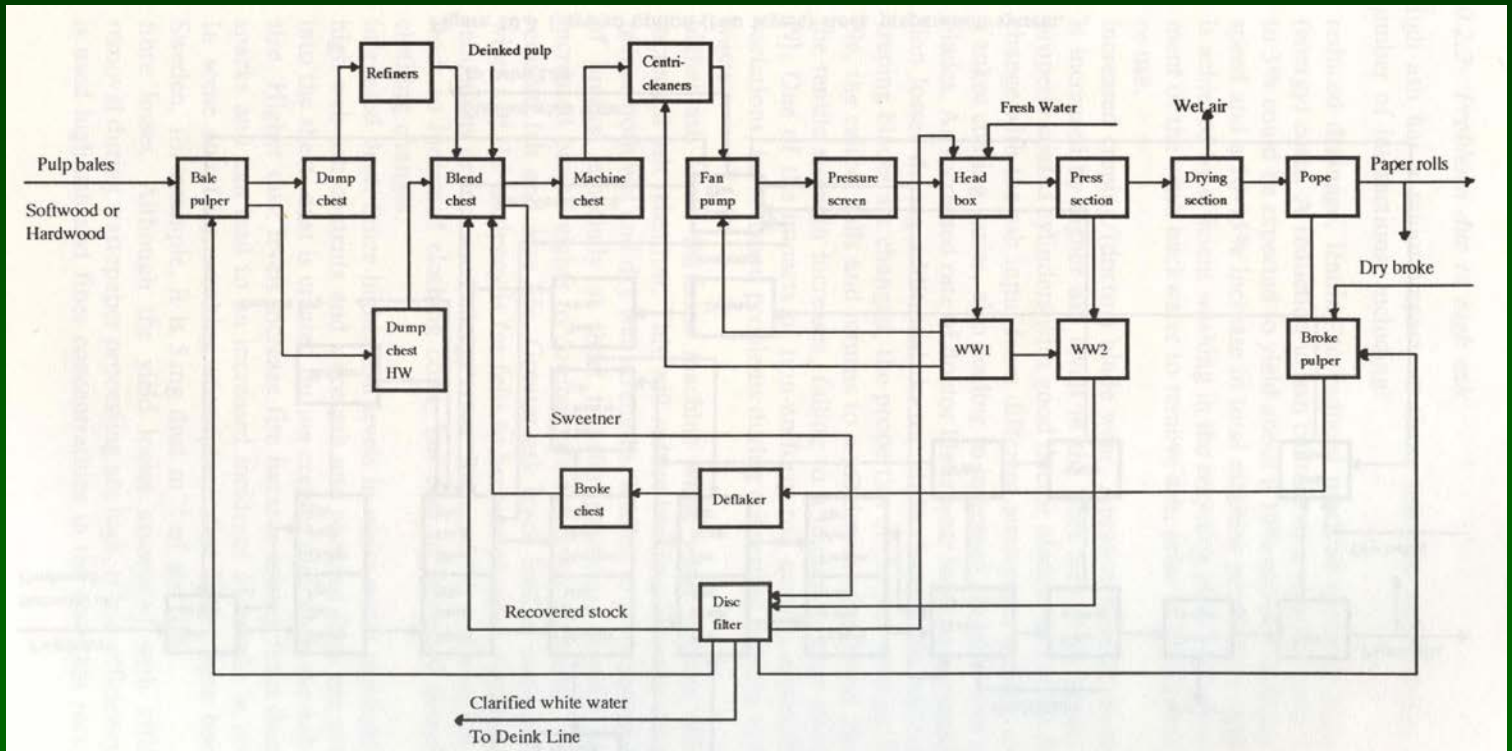


Figure 10.2 Single layer stock preparation system.

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Production Problems Associated with Recycled Fibers

- Stock Prep
  - a twin layered stock prep option

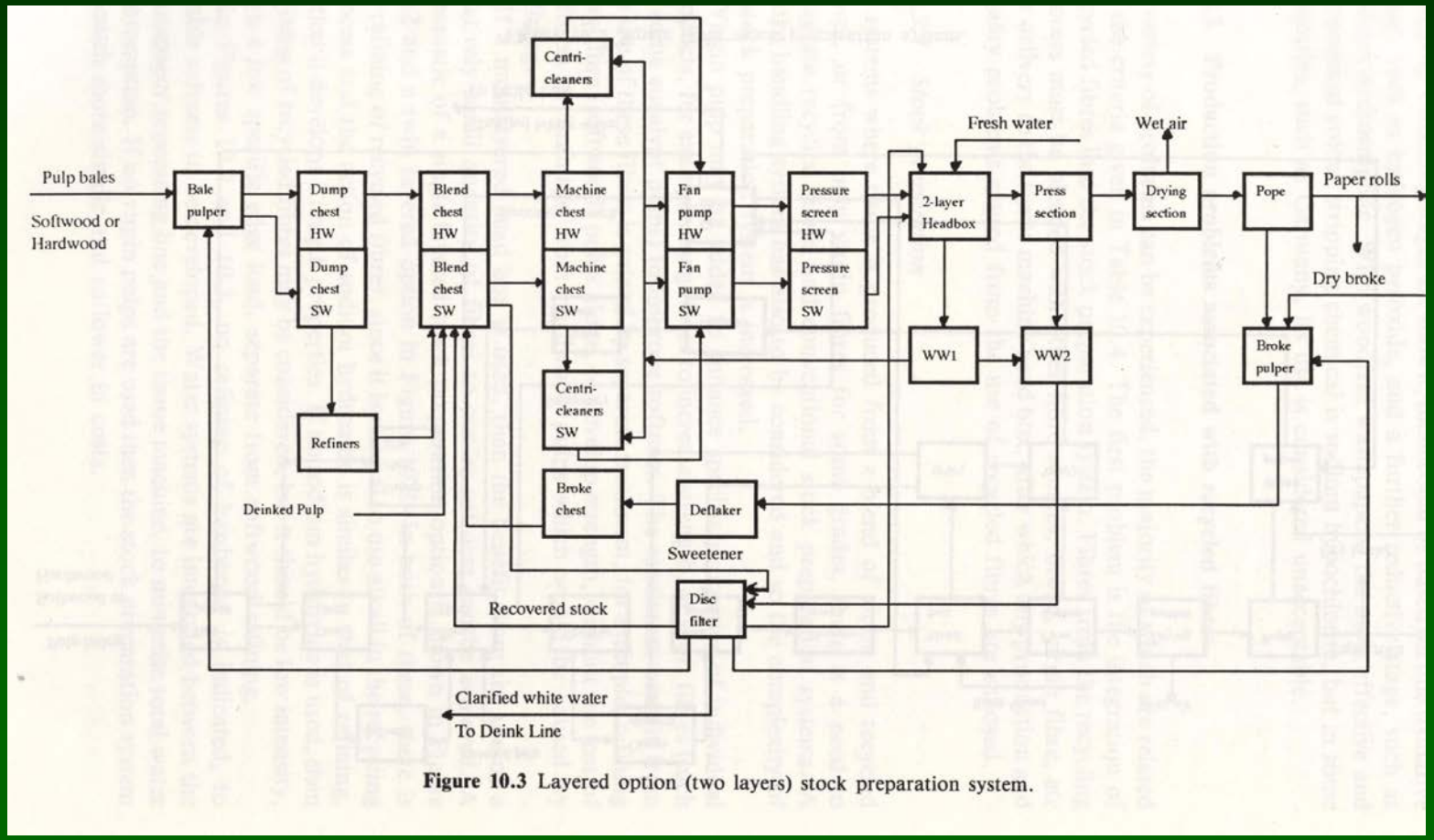

Figure 10.3 Layered option (two layers) stock preparation system.

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Production Problems Associated with Recycled Fibers

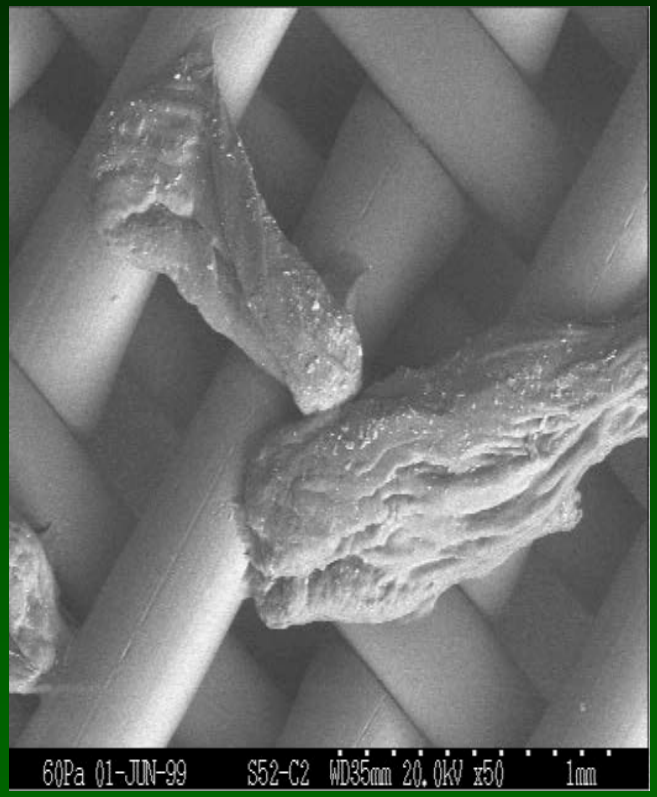
- Problems due to high ash
  - High ash has a major impact on tissue machine productivity, including:
    - Reduced drainage
    - Increased creping / doctor blade wear
    - Increased ash in white water system which leads to higher ash retention
    - Reduced felt and wire life
    - Increased dust

CERADIA 200

- **http://www.clouth-sprenger.com/creping_blades.html**

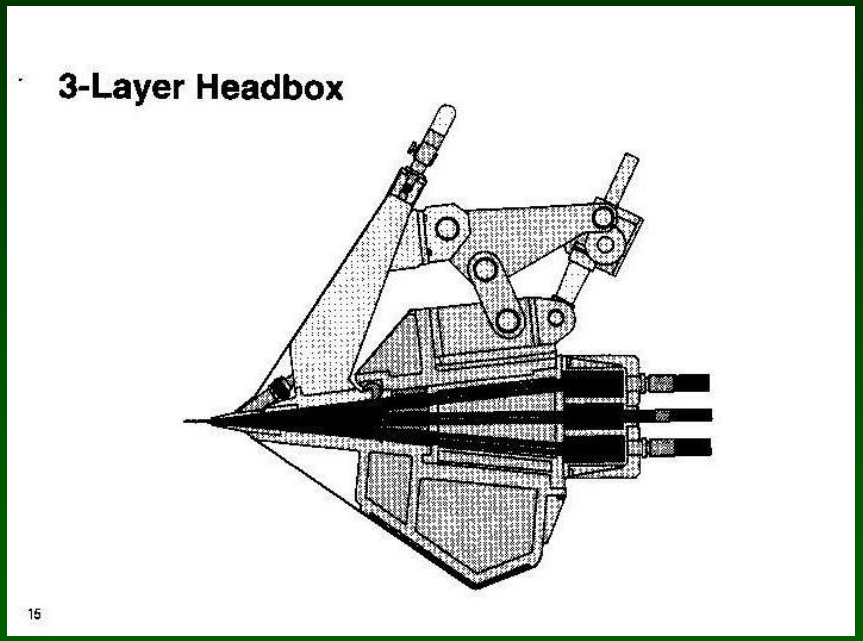
Production Problems Associated with Recycled Fibers

- Problems due to stickies
  - Stickies can affect productivity
    - Adhere to forming fabrics and press felts and can build up at doctor blades and on rolls, which tend to cause holes and breaks
    - Can reduce machine clothing life
    - Production losses due to machine downtimes to clean wires and felts
  - Stickies affect product quality
    - Unsightly dirt specks
    - Printing issues
  - Sticky removal is one of the most critical parts of recovered paper processing.



Effects of Recycled Fiber Use on Tissue Quality

- Effects on Softness
  - Fiber selection is important factor in developing softness
    - Need thin walled flexible fibers
    - Recycled fibers are stiff, not flexible
  - To try to subdue effects of recycled pulp fibers, multilayered headboxes can be used to “hide” recycled fibers between layers of virgin fibers



Effects of Recycled Fiber Use on Tissue Quality

- Effect on Appearance
  - Appearance is adversely affected by recycled fiber
    - Because ink removal is <100% efficient, specks are normally present
    - However, a large proportion of consumers have accepted the recycled signature of a specky product
    - Lower brightness

Lecture

Manufacture of printing and writing papers from recovered paper

Printing and Writing Grades

- Printing grades include a broad classification of paper products that have traditionally been referred to as ‘fine paper’
- The general classification of printing and writing papers is:
  - Uncoated groundwood grades
  - Coated groundwood grades
  - Uncoated free sheet grades **largest segment**
  - Coated free sheet grades
  - Specialty grades

Printing and Writing Grades

- The following grades can be commercially produced using printing and writing grades
  - Reprographic bond and writing
  - Ledger
  - Forms bond
  - Carbonless
  - Tablet
  - Envelope
  - Offset
  - Premium text and cover
  - Commercial printing
  - Book paper
  - Technical specialties

Recovered Paper Grades

- To make a commercial P&W product
  - Recovered paper must be chosen carefully
    - Wood vs wood-free recovered paper
    - Colored versus white paper
  - The processing system must be suitable to remove contaminants and produce paper with well defined optical and physical properties
  - The market must accept the properties of the paper

Properties of Recycled Fibers

- It is well known by now that chemically pulped and bleached recycled fibers demonstrate a noticeable loss in strength properties
  - So they are also assumed to be inferior, unpredictable, and unsuitable for the production of quality grades of printing and writing papers
  - This is not true considering the successful commercial production of printing and writing grades

Properties of Recycled Fibers

- Much information about running recycled paper has come from experience, one study concluded:
- Recycled paper can have a similar strength but at lower freeness than virgin fiber
- Intrinsic fiber strength is the same
- Similar tear strength
- Anionic trash and other contaminants can lower recycled strength
- Lower bonding capability also lowers recycled strength

Requirement for White Ledger, US Purchasing Guidelines

- Less than 1 % groundwood
- Lignin less than 3%
- pH greater than 6.5 for white paper
- Grammage: 90 g/m2
- Bursting strength: 21.75 psi
- Tear: 340 mN
- Thickness 0.105 mm
- Good erasing
- No feathering
- Brightness > 81 ISO
- No more than 1 speck, less than .025 mm2 per 650 cm2
- No more than 650 specks for 1 m2

- **Government Paper Specification Standards February 1999 No. 11**

Amount of Rejects and Sludges for Production of Paper Grades

Produced paper	Recovered paper grade	Amount of total waste	Amount of waste [% by dry weight]			
			Rejects		Sludges	
		[% by dry weight]	Heavy-weight & coarse	Light-weight & fine	Flotation deinking	White water clarification
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	Superior grades	10–25	< 1	≤ 3	7–16	1–5
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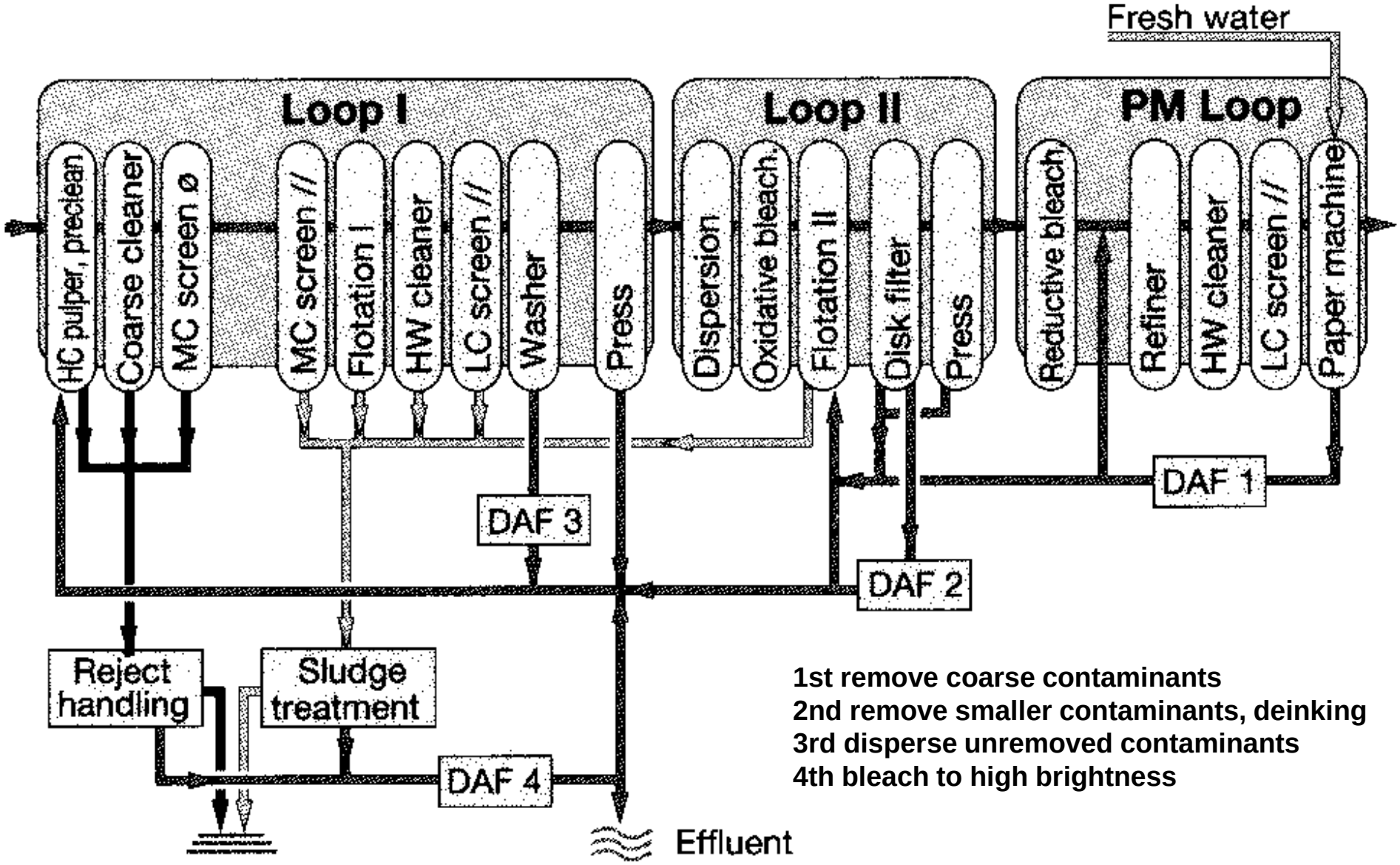
Market DIP	Office paper	32–40	< 1	4–5	12–15	15–25
Liner, fluting	Sorted mixed recov. paper, supermarket waste	4–9	1–2	3–6	–	0–(1)
Board	Sorted mixed recov. paper, supermarket waste	4–9	1–2	3–6	–	0–(1)

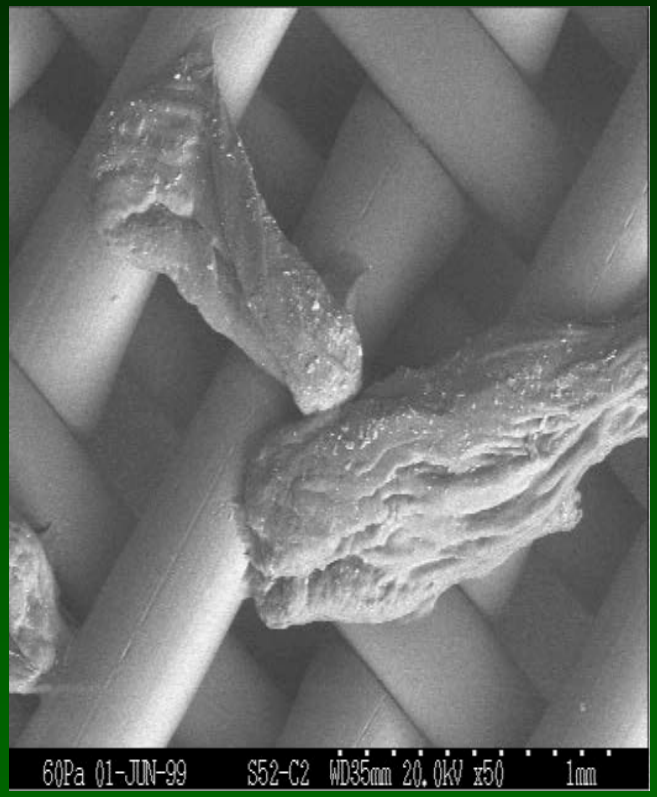
High Grade Printing and Writing Grades



1st remove coarse contaminants
2nd remove smaller contaminants, deinking
3rd disperse unremoved contaminants
4th bleach to high brightness

Production Problems Associated with Recycled Fibers in P& W

- Problems due to stickies
  - Stickies can affect productivity
    - Adhere to forming fabrics and press felts and can build up at doctor blades and on rolls, which tend to cause holes and breaks
    - Can reduce machine clothing life
    - Production losses due to machine downtimes to clean wires and felts
  - Stickies affect product quality
    - Unsightly dirt specks
    - Printing issues
  - Sticky removal is one of the most critical parts of recovered paper processing.



Production Problems Associated with Recycled Fibers in P& W

- Carryover of deinking chemicals
  - Foaming issues
- Problems due to anionic trash
- Lower chemical additive efficiency
- Increased deposits
- Changes in fiber chemistry
- Reduced bonding
- Strength reduction and paper machine breaks
- Slower drainage possible
- Fines Buildup
- Higher COD loads in the water effluent

Product Properties Associated with Recycled Fibers in P& W

- Effect on Product Properties
  - Appearance can be adversely affected by recycled fiber
    - Because ink removal is <100% efficient, specks are normally present
    - Possible: Lower brightness
    - Possible: More color
    - Possible: Color reversion
    - Changes in fiber chemistry and impact on printing

Solutions to the issue of using Recycled Fibers in P& W

- Blending recycled with virgin
- Improved processing of the recycled fibers
- Increased amounts of cationic starch
  - Increased strength
  - Anionic trash collector
- Use of talc or other inorganics to address stickies
- Chemical additives
- Proper refining