Cost-Saving Strategies in Papermaking Chemistry – Mini-Course Version

By Marty Hubbe and Kasy King

TAPPI PaperCon 2011
May 4, 2011

Today's Topics

First 90-minute session

- Introduction
- Group exercise: Thinking about cost items
- Different kinds of costs
- Using paper chemicals cost-effectively

Break (30 minutes)

Second 90-minute session

- "Rising retention aid costs" case study
- Key concepts from the textbook
- Discussion of "question card" issues

Costs at “ACME Paper Co.” are too high!

During the next 180 minutes (two conference sessions, with a break in the middle) we will work as a team to change that situation.

Let’s go over the brief list of items that “management” wants us to consider...

“Dear cost-savings task group, please consider…”:

1. Losses (wasted materials, unrecovered broke, *etc.*)
2. Slow production rate (fixed costs spread out over too few tons)
3. Downtime (length of scheduled downtime, frequency and duration of unscheduled downtime)

"Dear cost-savings task group, please consider…":

4. **Inefficient use of functional additives (higher than necessary costs for sizing, dry strength, wet strength, opacity, retention aids, *etc.*)**

5. **Process additives and their control (to reduce the standard deviations of measurable variables)**

"Dear cost-savings task group, please consider…":

6. **Reduction in the amount of fiber needed to make a ton of product (including basis weights, filler levels)**

7. **The amount of energy required to produce a ton of product (moisture out of the press section, vacuum energy, *etc.*)**

A Simple Way to Look at It

Receipts - Costs = Profits

Decrease this item!!

Many kinds of losses hurt us here!!

A Simple Way to Look at It

Receipts $\propto$ Price X

Production rate

X Fraction of uptime

X Fraction saleable product

"If it ain't broke…"

Let’s review how “ACME” is doing…

Three paper machines / product areas:

PM#1 – Specialty printing paper
- **50-100% bleached virgin kraft**
- **0-50% de-inked mixed office waste**
- **Hybrid former, size press, *etc.***
- **Many short runs (colors, *etc.*)**

Paper Machines 2 & 3

PM#2 – Coated magazine paper
- **80-100% thermomechanical pulp (TMP)**
- **Gap former,40-55 lb/3300 ft^2**
- **On-machine coated (blade)**
- **Long production runs**

PM#3 – Multi-ply board
- **50-100% old corrugated cont. (OCC)**
- **0-30% other recycled pulp (e.g. MOW)**
- **0-10% bleached virgin kraft**
- **Multi-cylinder (6 plies)**
- **Off-machine coating option**

Recent Production Summary

Machine:	1
Grade:	Uncoated fine printing
Uptime (%):	79
Saleable (%):	90
Max tons/day:	100
Limiting factor:	Dryers
Key issues:	Transition time, cost of opticals, sizing costs, variability, deposits

Recent Production Summary

Machine:	2
Grade:	Light-weight coated
Uptime (%):	79
Saleable (%):	98
Max tons/day:	100
Limiting factor:	Drives
Key issues:	Web breaks, picking

Recent Production Summary

Machine:	**3**
Grade:	**Paperboard (folding boxes)**
Uptime (%):	**96**
Saleable (%):	**95**
Max tons/day:	**100**
Limiting factor:	**Drainage**
Key issues:	**Strength, coverage**

Meet Some of your Team-Mates

- **Please form a group with 3-6 people sitting near to you.**
- **Your assignment is to make a recommendation of at least one issue for the company to focus on *in the short term*. Report this idea in a 1-minute statement, giving reasons.**

Things to Focus on during Group Work

PM#1	PM#2	PM#3
Fine printing	Light-wt coated	Paperboard
50-100% bl. kraft	80-100% TMP	50-100% OCC
0-50% DIP MOW	Gap former,	0-30% MOW, etc.
Hybrid; size press	40-55 lb/3300 ft2	0-10% bl. kraft
Short runs (colors)	On-machine ctd	Multi-cylinder
Uptime: 79%	Long runs	Off-machine coat
Saleable: 90%	Uptime: 79%	Uptime: 96%
Limit: Drying	Saleable: 98%	Saleable: 95%
Issues: Transition	Limit: Drives	Limit: Drainage
Time, opticals	Breaks, picking	Strength, coverage

Materials losses (yield); Low production rate; Downtime; Inefficient use of functional additives; Process variability; High costs of materials; Energy costs; Shipping costs

Definition: "Fixed Costs"

Costs that do not depend on the rate of production

Examples:

- **Administration**
- **Property taxes**
- **Insurance**
- **Debt**

Also called…

"Indirect costs"

Definition: "Direct Costs"

Costs that *DO* depend, at least partly, on the rate of production

But there are two types of direct costs…

- **Variable**
- **Semivariable**

Examples of Direct Costs

Variable

Manufacturing materials

Semivariable

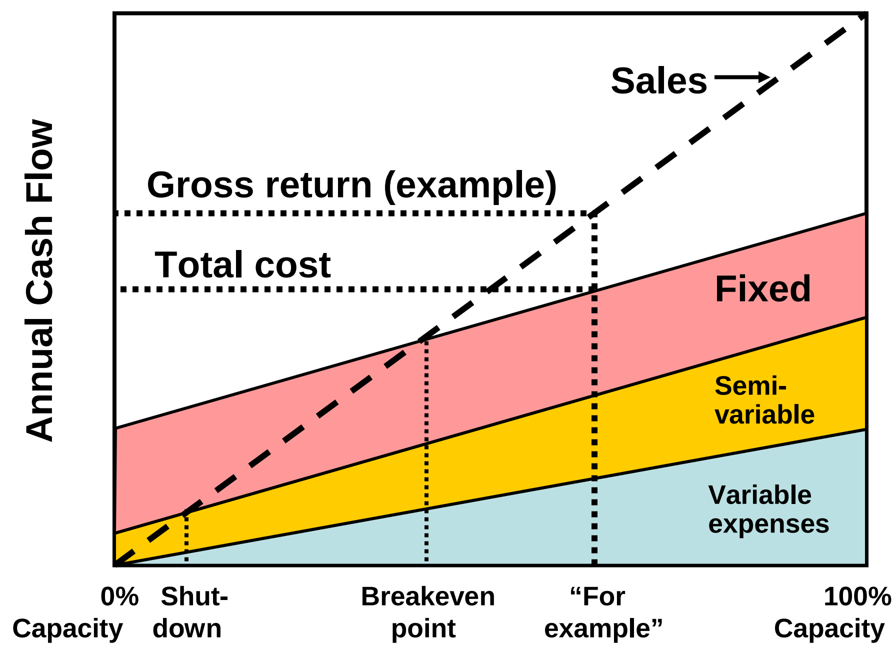
Manufacturing labor

Now it's your turn; please suggest categories for the following items:

	DIRECT COSTS Variable	DIRECT COSTS Semi-V.	INDIRECT (Fixed)
Purchased pulp			
Maintenance			
Pension fund			
Insurance			
Water treatment			
Social security			
Depreciation			

Now it's your turn; please suggest categories for the following items:

	DIRECT COSTS Variable	DIRECT COSTS Semi-V.	INDIRECT (Fixed)
Chemical costs			
Energy			
Fresh water use			
Lease/rentals			
Property mortgage			



It costs money to meet customer requirements!

Reciepts - Costs = Profits

But the market price may be in the "commodity" range, cutting into your profitability.

Variable costs are driven higher by customer needs for sizing, opacity, color, dry strength, wet strength, *etc.*

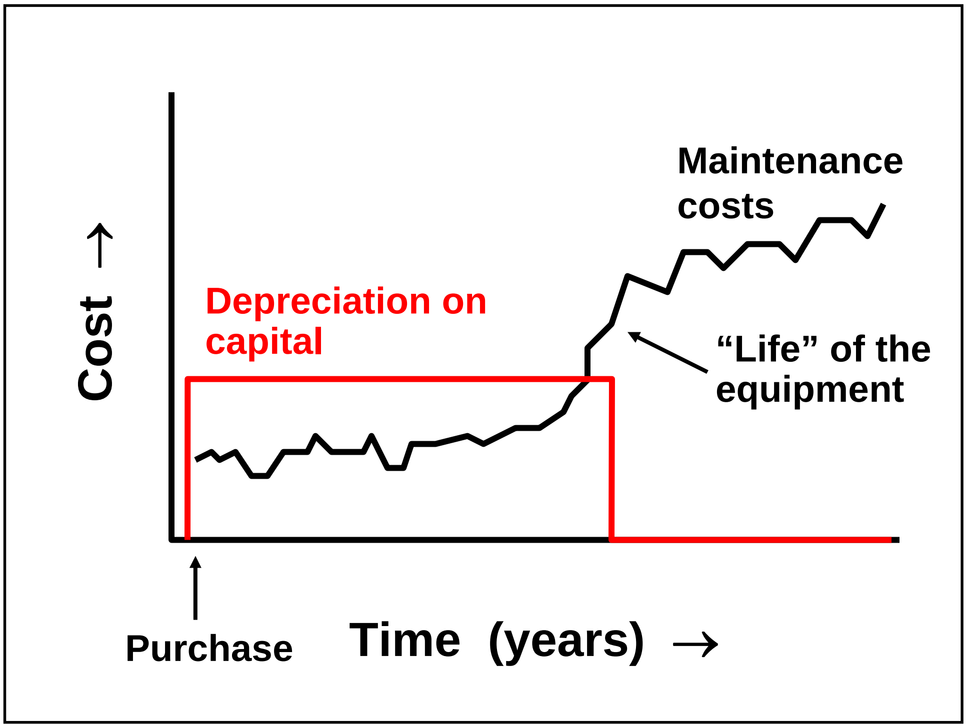
The Solution: Achieve Specifications at Lower Cost

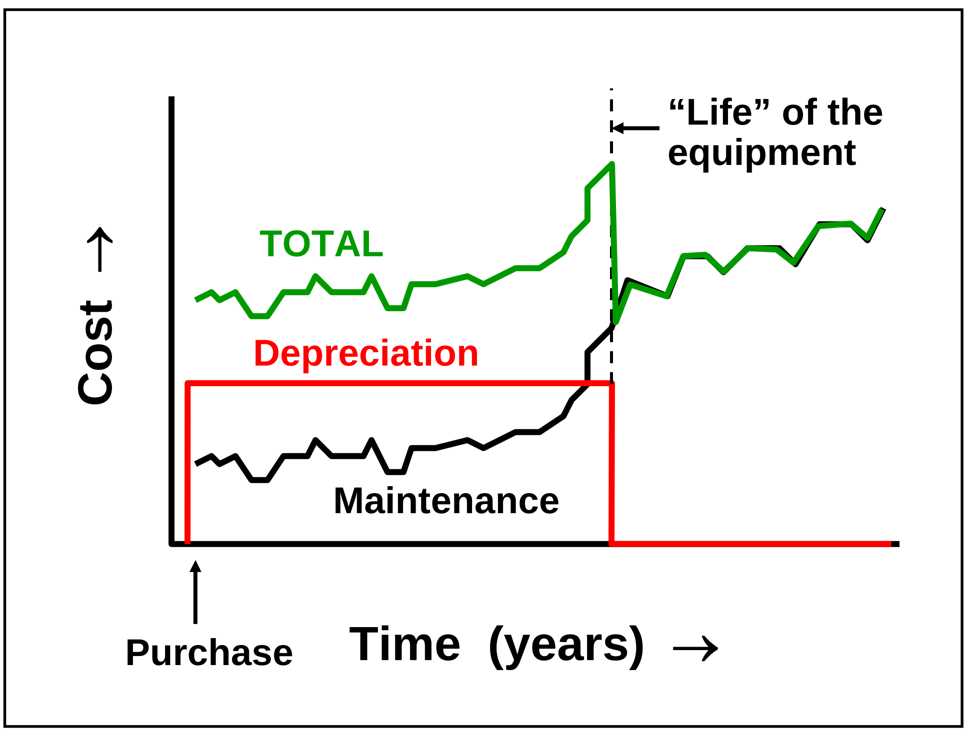
"That's easy for YOU to say…"

Depreciation

Linear: **An attempt to estimate the loss in value of equipment**

Accelerated (double-declining balance, sum-of-years-digits, *etc.*): Tax systems intended to encourage companies to make capital investments


Maintenance
costs
Depreciation on
capital
"Life" of the
equipment
Cost →
Purchase
Time (years) →


"Life" of the
equipment
TOTAL
Depreciation
Maintenance
Cost →
Purchase
Time (years) →

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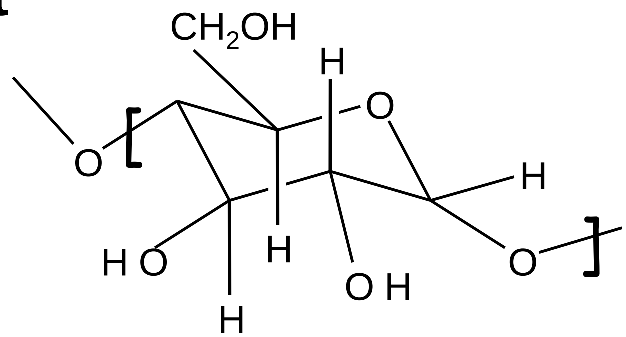
Ways to Reduce Costs of Functional Additives

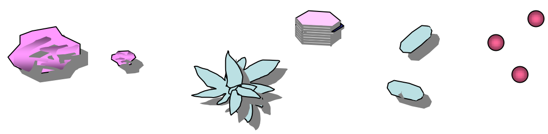
1. Use functional additive(s) more efficiently and don't use more than you need.
2. Deal with various interferences to functional additives.
3. Deal with factors that cause the functional additives to decompose.
4. Control your process more precisely.

Reasons Why Sizing Can Be Inefficient

Water-loving nature of the fibers

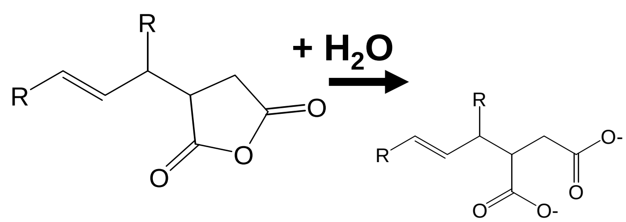


High surface area of fillers, *etc.*



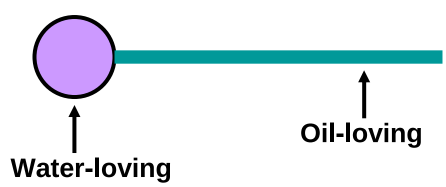
Reasons Why Sizing Can Be Inefficient

Breakdown of the size

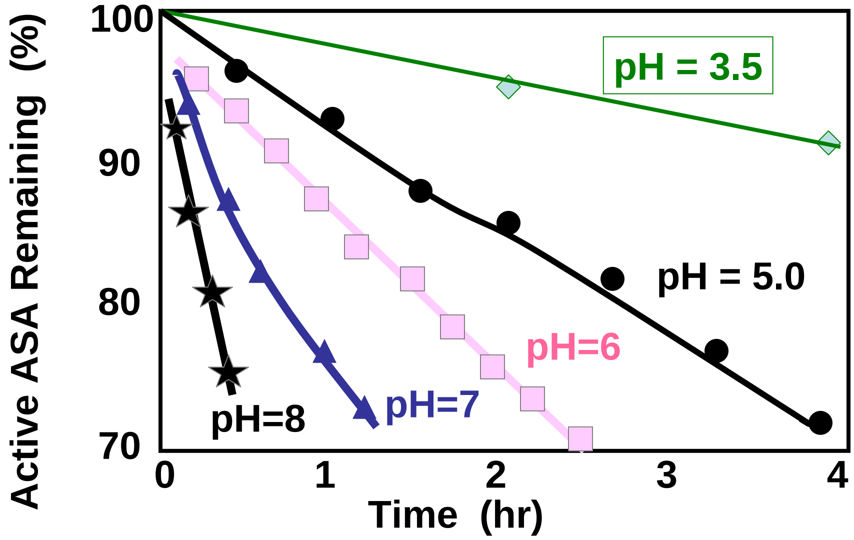


AKD breaks down too, but not as fast.

Surface-active agents

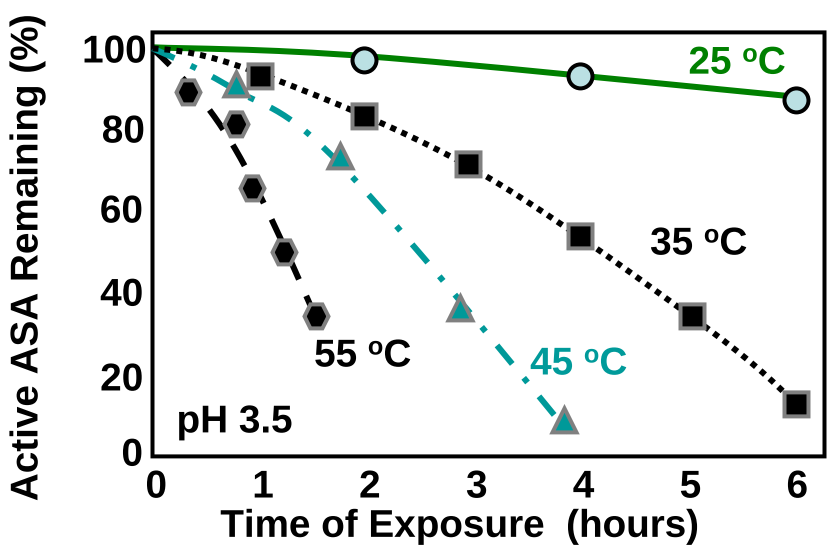


ASA Hydrolysis *vs.* pH



Wasser, *J. Pulp Paper Sci. 13* (1): J29 (1987), adap.

ASA Hydrolysis *vs.* Temperature



Wasser, *J. Pulp Paper Sci. 13* (1): J29 (1987), adap.

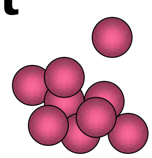
Reasons Why Sizing Can Be Inefficient

Sizing agent poorly retained

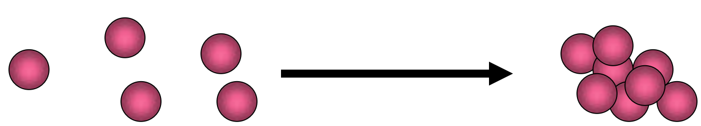
- Retention aid system needs attention.
- System charge is out of balance.

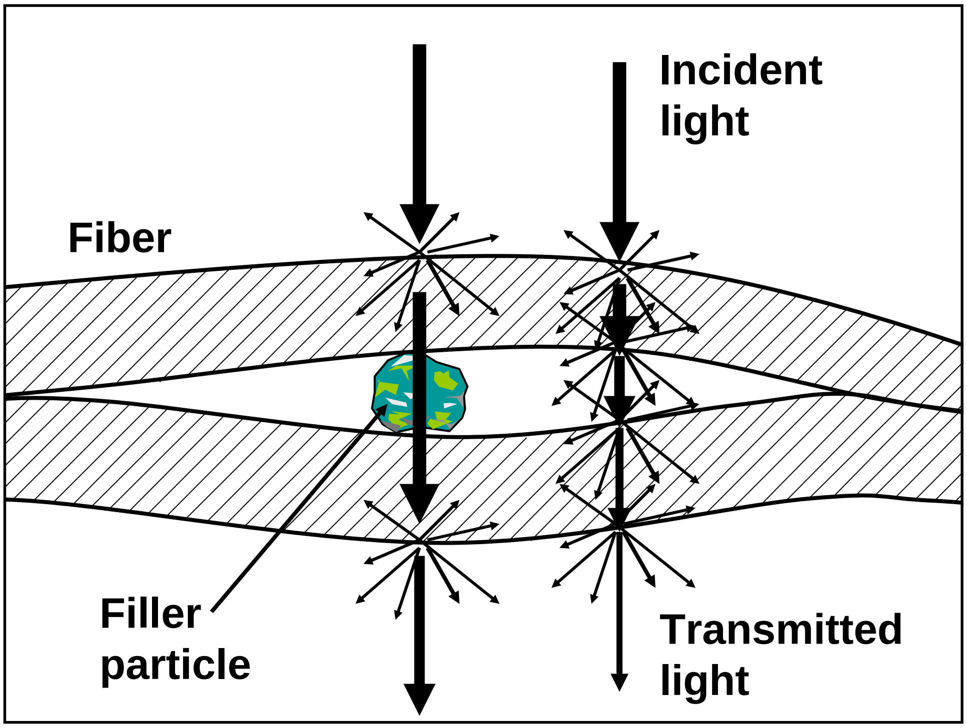
Reasons Why Opacifying Fillers Can Be Inefficient

Never got properly dispersed.



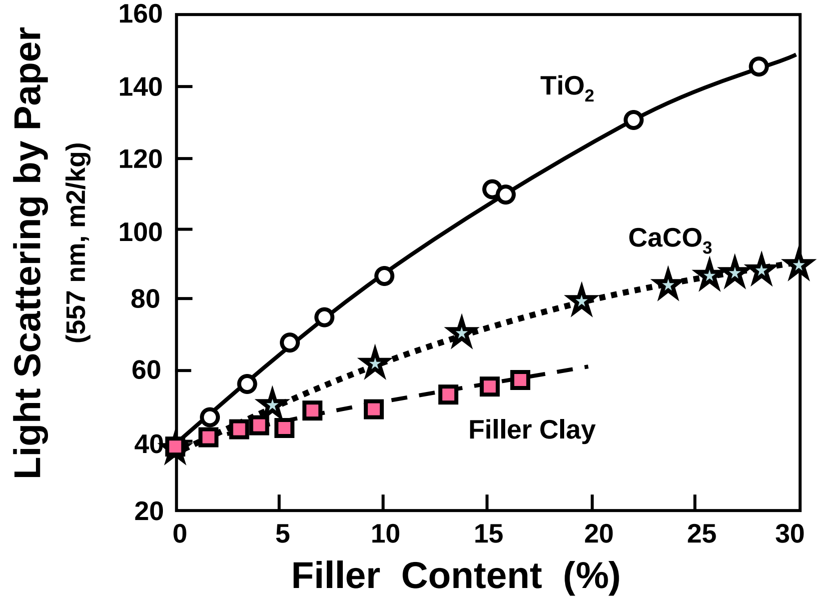
Got agglomerated during storage or use.





More Strategies to Get Opacity at Lower Cost

- High filler levels (Ch. 7 of textbook)
- Maintain "bulk" (lot's of air spaces)
  - Stiff, bulky fibers, *e.g.* CTMP
  - Composite-type fillers, *e.g.* rosettes
- Selecting the fillers to be used



Middleton *et al.*, *J. Pulp Paper Sci. 20* (8): J231 (1994), redrawn.

Wet-Strength Cost Saving Strategies

Adjust charge conditions, pH conditions, so that it retains well and cures well.

Retain the resin on the fibers, rather than the fines (thick stock addition).

But add it *after* the refiners…

Key Cause of Poor Performance of Strength Additives: Cationic Polymer Neutralized by “Trash”

Cationic starch

Polyamidoamine-epichlorohydrin (PAAE)

Use a cheaper “sacrificial” additive, a “trash collector” (high-charge-density cationic)

Additives Used for Charge Control

Alum: $Al_2(SO_4)_3 \cdot 14\ H_2O$

PAC: $[AlO_4Al_{12}(OH)_4(H_2O)_{12}]^{7+}$, etc.

Polyamine: $-[-N^{+}-(CH_3)_2-CH_2-COH-CH_2-]_n$

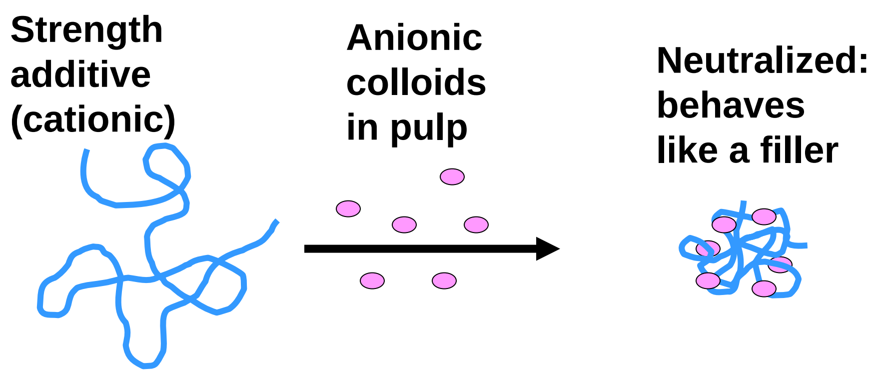
PEI: $H_2N-(CH_2CH_2N)_x-(CH_2CH_2NH)_y-$

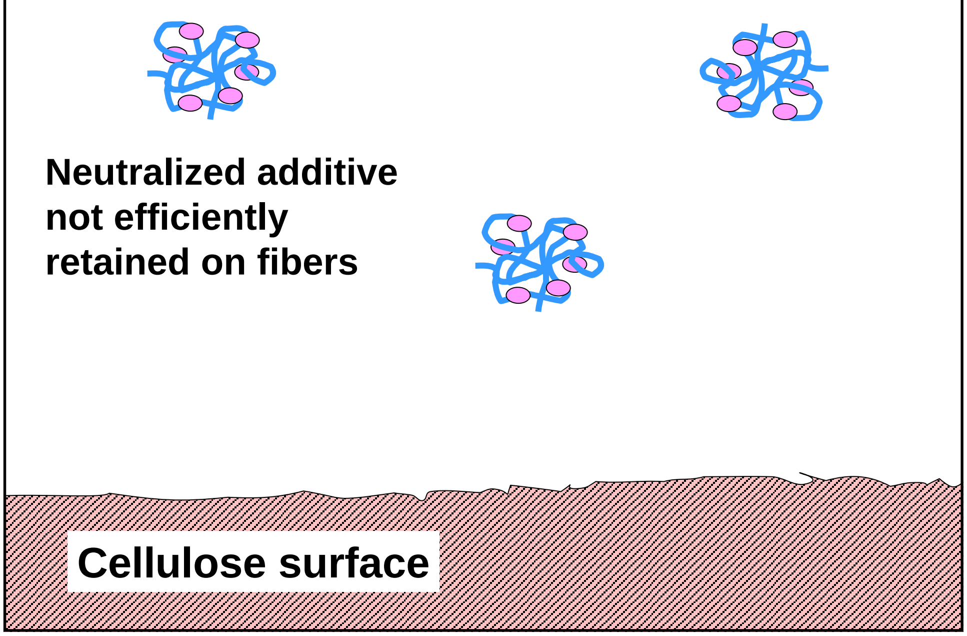
$CH_2CH_2NH_2$

Polyamides, other

Optimize the Charge Demand

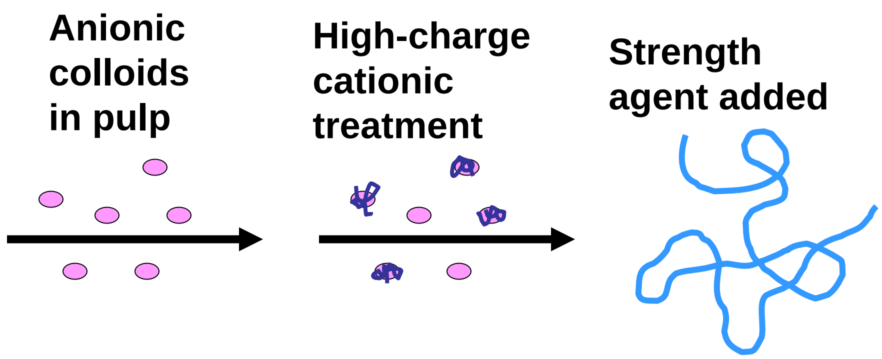
Case one: too negative





Optimize the Charge Demand

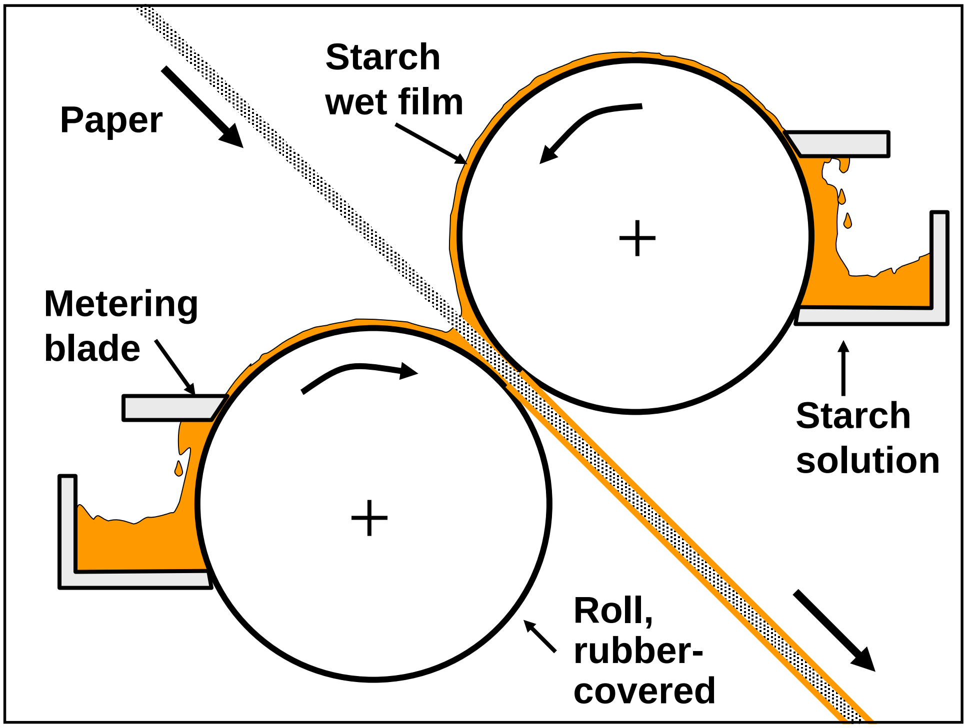
Case two: high charge additive used

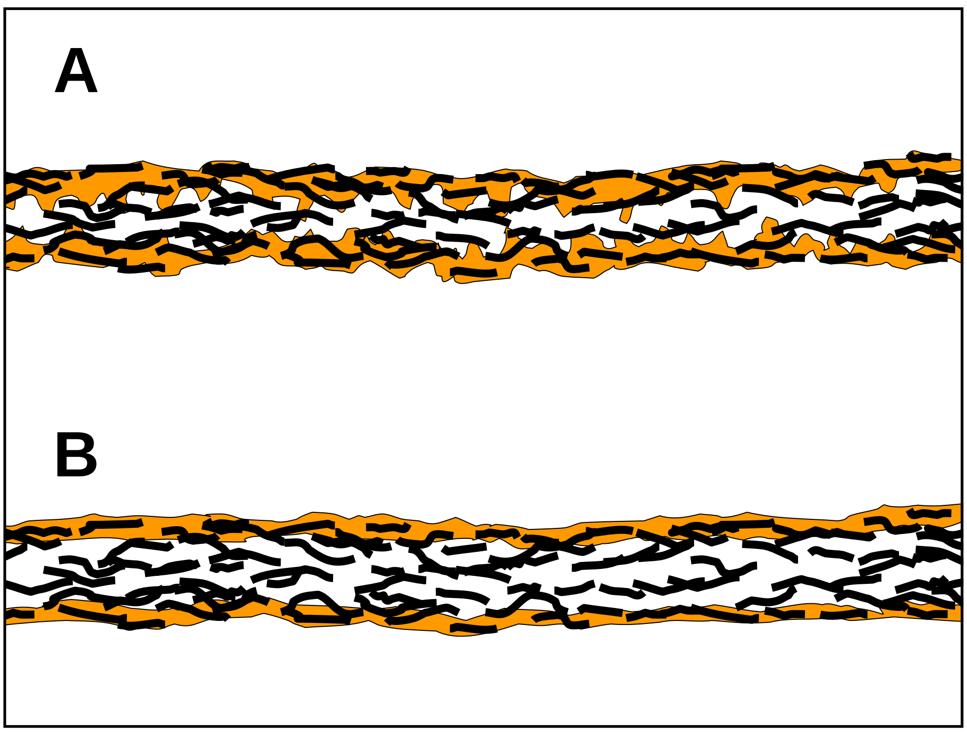


Think Outside the Box

The size press can be cost-effective for strength, especially surface strength.

But the size press application can be made *more* effective by internal sizing…


Paper
Starch
wet film
Metering
blade
Starch
solution
Roll,
rubber-
covered


A
B

A Little Case Study

Project team asked to reduce cost of size-press application.

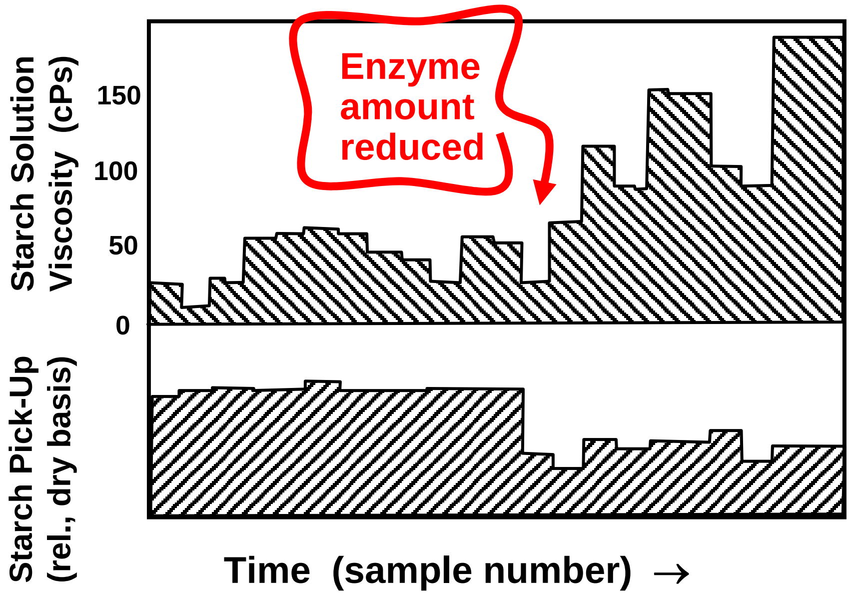
Already, the lowest-cost starch is being used, with in-mill "conversion" to reduce viscosity for size press use.

Strength targets being met, but size press "maxed out" in amount applied.

Conventional Wisdom: Reduce Starch Viscosity

- **Runs better at size press**
- **Possible to apply higher solids solution**
- **Higher pick-up**

But you may be losing money…



Dobbs, *Paper Technol. 34* (2): 16 (1993), redrawn

Case Study Results

- Enzyme costs reduced (by reduced need to break down the starch molecular mass)
- Starch costs reduced (lower starch solids and less penetration due to higher molecular mass)
- Strength targets met (because of better bonding by higher-mass polymer)

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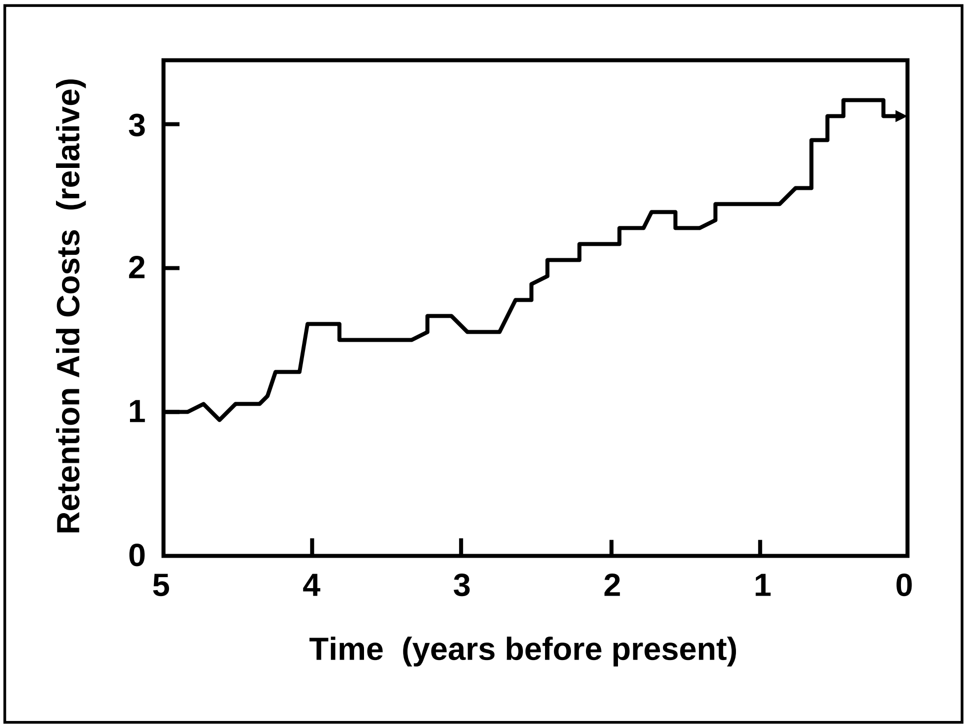
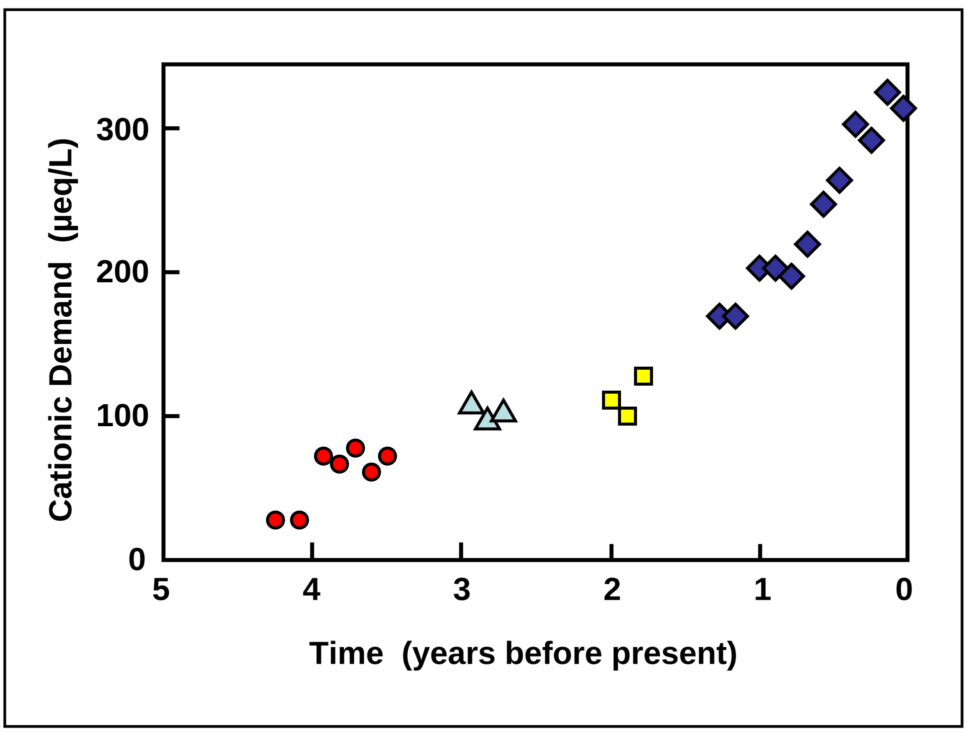
Case Study: "Rising Retention Aid Costs" *

Team goal: Reduce retention aid costs by 30% or more.

1. Study next two figures.
2. Then study a list compiled by the summer intern, who has now returned to their university.
3. Choose the "top one or two" options for your boss to consider first.

* Chapter 5 of *Cost-Saving Strategies in Papermaking Chemistry*


Retention Aid Costs (relative)
0
1
2
3
5
4
3
2
1
0
Time (years before present)


Cationic Demand (µeq/L)
0
100
200
300
5
4
3
2
1
0
Time (years before present)

Things that have Changed

- Speed increases (4 years ago)
- Basis weight decrease (time hard to pin down)
- Increase in brightness requirements (2.5 years ago)
- PCC use (2.5 years ago)
- Peroxide bleaching (2 years ago)
- Fluorescent whitener in the coating color
- Broke content increased about 10%, in relative terms
- Overall increase in the amount of pulp produced
- Cationic demand increased over whole period, apparently
- Fresh water usage reduction (last 13 months)
- No change in retention aid brand, type, or target FPR .

Suggestion

Start by reading through the details of what has changed in the system over the past 5 years.

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- **Key concepts from the textbook**
- **Discussion of "question card" issues**

Objective: Speed up the process!

- **Increase revenue.**
- **Avoid increasing fixed costs (strategies that involve no or minimal capital spending).**
- **We'll assume that process efficiency (*i.e.* "uptime") remains constant (those issues will be discussed in the subsequent section).**

A Simple Way to Look at It

Proceeds - Costs = Profits

Variable (materials, *etc.*)

Semivariable (labor, *etc.*)

Fixed (debt, insurance, property taxes, *etc.*)

Speeding up the process mainly is expected to increase two items:

Receipts - Costs = Profits

Variable (materials, *etc.*)

Semivariable (labor, *etc.*)

Fixed (debt, insurance, property taxes, *etc.*)

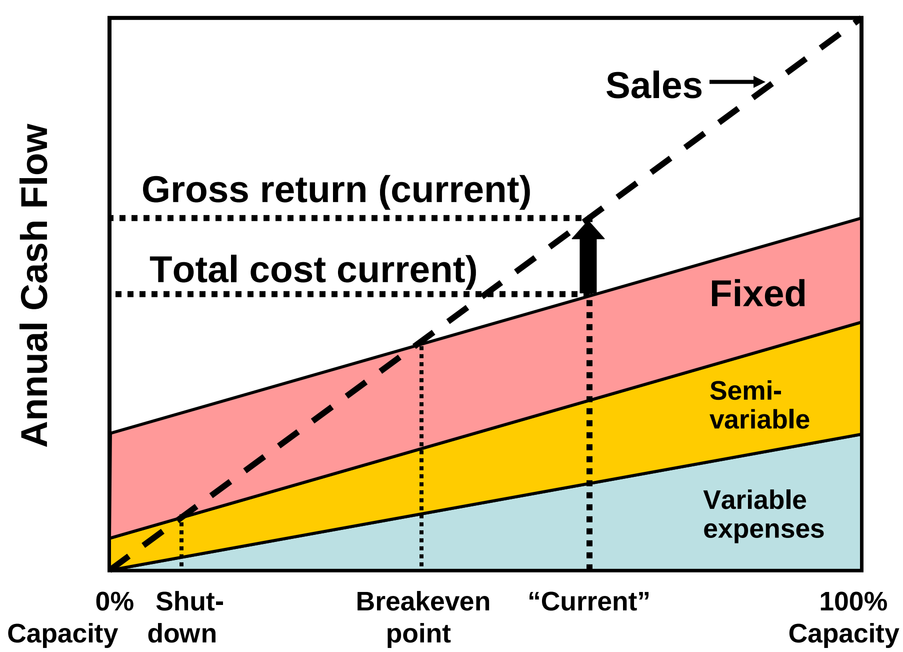
Concept of Marginal Costs

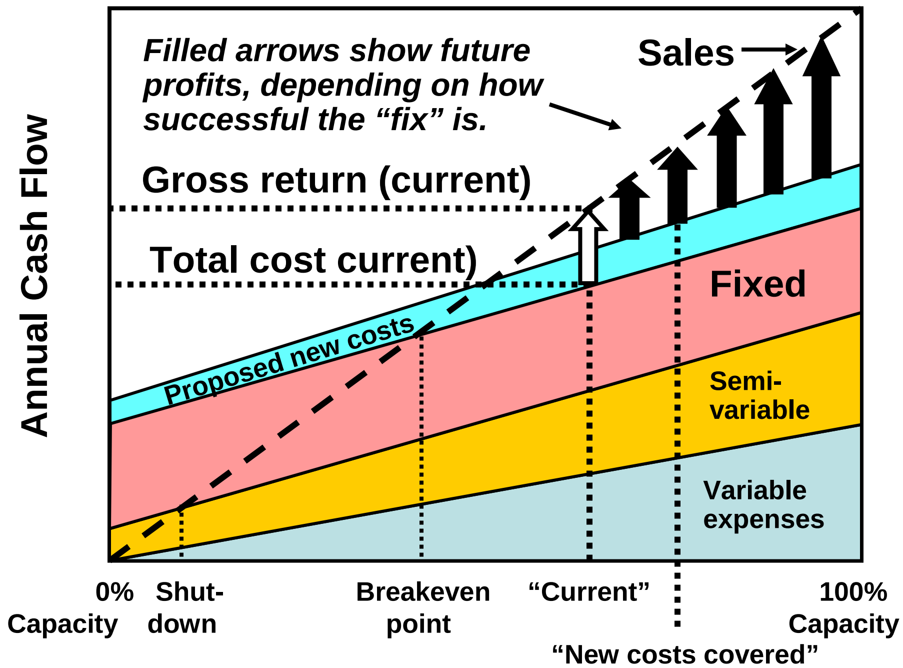
"What is the cost of the final 1% of production?

How much more did you earn, compared to if you made 99% of what you did?

Simplifying Assumptions:

Fixed costs, labor, not affected.
Process efficiency not affected.
Variable costs ∝ production rate.





When "Faster" Doesn't Pay

Your paper is being warehoused *vs.* sold due to low customer demand.

- **(Trim costs; maybe run slower.)**

Variable costs exceed selling price.

- **(Look for ways to cut costs, rather than increase production.)**

Variable costs start to increase out of proportion to the production rate.

- **(Try to find out why you lose efficiency, cost-effectiveness when running faster.)**

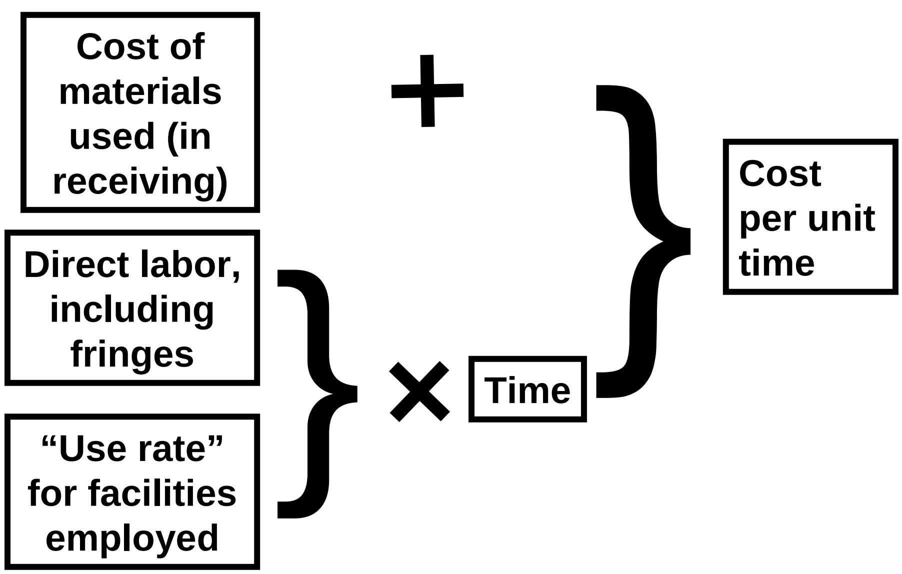
Using a paper machine is something like renting a car…

Rental fee ≈ Cost charged to you for use of the capital equipment (overhead charges assignable to the manufacturing activity)

Driver ≈ labor

Gas ≈ materials

See: Sims, R., *Precision Manufacturing Costing*, Dekker, 1995.



Sims, R., *Precision Manufacturing Costing*, Dekker, 1995, adapted

Refining and high levels of fines can result in slow dewatering.

1. Increased effective surface area (*S*).

Kozeny-Carman equation for flow rate:

$$\frac{dQ}{dt} = \frac{1}{K} \frac{(1 - C)^3}{S^2 C^2} \frac{1}{\mu}$$

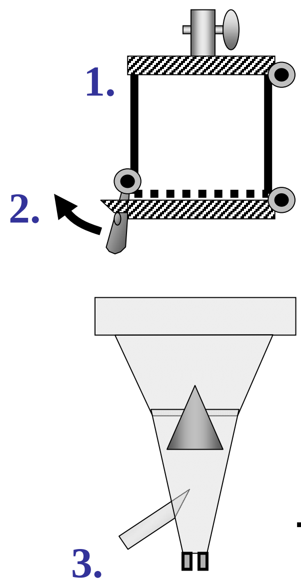
where *C* is the volume fraction of solids, μ is the solution viscosity, and *K* is a constant

Refining and high levels of fines can result in slow dewatering.

2. The “choke point” effect – unattached fines blocking of drainage channels in the wet web (to be discussed later)

3. Increased flexibility of fibers, when refined, allows them to conform to each other’s surface in a denser mat, leaving less space for water to flow around them.

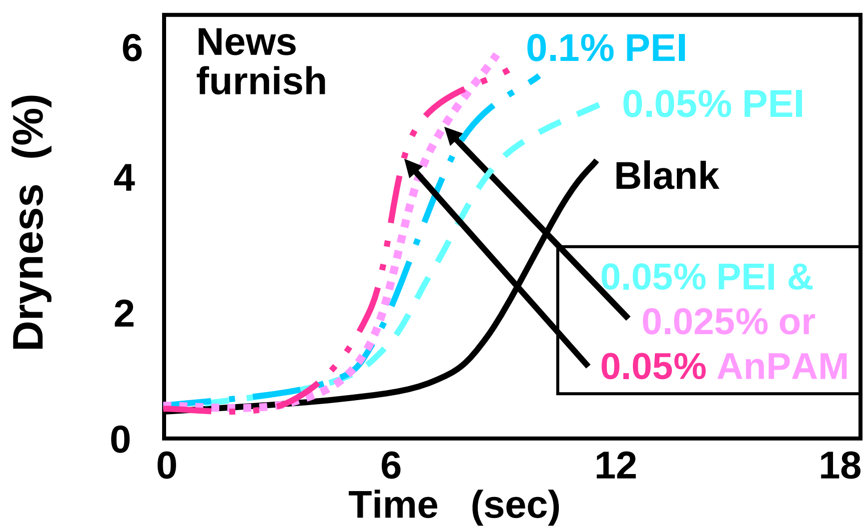
Canadian Standard Freeness



1. 1 liter mixed stock, 0.3% solids. Close top lid & stop-cock.
2. Open bottom lid & stop-cock.
3. Measure volume.

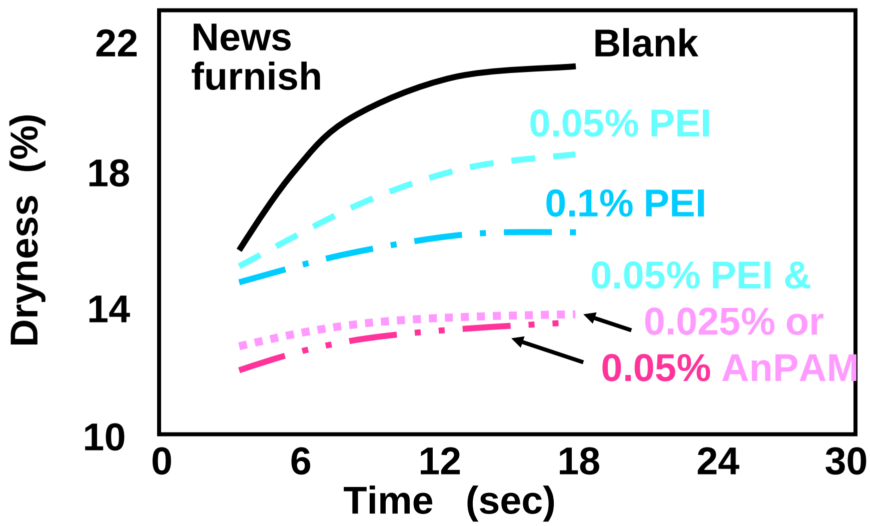
TAPPI Test Method T 227

Gravity Drainage *vs.* Polymers



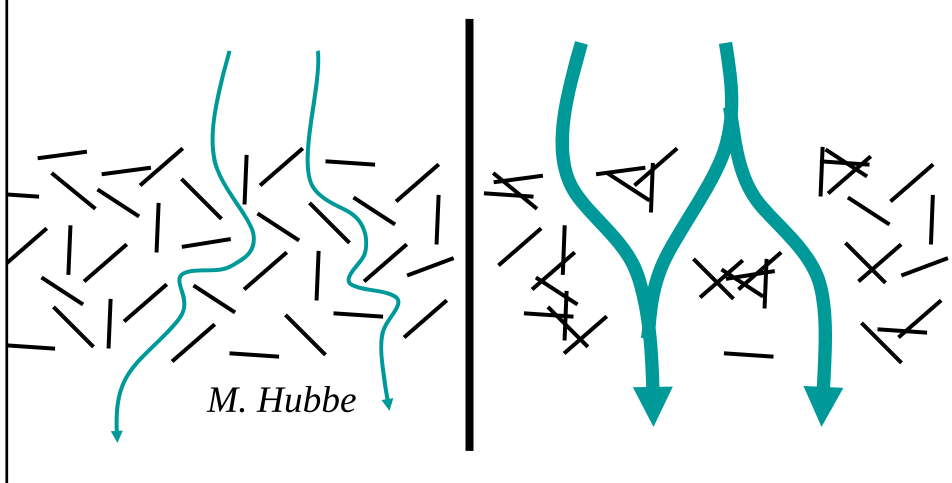
Britt & Unbehend, *Tappi J. 68* (4): 104 (1985), adapted

<u>Vacuum</u> Dewatering *vs.* Polymers



Britt & Unbehend, *Tappi J. 68* (4): 104 (1985), adapted

Why did the drainage aids seem "bad" for vacuum dewatering?



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Dewatering *vs.* Polymer Use

Additive	Consistency on wire (%)	Consistency after couch (%)
None	4.4	16.3
PEI (0.8%)	2.1	17.6
PEI (0.8%) + An.PAM (0.1%)	8.8	15.5
PEI, An.PAM, then dispersed	10.4	20.9

Britt & Unbehend, *Tappi J. 63* (4): 67 (1980), adapted

Chemical strategies to accelerate dewatering can have up to 4 parts.

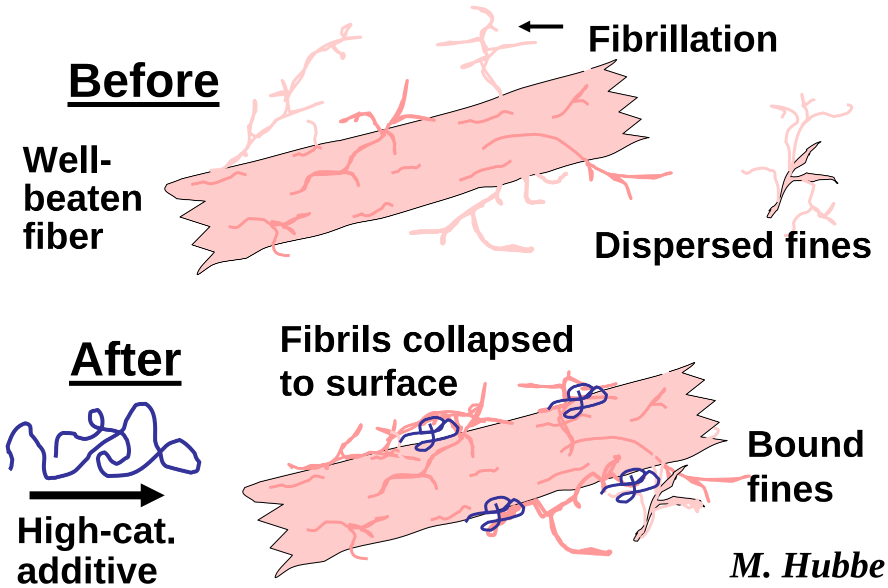
1. Neutralize negatively charged colloidal substances (anionic trash). { **Alum, PAC, polyamines, PEI, *etc.***

2. Create positively charged patches for electrostatic attractions. { **PEI copolymer, poly-DADMAC, polyamines, *etc.***

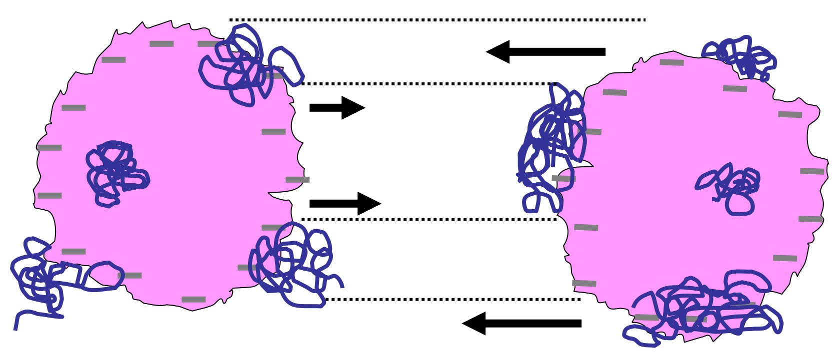
3. Bridge with high-mass retention aids. { **Cationic PAM or dual (high-cationic, then anionic PAM)**

4. Use microparticles (see later discussion). { **Colloidal silica, bentonite, micro-polymer**

Highly Cationic Drainage Aids

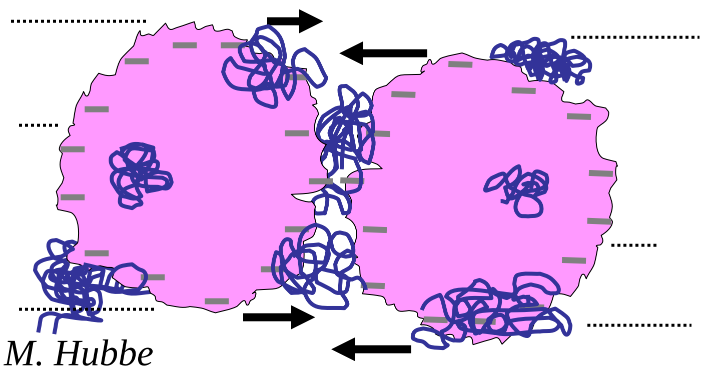


Patch Mechanism Schematic

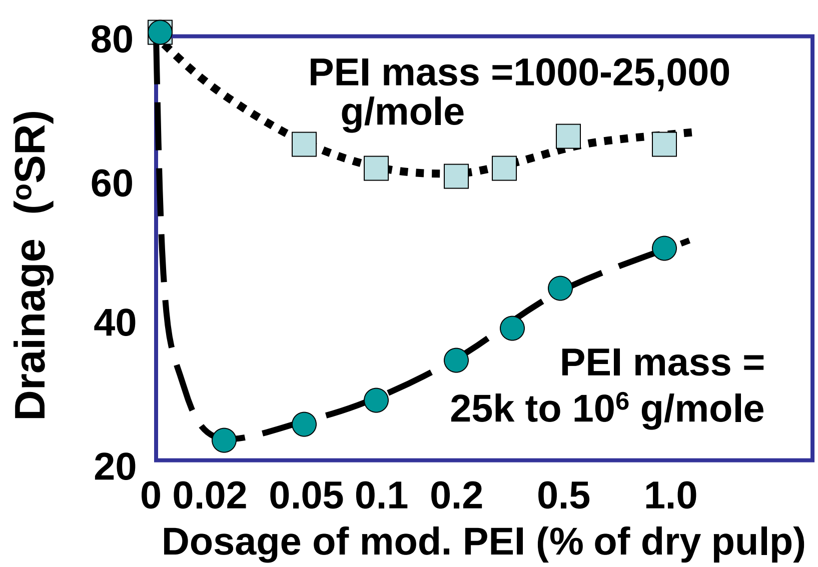


M. Hubbe

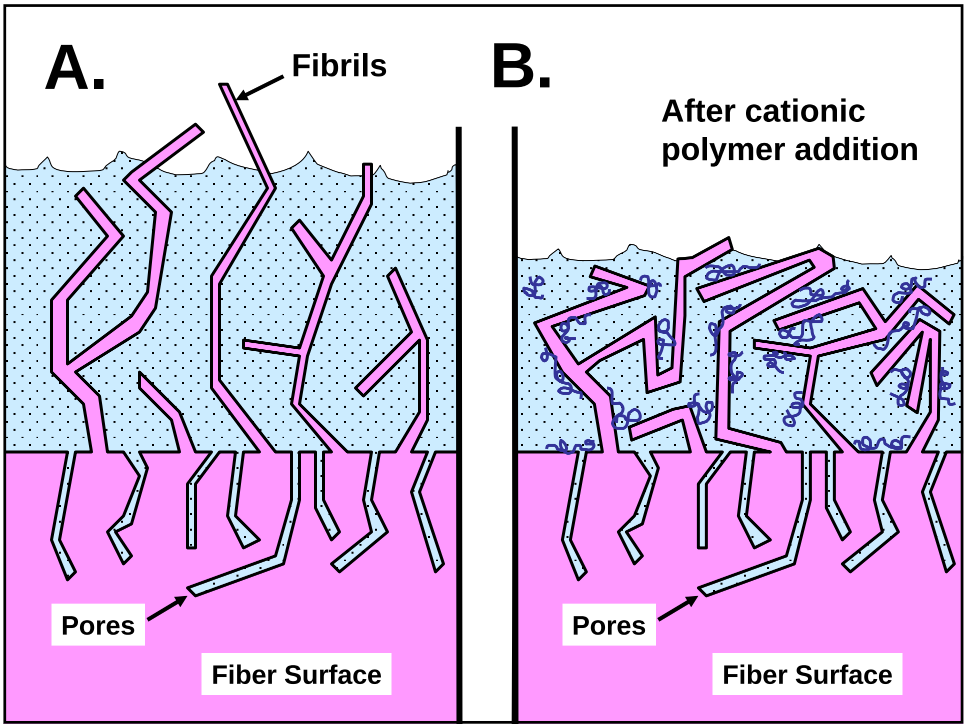
Further Evidence of Patch Mechanism

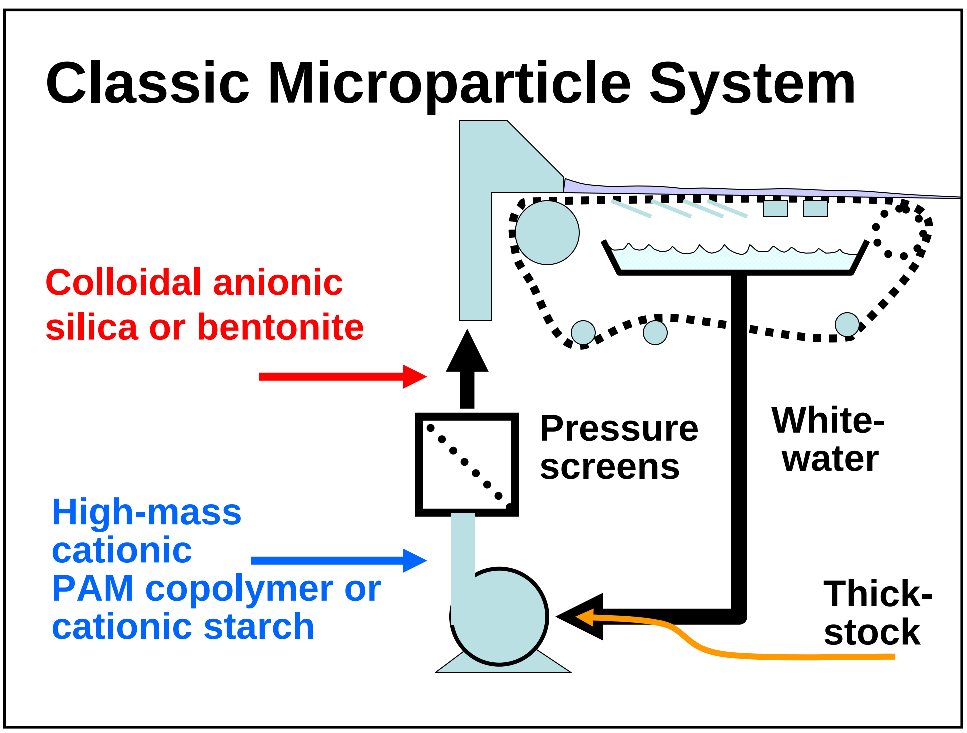


Flocs form again with ~ same strength.



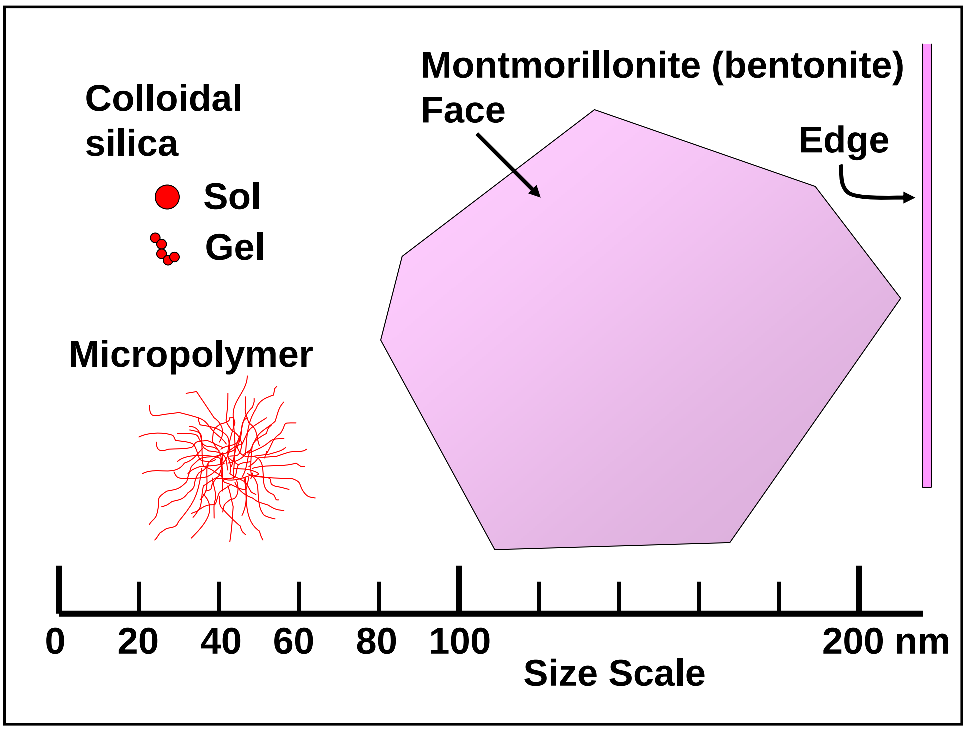
Ström & Kunnas, *Nordic Pulp Paper Res. J. 6* (1): 12 (1991), adapted

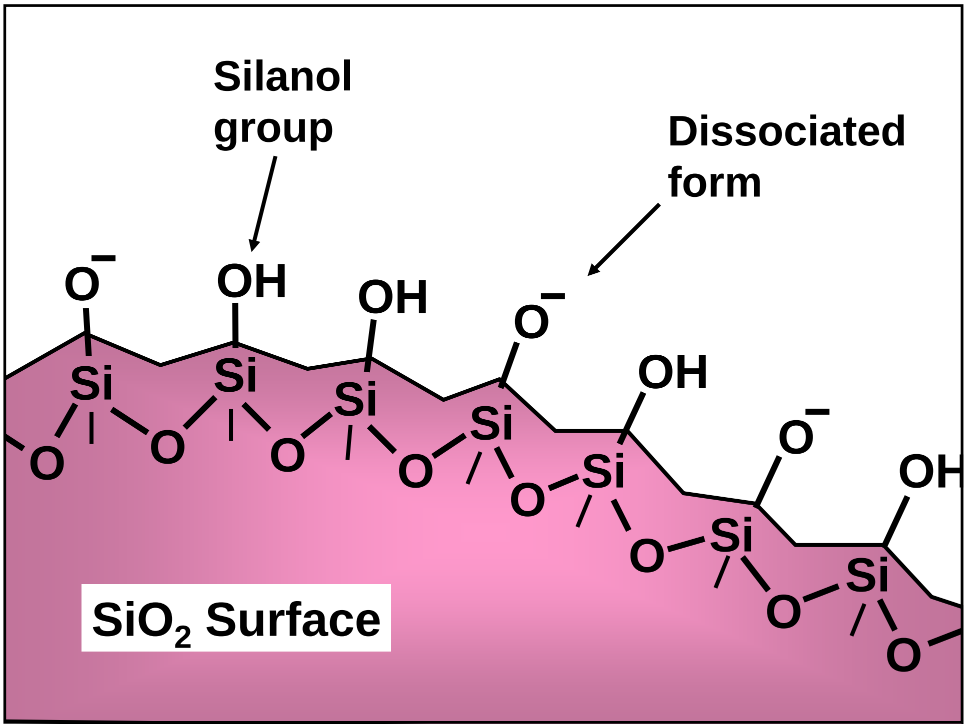

A.
Fibrils
B.
After cationic
polymer addition
Pores
Fiber Surface
Pores
Fiber Surface

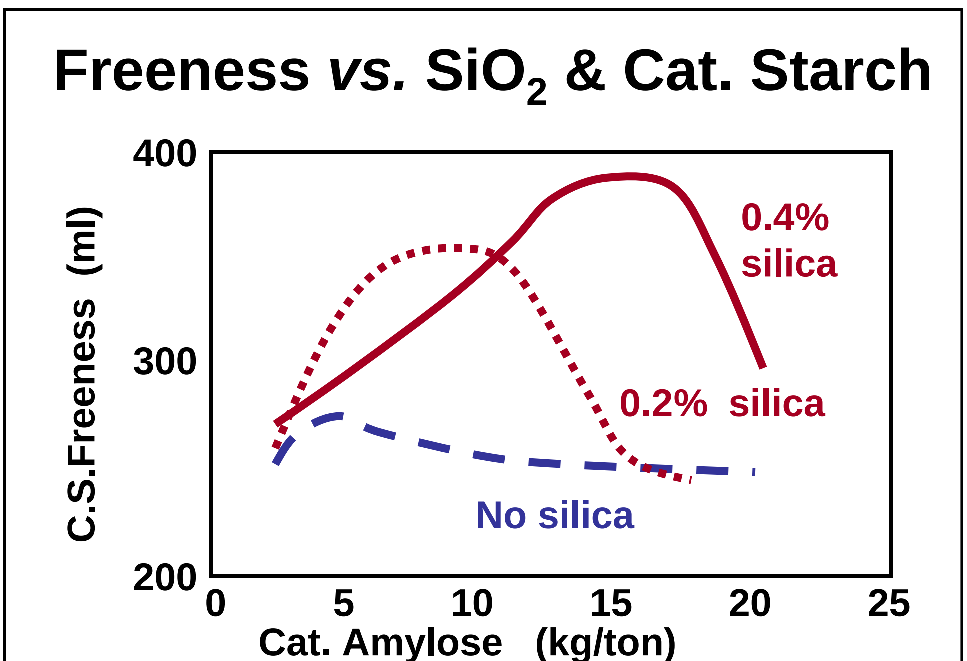

Classic Microparticle System
Colloidal anionic
silica or bentonite
Pressure
screens
White-
water
High-mass
cationic
PAM copolymer or
cationic starch
Thick-
stock

Microparticle systems differ from traditional retention aids.

- They involve tiny, three-dimensional, negatively charged particles having strong interaction with cationic polymers.
- They may demand more careful control of dosages and charge balance.
- They can accelerate dewatering more, in addition to increasing retention.







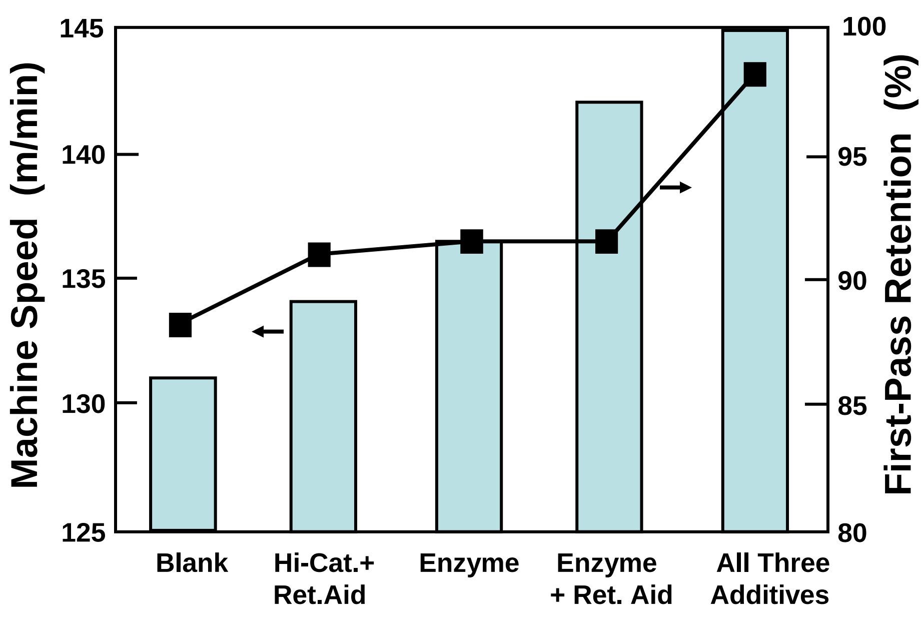
Carlson, *Proc. 24th EUCEPA Conf.*, 1990, 161, adapted

Facts about Microparticle Systems

Tend to be most effective if excess charges are neutralized first

Require interaction between a microparticle and cationic polymer(s)

If all you need is retention, then scrutinize the operating costs carefully.



Moran, *Pulp Paper 70* (9): 119 (1996), redrawn

Why Entrained Air Can Slow the Paper Machine

Just like fines, the bubbles tend to "plug the drainage channels" in a wet web!

Solution: Defoamer additives, especially if they can be used in combination with deaeration equipment

Capital Investment Scenario

Suppose "PM1" is at the limit of its drying capacity, and that installation of a shoe press is expected to increase production by 4%.

"Apples & oranges" situation:

- **The capital expense is incurred in year one.**
- **The revenue increases stretch into the future.**

Ways to Judge whether an Investment is Worthwhile

Payback: How long will it take for the increased profits to pay for the investment?

Return on investment: What percentage rate of return will this project earn?

Net present value: Considering the time-value of money, how much is the whole project worth when the decision is made?

See: Humphreys and English, *Project and Cost Engineers' Handbook*, 3rd Ed., AACE International, Dekker, New York, 1993

In summary…

Speeding up usually pays, if you can do so without hurting your cost situation.

Check whether speed is limited by the dewatering rate.

But don't pay so much for dewatering aids that the variable costs approach the selling price!

Process Additives

“Used to make the machine run better”

Examples
- **Retention aids**
- **Biocides**
- **Defoamers**
- **Deposit control aids**

Yes, we need ‘em, but let’s find a way to reduce the cost of the benefits they provide…

Approaches to be Considered

- **“Zero-cost” strategies: Changing how things are added, diluted, mixed**
- **Process control: Reducing variability and avoiding need (temptation) to overdose**
- **Pretreatments: Using one additive to promote the effect of another**

Addition Point Locations

- Optimize contact times

- Maximize mixing
- Separate cationic & anionic additives (all separately is best)
- Take advantage of shear

Efficient Preparation and Feeding of Additives

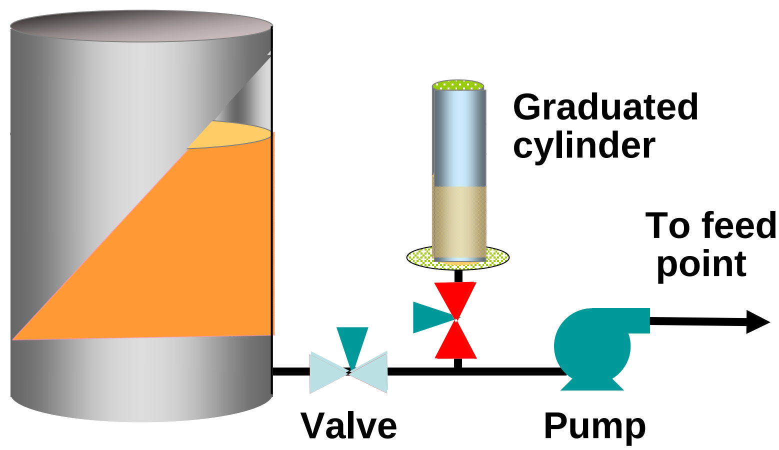
Avoid waste resulting from preparation.

Calibration: Make sure you know how much is being added.

Dilution: An easy way to achieve better mixing, more effective use of additives

Filtering: “At least do no harm” when you add chemical additives.

Chemical Feed Calibration



Why Dilute after Metering? *

- Metering pumps can be small.
- Amount of additive delivered, not its concentration, is more critical.
- Promptly deliver metered amount to the process, avoiding process control delay.
- Remember: Diluted additive mixes better with the stock due to lower viscosity and higher flow.

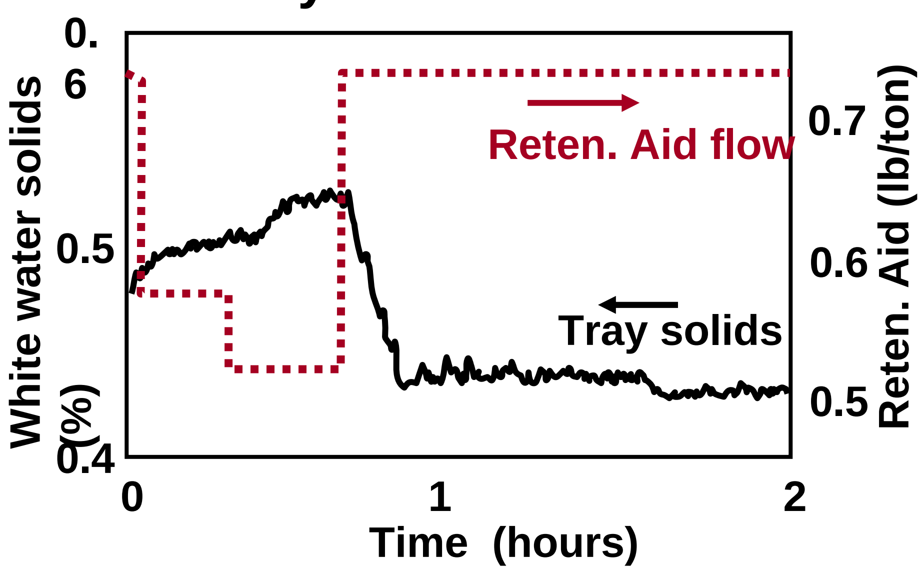
** Often dilute just before point of addition, to minimize contact time with white water.*

Online Process Control

Step 1: There must be a strong, reliable relationship between the controlled variable and the monitored variable!

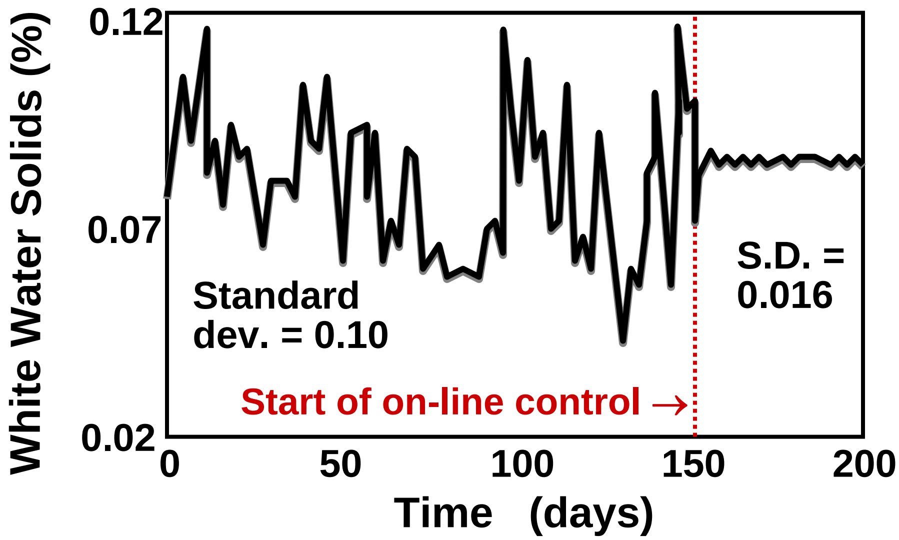
Example: Retention aid "bump" test:

On-Line Tray Solids Measurements



Ruetz *et al.*, *Wochenblatt Pap. 126* (3): 88 (1998) adapted

On-line Control of Tray Solids



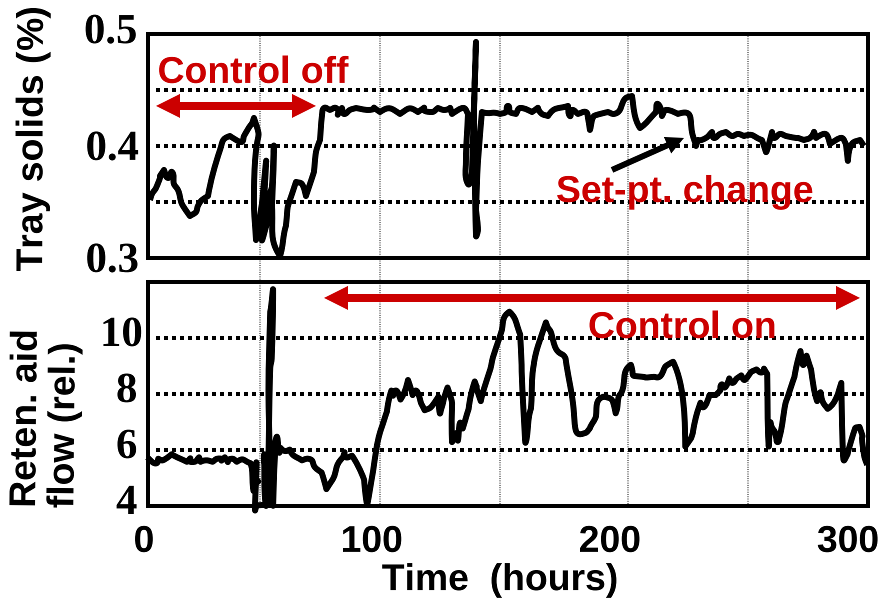
Ruetz *et al.*, *Wochenblatt Pap. 126* (3): 88 (1998), adapted

Same retention can give different tray solids & PM cleanliness.

FPR_1 = 100% x (0.6 – 0.2) / 0.6 = 66.7%

FPR_2 = 100% x (0.9 – 0.3) / 0.9 = 66.7%

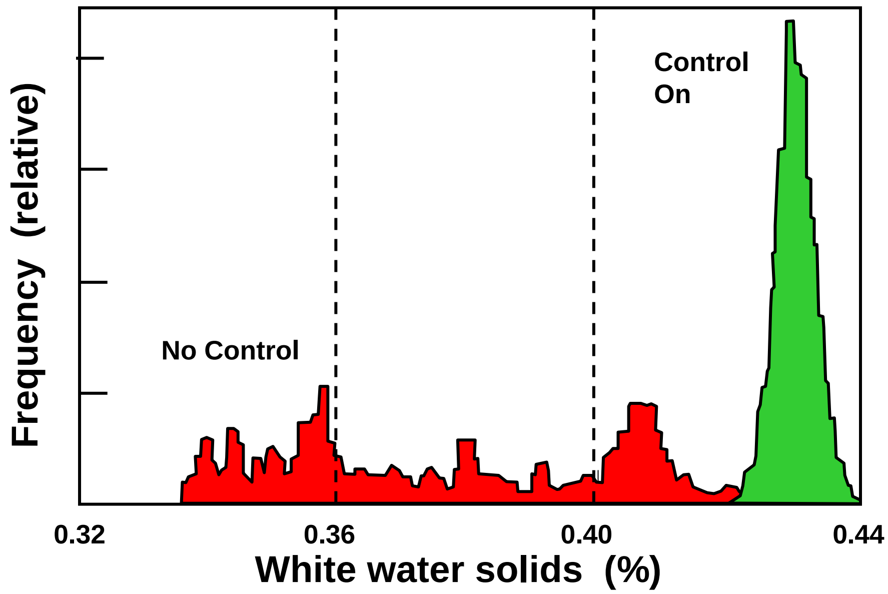
But PM1 is "cleaner" than PM2!



Artama *et al.*, in *Use of Minerals in Papermaking*, 1997, adap.

The Good News

- **Controlled, constant white water solids should yield steadier operation, less variability of the product.**
- **Because danger of "underdose" is removed by monitoring, operators have confidence to reduce average chemical feeds, saving money.**

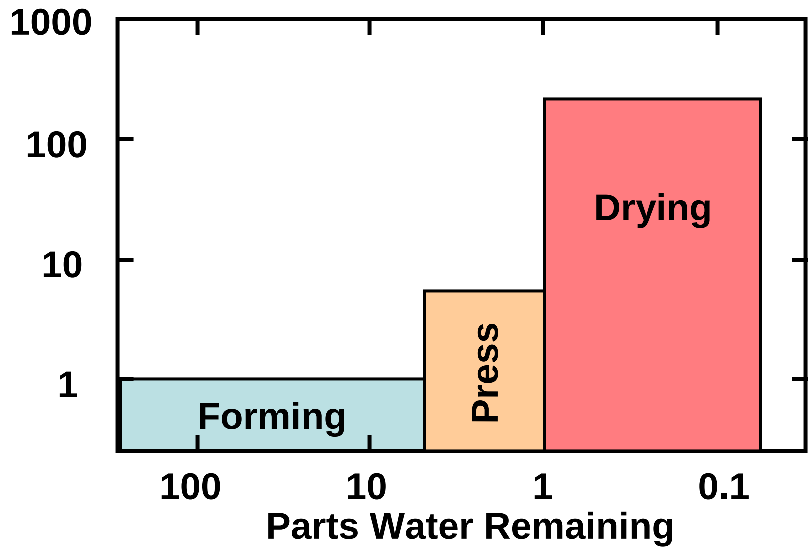


Artama and Nokelainen, *Paper Technol. 38* (8): 33 (1997), redrawn

Summary, Using Process Additives Efficiently

- **Take advantages of synergies and avoid interferences (especially, adding substances that neutralize each other at the same addition point).**
- **Implement online control, if there is a strong cause-effect relationship shown.**
- **Dilute, mix well (but not excessively), calibrate, and choose addition points with care.**

Relative Costs of Water Removal



Data from: McGregor, Knight, *Paper Technol. 37* (8): 31 (1996).

Energy Uses during Papermaking

Evaporative drying

Vacuum pumping

Forming section drives
  Overcoming vacuum-induced friction

Heating of process water

This is not a complete list!

More subjects are covered in the textbook:

Solids losses *vs.* retention aid costs
Downtime avoidance costs
Retention aid efficiency
Reduction in furnish costs

Extensive bibliographic references
Time to work on case studies in groups
Many more examples and grade issues

We appreciate your attention!

And thank you to TAPPI for making this event happen!

For follow-up questions:

hubbe@ncsu.edu
kasyking@att.net