Consistency Measurement and Control

PAPTAC Bleaching Committee Fall 2016 Meeting

- *Defining and measuring consistency*
- *Factors affecting consistency measurements*
- *Consistency measurement sensor types*
- *Things to think about*
- *Some ideas on control strategies*

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Consistency Basics

Definition and available measurement technology

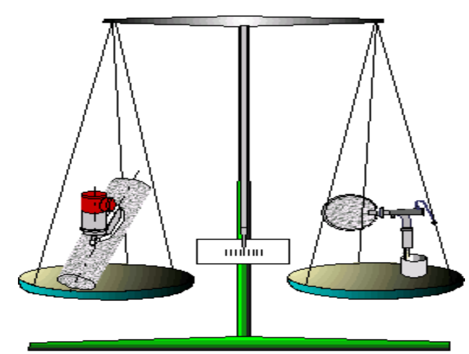
Measuring Consistency

- Consistency, total (%)
  - = (dry weight of fiber/ total weight of sample) X 100
- Consistency, fiber only (%)
  - = (dry weight of sample (solids – additives)) / total weight of sample X 100
- Production (t/h)
  - = pulp flow (m3/h) X consistency (kg/m3) / 1000

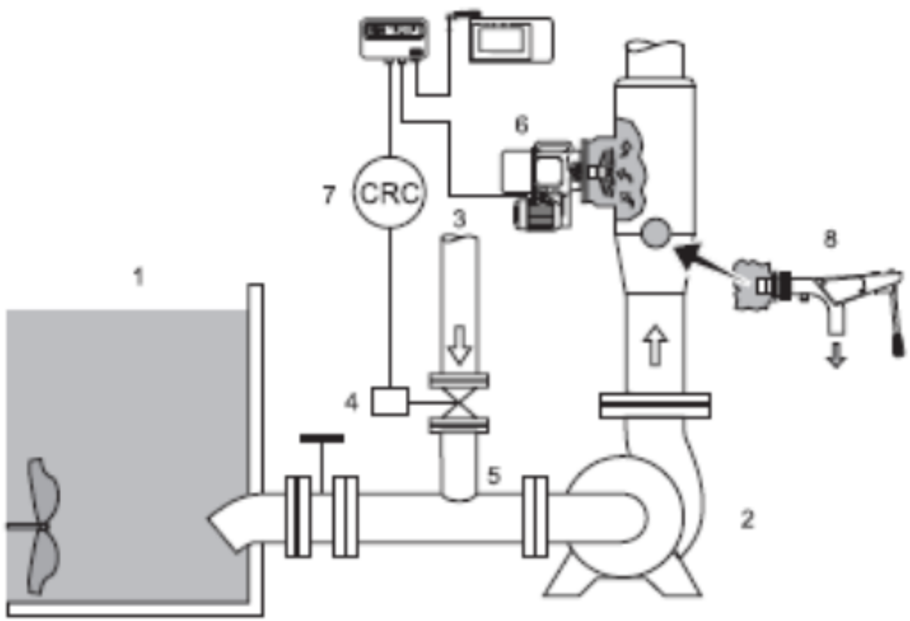
Available Measurement Technology

- Shear force (blade and rotary)
  - Fiber force to consistency
- Optical
  - Attenuation/reflection/dispersion/de-polarization of light
- Microwave
  - Time of flight

All consistency sensor are inferred measurements!



Basic consistency control loop



1. Stock chest with agitator
2. Stock pump
3. Dilution water supply
4. Dilution control valve
5. Dilution nozzle
6. Consistency transmitter
7. Controller
8. Sample valve
9. Lab work

The weakest link will decide the result!

Consistency Control

Some factors actors affecting accuracy and repeatability

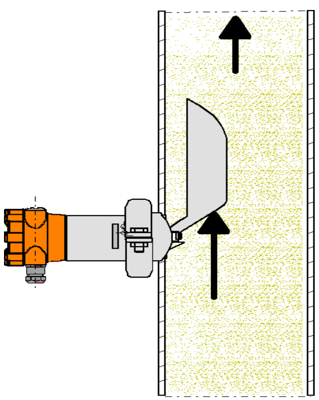
- Poor mixing in chest/tower including dilution zone
- Poor sensor installation
- Poor dilution control valve dynamics limiting resolution
- Variable dilution header pressure – multiple demand
- Poor control strategy / controller tuning
- Process dynamics like large flow turndown or freeness swings
- Poor level control tuning of pulp storage chests
- Limited instrument calibration range - production range?
- Sampling point lag to instrument

Shear force measurement

- Static and rotary, around 50+ years.
- Most common technology - well accepted
- Works in most mill processes
- Recipes based on fiber force acting on sensor, laboratory correlation into Cs.

Different fibers generate different forces

Species	Fiber length mm	Fiber diameter microns	Wood density lb/cu ft
Southern Region			
Longleaf Pine	4.9	35-45	41
Shortleaf Pine	4.6	35-45	36
Loblolly Pine	3.6	35-45	36
Slash Pine	4.6	35-45	43
Northeast Region			
Black Spruce	3.5	25-30	30
White Spruce	3.3	25-30	26
Jack Pine	3.5	28-40	30
Balsam Fir	3.5	30-40	25
Northwest Region			
Douglas Fir	3.9	35-45	34
Western Hemlock	4.2	30-40	29
Redwood	6.1	50-65	25
Red Cedar	3.5	30-40	23
Hardwoods			
Aspen	1.04	10-27	27
Birch	1.85	20-36	38
Beech	1.20	16-22	45
Oaks	1.40	14-22	46
Red Gum	1.70	20-40	34



Blade Type

- **Pros**
  - Most economical solution
  - Sensitive and repeatable
  - Wide range - sensor designs
  - Built in pulp stock recipes
  - Robust solution
  - Wide applicability in fiber line and bleaching
  - Insensitive to air and conductivity swings
  - Customer acceptance
  - Sensor materials for bleaching

- **Cons**
  - Intrusive to process
  - Fiber only measurement
  - Can be sensitive to large velocity swings
  - Needs good pipe run although turbulence generators are efficient and cheap to install

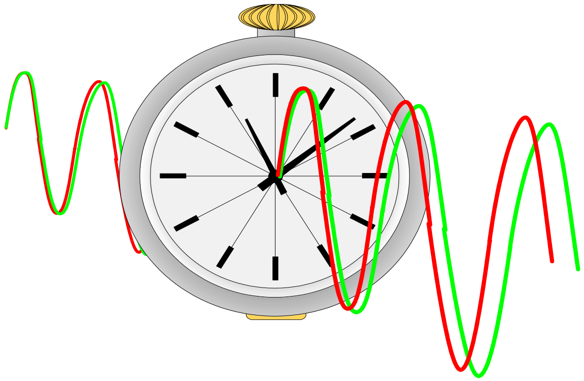
Rotary Type

- **Pros**
  - Sensitive and repeatable
  - Wide range - sensor designs
  - Built in pulp stock recipes
  - Robust solution
  - Wide applicability in fiber line and bleaching
  - Insensitive to air and conductivity swings
  - Customer acceptance
  - Sensor material for bleaching

- **Cons**
  - Intrusive to process
  - Fiber only measurement
  - High installation cost
  - High maintenance cost
  - Can be slow to adjust after disturbances – mechanical

Microwave measurement

- Around for 20+ years
- Most sensitive measurement
- Time of flight to consistency is linear relationship
- First choice for machine approach and stock prep applications
- Mostly used after bleaching process, with some exceptions



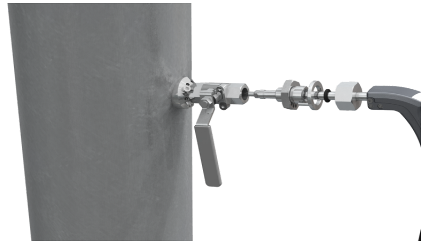
Microwave Type

- **Pros**
  - Most sensitive measurement
  - Total solids
  - First choice of paper makers
  - Insensitive to fiber mix, type, production swings or fillers
  - Wide range, linear to solids
  - Non intrusive, no moving parts
  - Mostly used after bleaching
  - Ideal in stock prep, broke, BW control and OCC applications
  - Simple calibration
- **Cons**
  - Conductivity limits
  - Sensitive to entrained air

Optical measurement

- Uses light reflection, dispersion, scattering or polarization or combination of above
- Around for 25 plus years
- Intended mainly for low consistency clean applications although manufacturers are pushing range limits

Optical Type

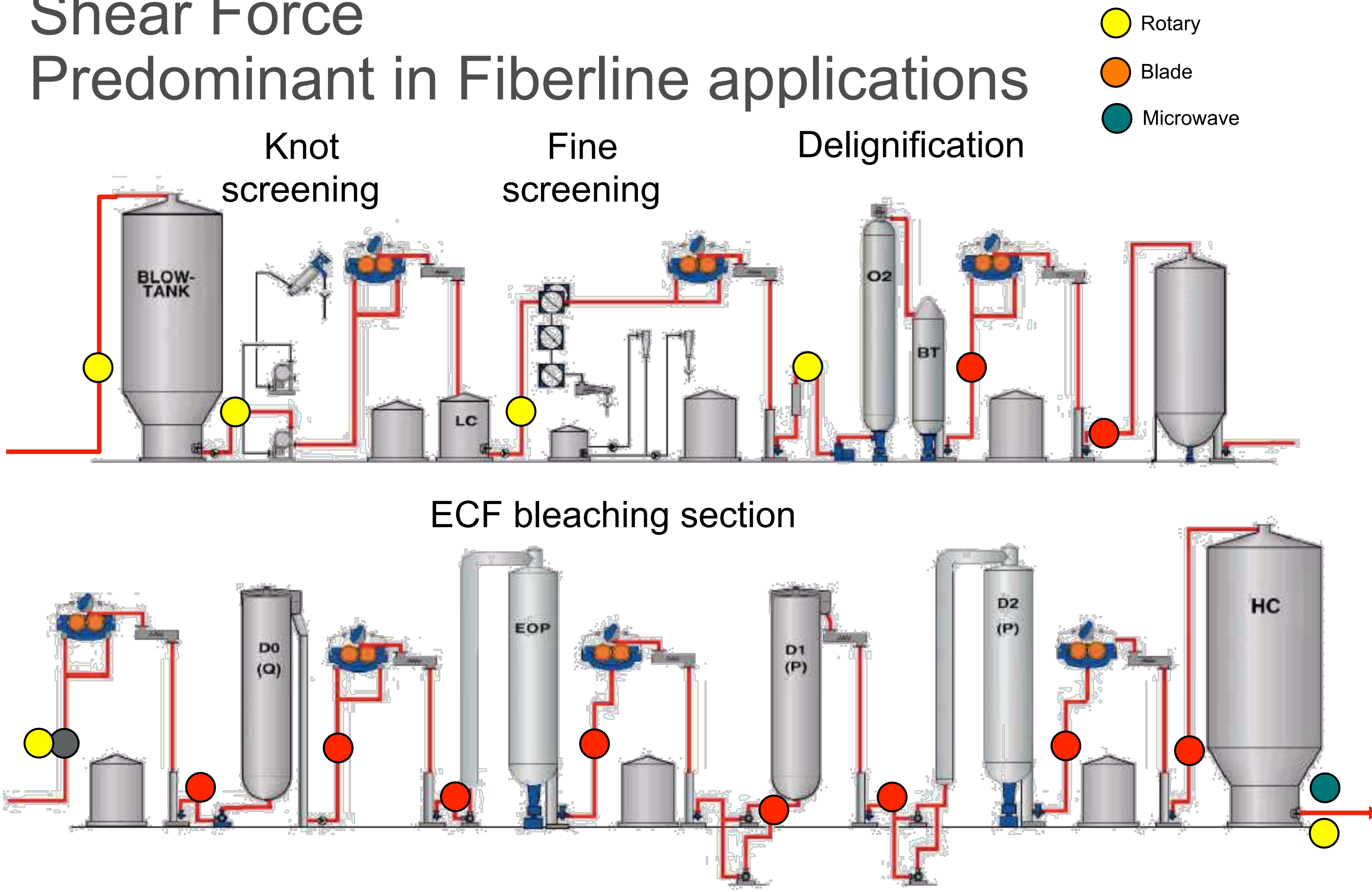


- **Pros**
  - Simplest installation
  - Best solution in low solids like white water circulation
  - No moving parts
  - Process removable
  - Can somewhat see fillers with recent technologies
- **Cons**
  - Range limits
  - Intrusive to process
  - Sensitive to color
  - Sensitive to freeness
  - Lens can become high maintenance issues in some mill processes – cleaning
  - Needs turbulent flow
  - Can be complicated to calibrate when fillers content vary

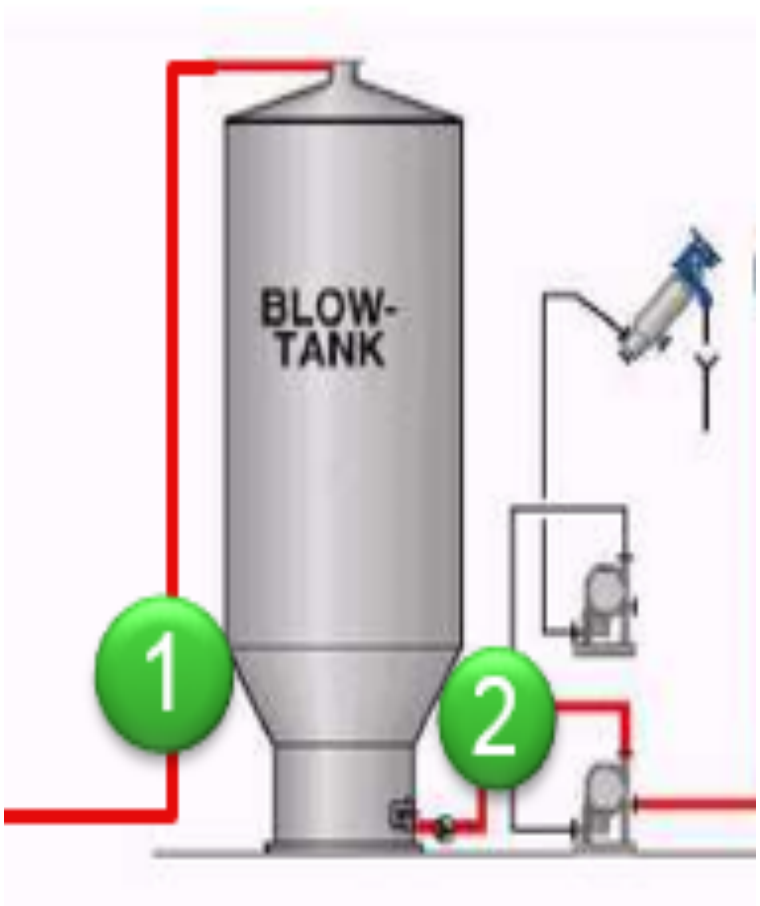
Sensor Comparison 1=weak 5=best

	Blade	Rotary	Microwave	Optical
Cs Range	4	4	5	3
Representative measurement	4	4	5	2
Sensitivity	4	4	5	4
Location piping	3	4	4	3
Flow profile	3	4	5	3
TSS (w/fillers)	2	2	5	3
Air content (P)	5	5	2	4
Brightness	5	5	5	3
Conductivity	5	5	3	5
Freeness	3	4	5	2
Ease of Calibration	4	4	5	3
Cost	5	2	2	3
Versatility	4	4	3	2

Shear Force
Predominant in Fiberline applications

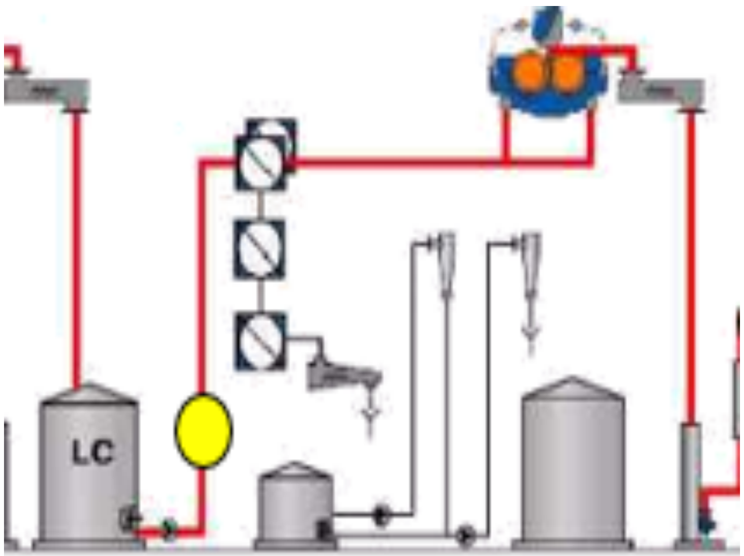


Critical Measurement
Digester blow and blow tank – rotary best



- First consistency measurement after cooking
- Reliable measurement helps control all downstream processes as well as help other measurements.
- Difficult location, sensor must be well protected.

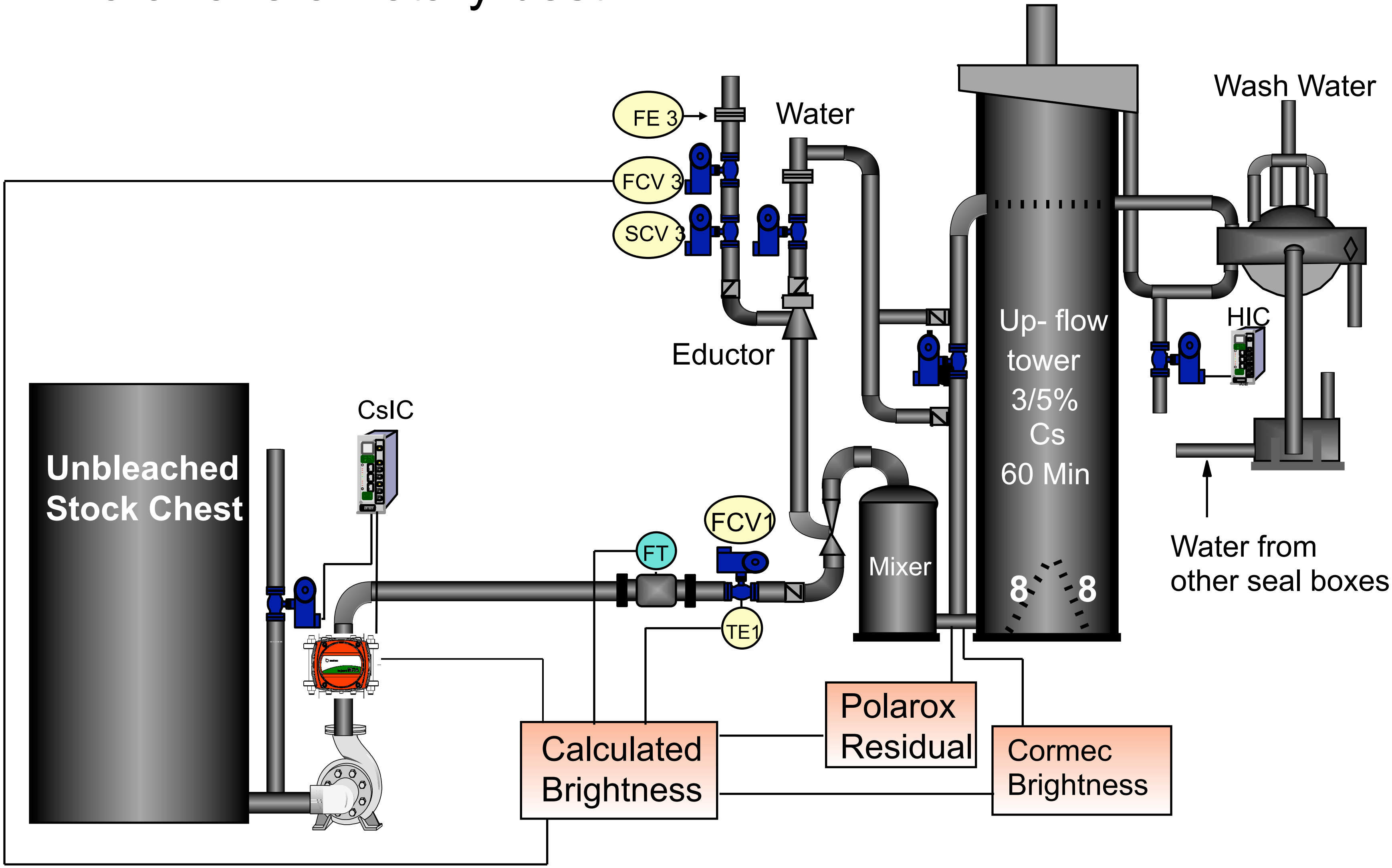
Critical Measurement
Feed to screening – rotary or blade best



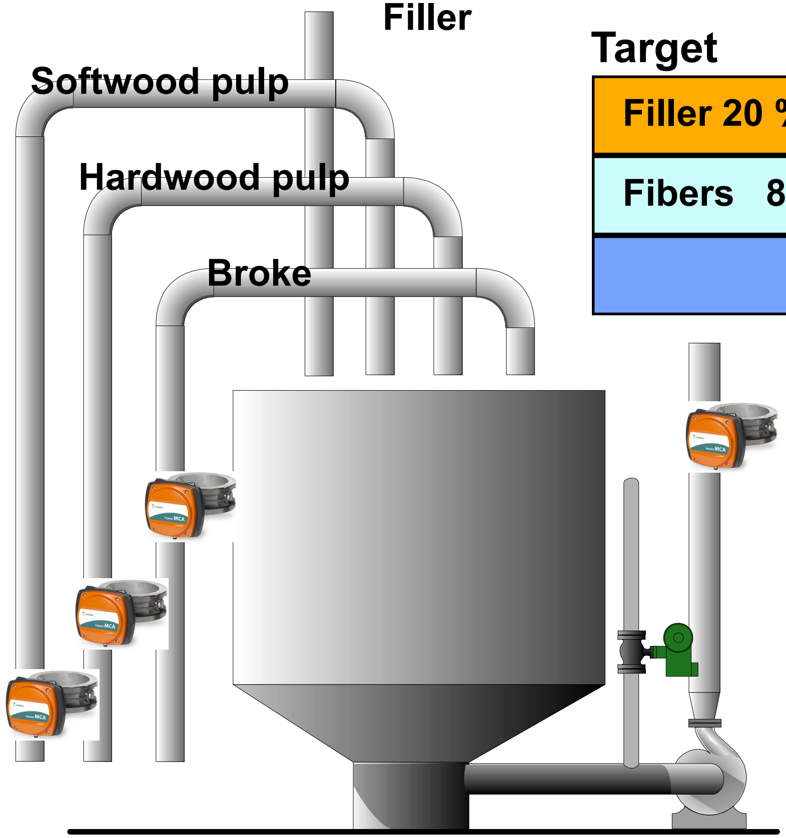
- Good measurement helps control the screening process.
- Impregnated chemicals mean shear force is best solution
- For late screening stages, such as in clean TMP process, lower consistency range may suit optical device.

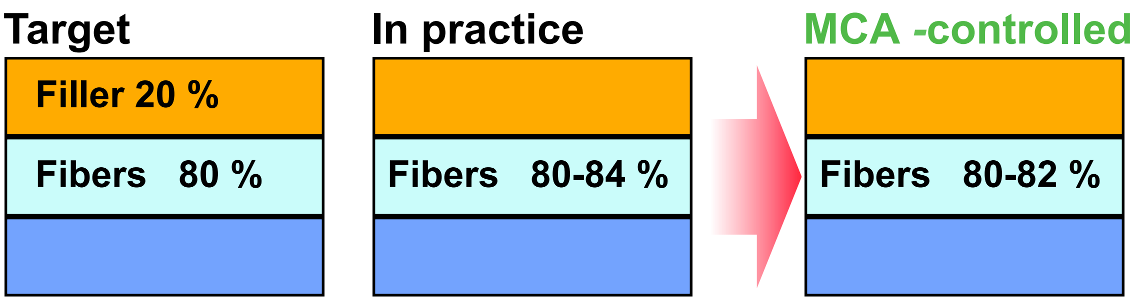
Critical Measurement

Stock feed to bleaching (chemical dosing) microwave or rotary best



Critical Measurement
Stock blending / stock prep – microwave best



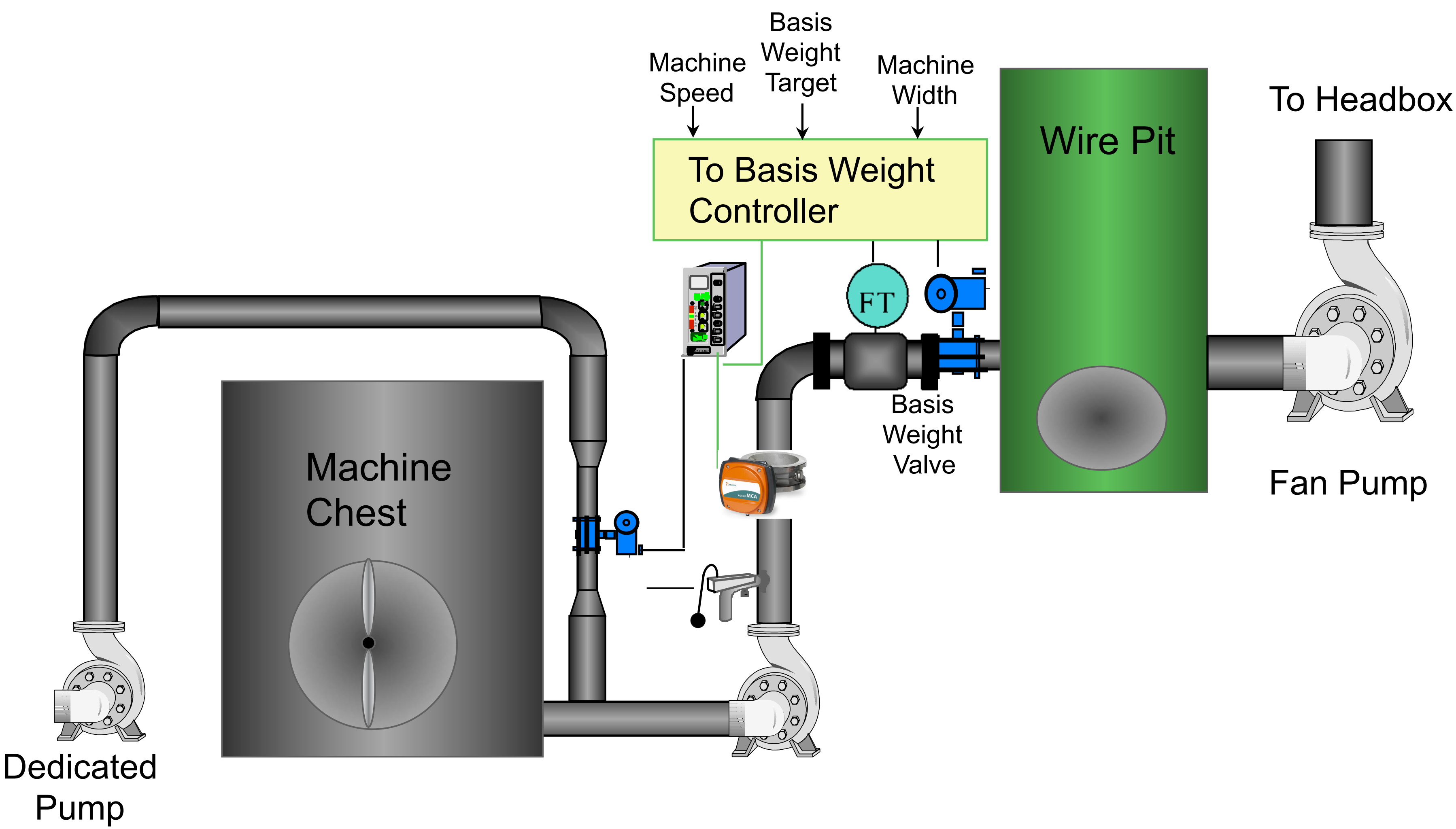


Production 100.000 t/y
1% (1000 t/y) of chemical pulp substituted with filler

$440,000 /a

Critical Measurement

FF BWC – improve CD/MD profile – microwave best



Consistency measurements
Things to think about

Influence of Consistency variation on ClO_2 comsumption

TX 1	Consistency %	Stock Flow lpm	Tonnage admtpd	Variation %	ClO2 %	[ClO2] g/l	ClO2 lpm	ClO2 kg/yr
	3.10	14000	694.4	-4.62	1.2	12.0	434	2624832
	3.25	14000	728.0	0.00	1.2	12.0	455	2751840
	3.40	14000	761.6	4.62	1.2	12.0	476	2878848
Std.dev (1 sigma)	0.15		33.6				21	127008

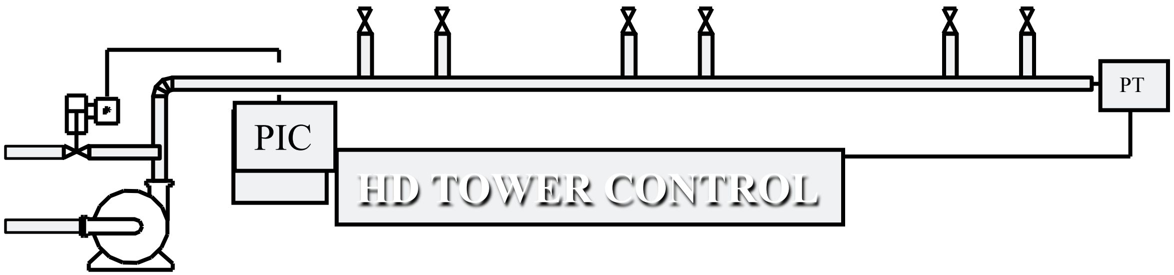
TX 2	Consistency %	Stock Flow lpm	Tonnage admtpd	Variation %	ClO2 %	[ClO2] g/l	ClO2 lpm	ClO2 kg/yr
	3.25	14000	728.0	-2.99	1.2	12.0	455	2751840
	3.35	14000	750.4	0.00	1.2	12.0	469	2836512
	3.45	14000	772.8	2.99	1.2	12.0	483	2921184
Std.dev (1 sigma)	0.10		22.4				14	84672

Operating day: 350 days/yr

If only chemical saving is seeked:

Reduction of std. dev. :	0.05	
Saving in chemical:	42336	kg/yr
Price of ClO2:	$3.50	/kg
Chemical Saving cost:	**$148,176**	**/yr**

Consistency Control Loop - Dilution

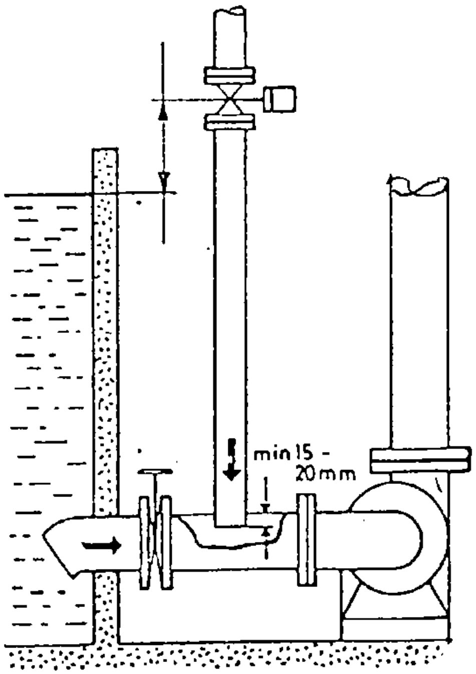


Consider for Header Pressure Control:

1. The pressure drop across the dilution control valve should be constant.
2. HD Towers and large intermittent users should have a dedicated pump.
3. If more than one consistency loop is supplied from the same header, the header pressure should be controlled to minimize interaction (VFD pump, or pressure control valve strategy).

Dilution Valve & Piping Installation

- Install valve as close as possible to the dilution point perpendicular to the stock flow.
- Dilution water pipe must enter main line close to the pump.
- Size the entry section to control flow velocity <4 ft/sec.
- Use a V-ported style ball valve.
- Valve to have a equal percentage inherit characteristic which leads to linearity under process pressure.
- Dilution water pipe to penetrate main line by ½ - ¾ inch minimum.



Process Dynamics for Consistency Loops

Targets

- Process Gain: 0.5-1
- Time Constant: 1 to 3 seconds
- Dead Time: 3 to 7 seconds

The process dynamics should be as linear as possible. A reasonable goal is that the process gain never changes by more than a factor of 2 over the entire operating range.

In double dilution strategy, pay attention to controller aggressiveness.

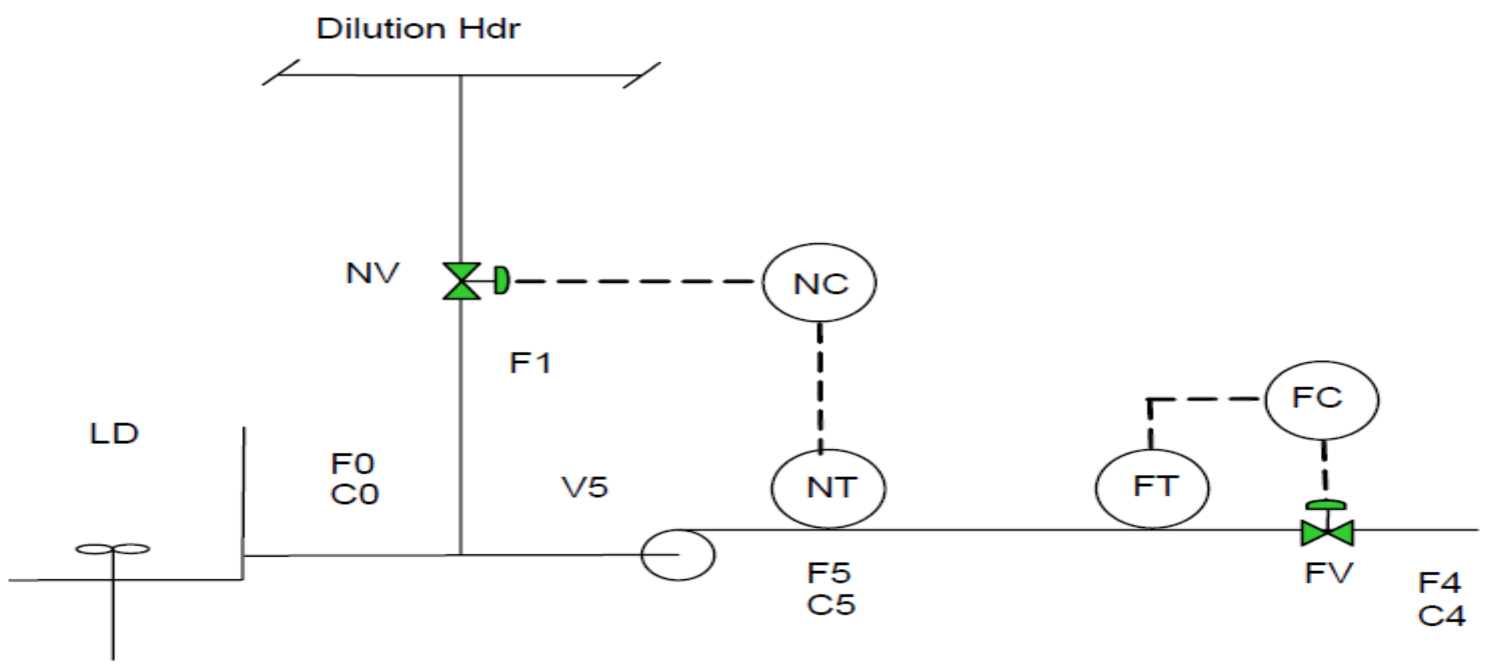
1. Small step, constant demand

Most common design

Fiber balance F4*C4 = F0*CO

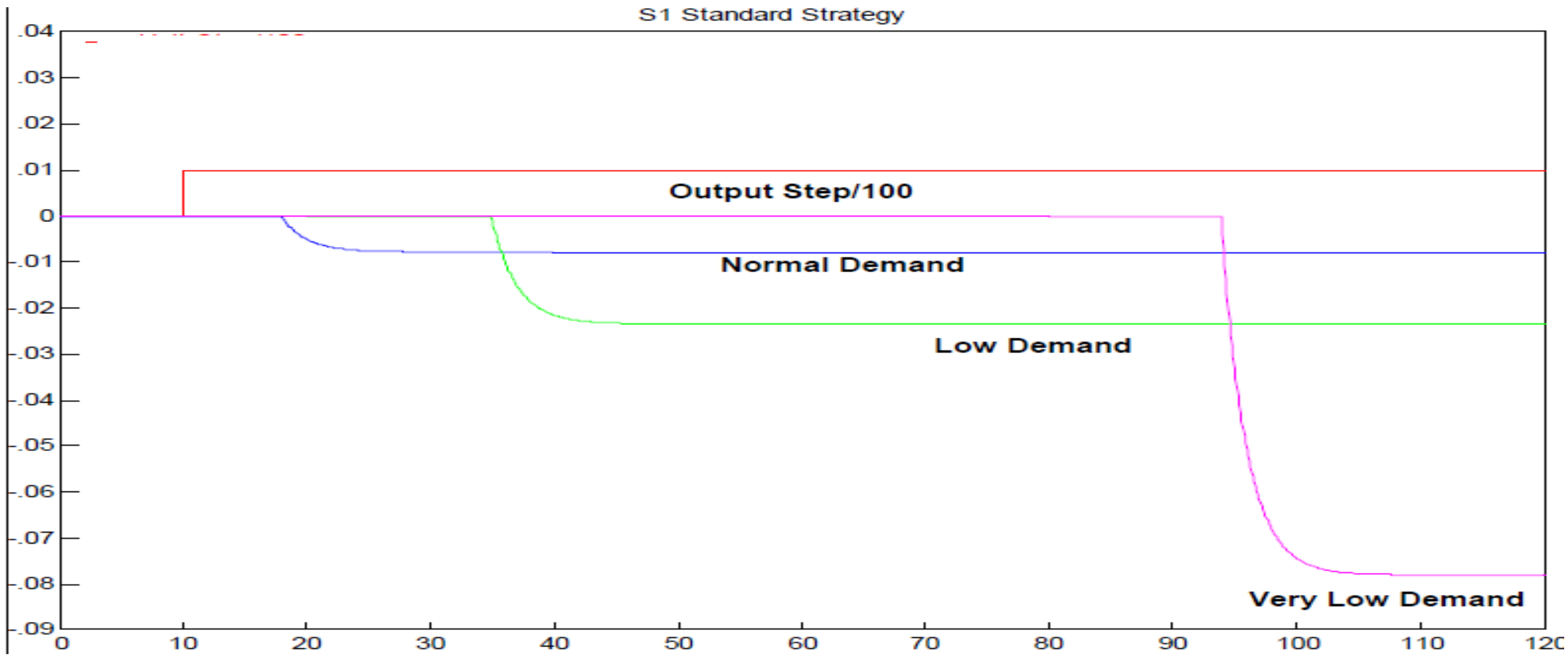
Consistency output controls dilution valve position.

Must have a linear gain installed control valve and stable header pressure!



1. Small step, constant demand
Response from open loop bump test

Simple strategy works well for normal demand



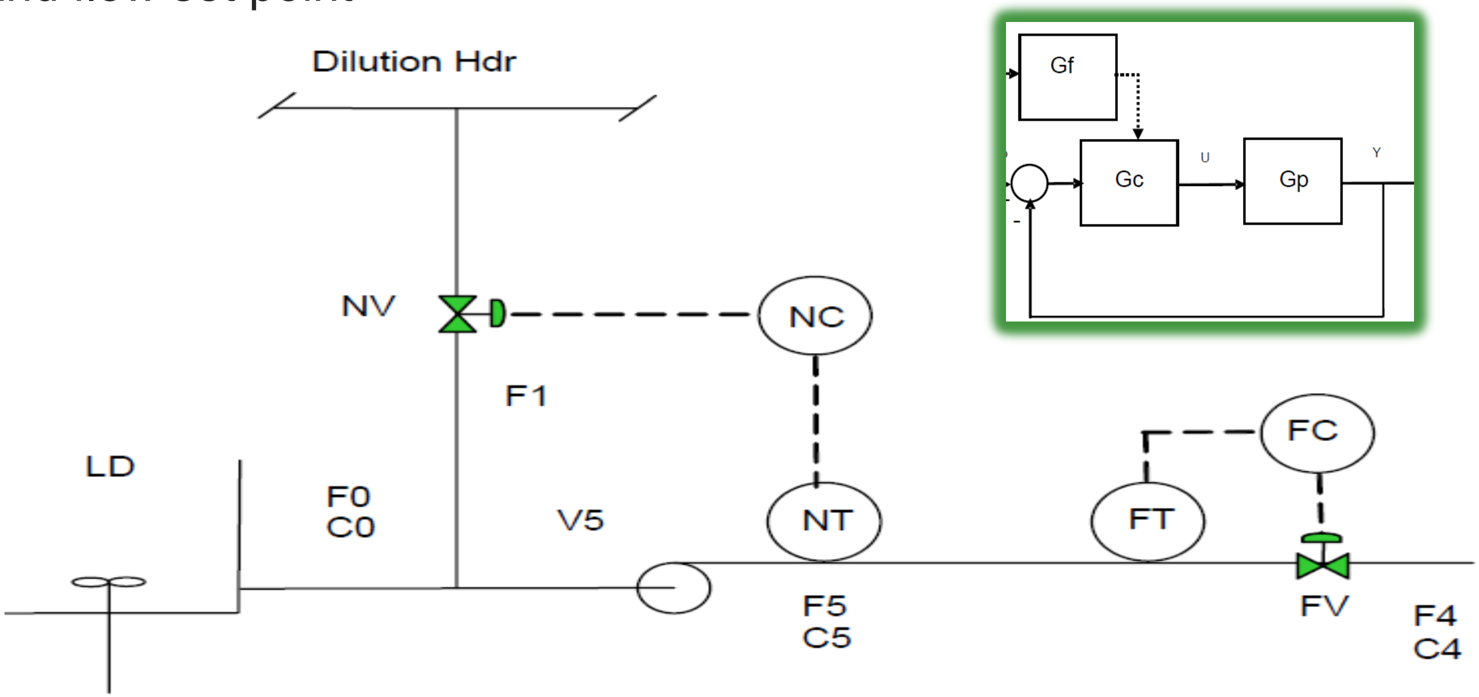
2. Small step, high demand flow (turndown)

Common in LD chests

Same strategy as first one, simple design

Same assumptions (header pressure, valve linear)

Add simple adaptive gain Gf determining controller gain and reset time based on demand flow set point

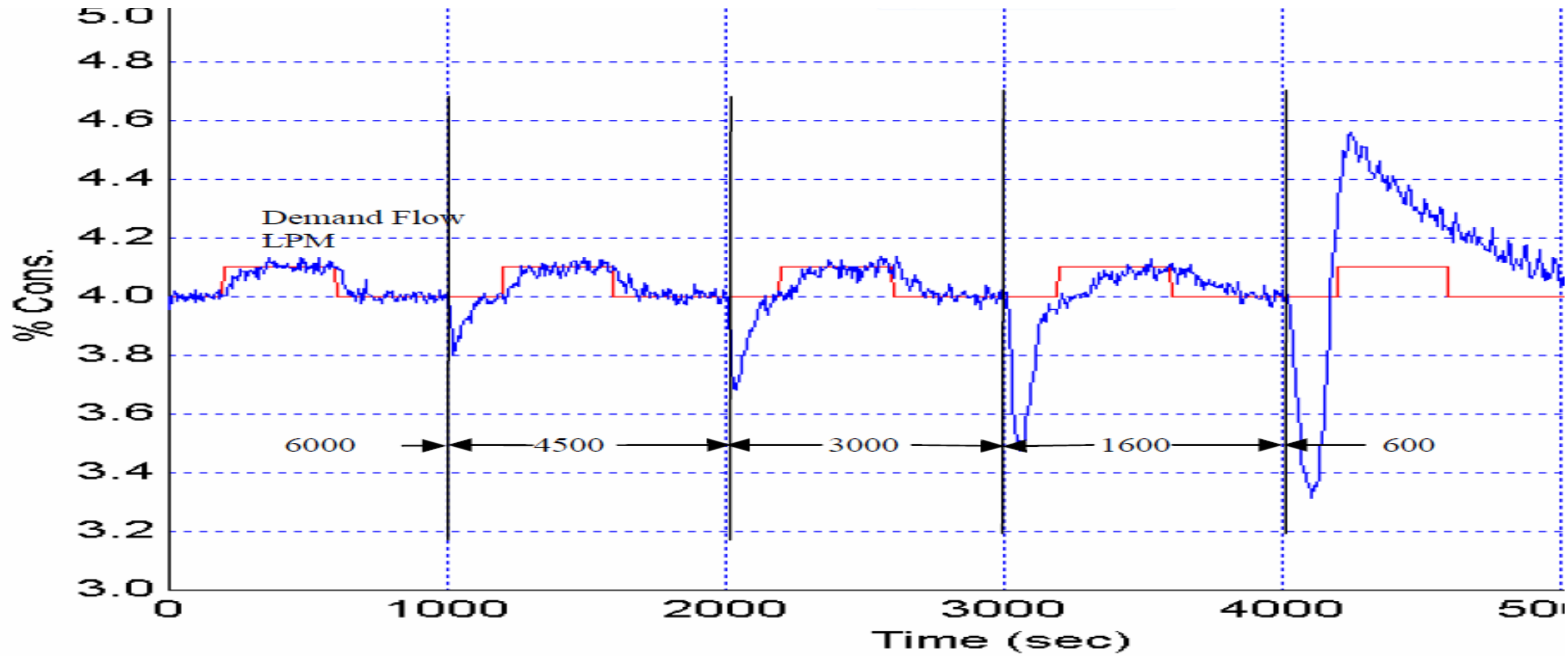


2. Small step, high demand flow turndown

Adaptive gain added – bump tests

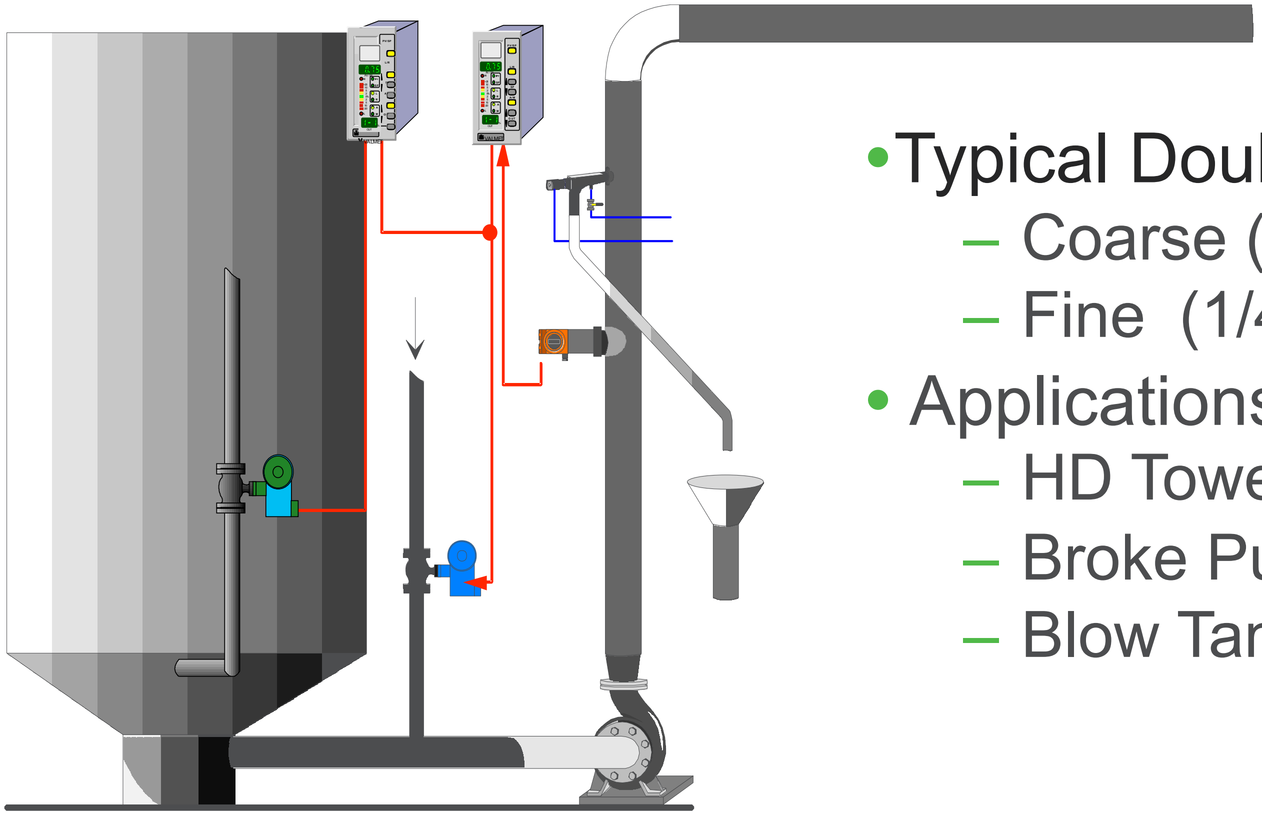
Simple strategy works better for flow variations

Note at low flows the process variable (PV) tracking the set point becomes sluggish, showing this works best for turndowns of less than 4 (6000/1600 LPM)



3. Large step, constant demand
Dual dilution system

A trim dilution valve is controlled from the consistency transmitter in the demand flow, at the same time that much larger water flow is controlled in dilution zone of tower.

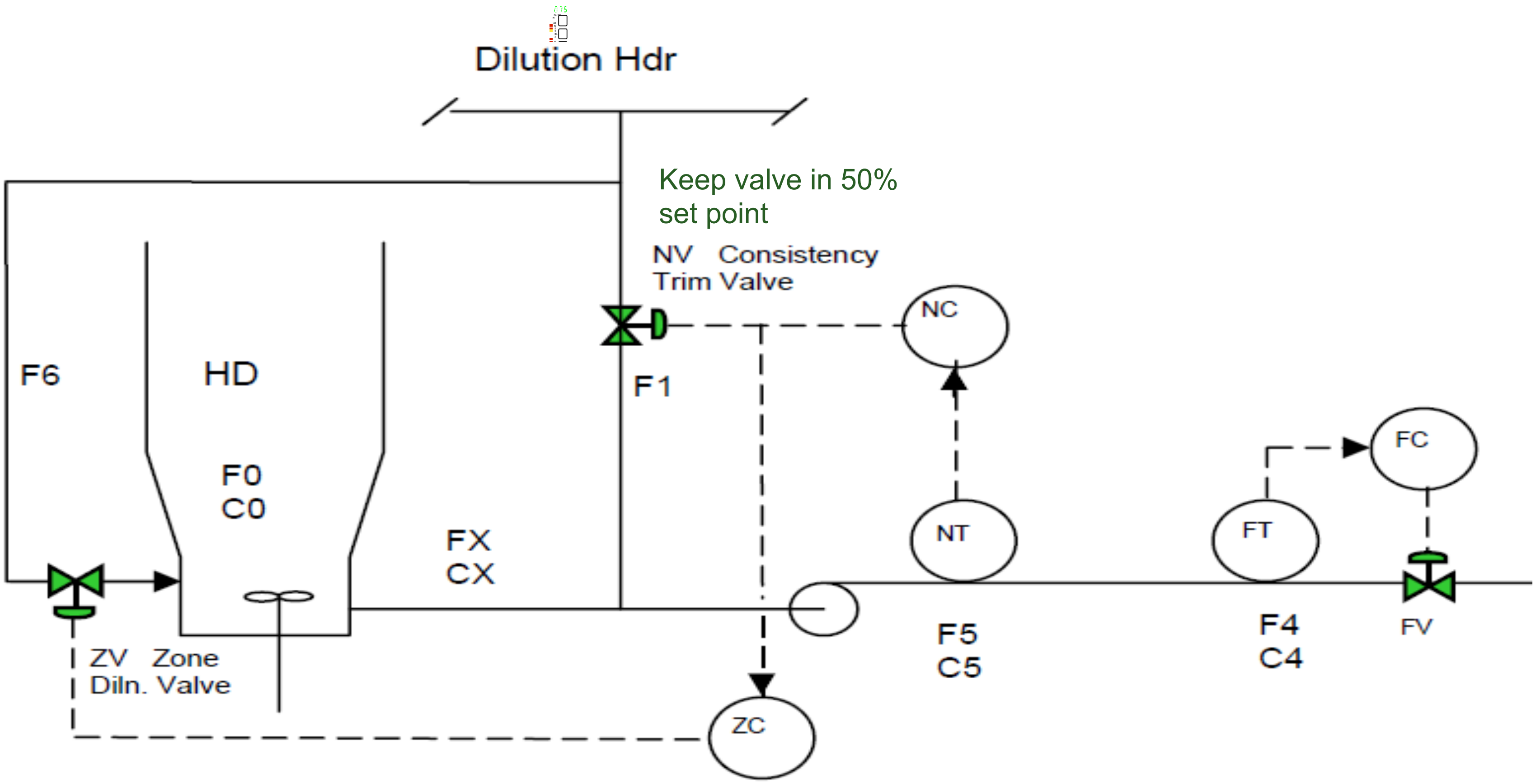


- Typical Double Dilution
  - Coarse (3/4)
  - Fine (1/4)
- Applications
  - HD Towers
  - Broke Pulpers
  - Blow Tanks

3. Large step, constant demand

Dual dilution system with mid range controller added (ZC)

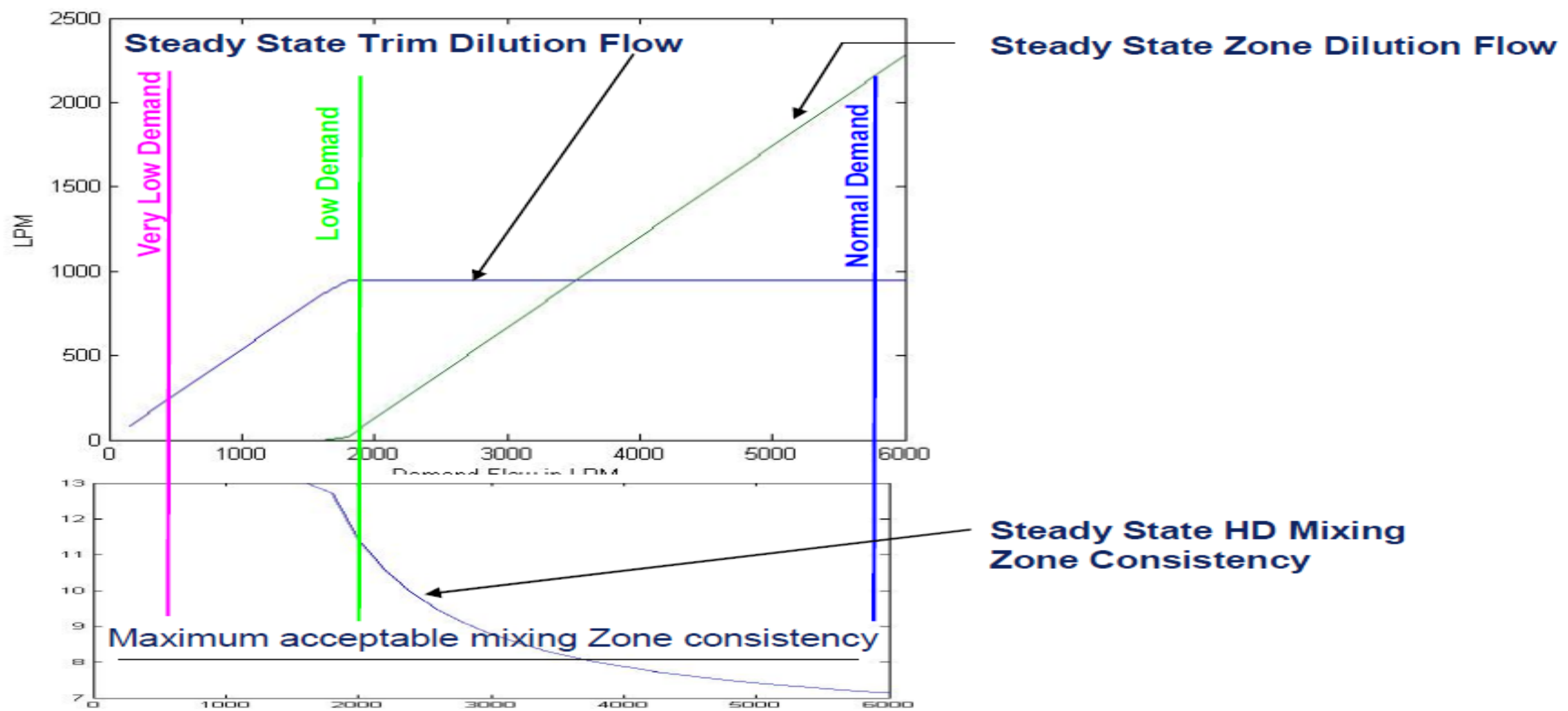
Common on HD towers, where dilution valve set point is kept at target (50%) tuned slowly, helps maintain a constant consistency in mixing zone when consistency of the supplied HD stock varies.



3. Large step, constant demand

Dual dilution system with mid range controller added (ZC) HD Towers example

Tower dilution flow midranges the trim dilution valve until the demand is so low that the tower dilution valve is closed. With tower dilution closed, if demand flow drops significantly, the strategy will not work.

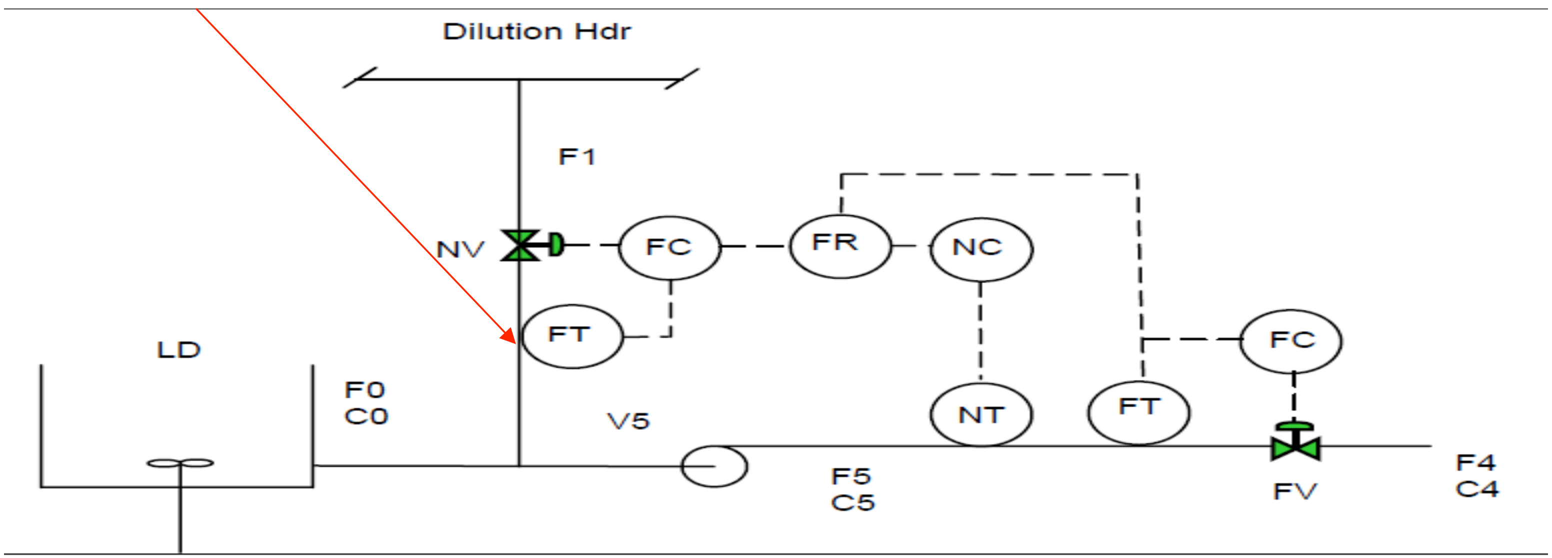


4. Large step, high demand turndown
Ratio control

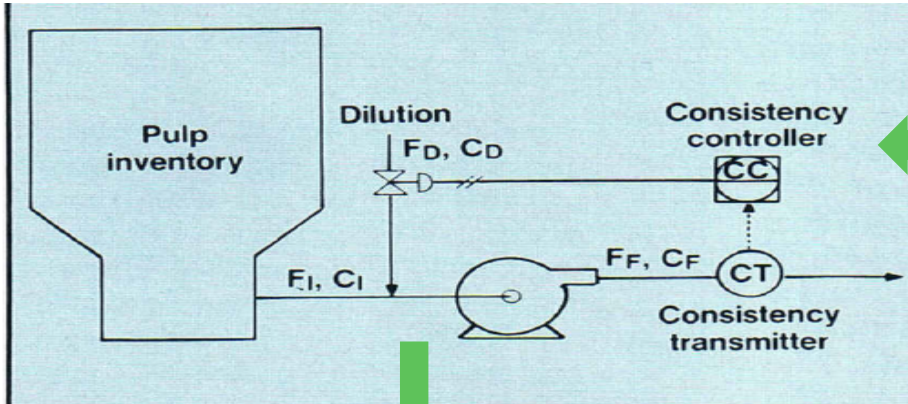
In this strategy the stock flow is multiplied by the consistency controller output. The product (scaled) becomes the remote set point of the dilution flow controller.

This strategy has feedforward capability since any changes in stock flow will instantly result in a proportional dilution flow set point change. The consistency will be relatively undisturbed. Great for machine chest application! The dilution flow controller will attenuate disturbances in header pressure even more effectively.

Added cost is a dilution line sensor, and a bit more complicated tuning.

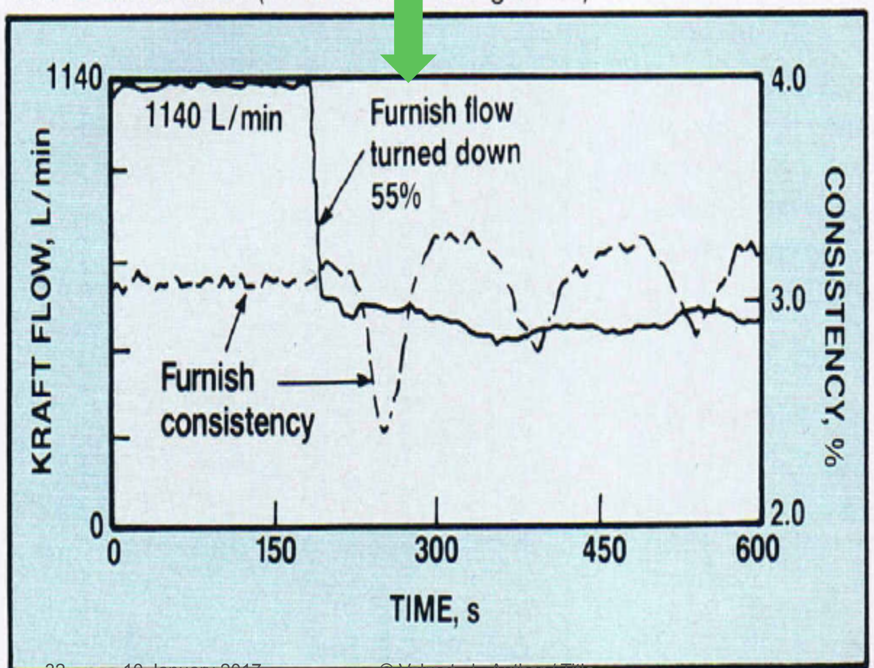


Ratio control can help eliminate cycling loops

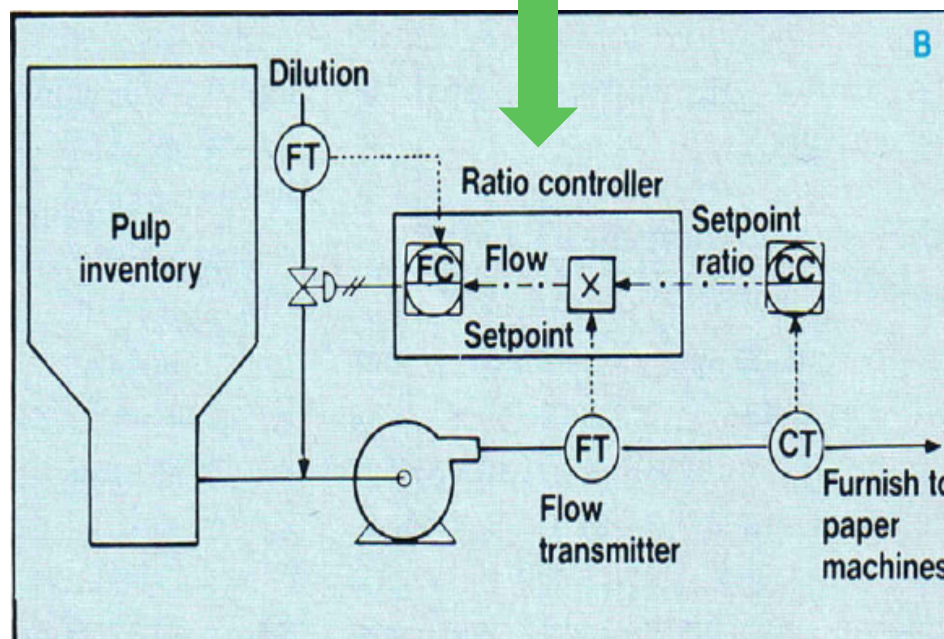


Typical loop set up based on Cs set point

3. Loss of stability with conventional consistency control when furnish flow is turned down (1140 L/min = 300 gal/min)



Perfect place to redesign with ratio flow control



Consistency Control
Think it through

- Poor mixing in chest/tower including dilution zone
  - Test agitation and mixing, review retention time
- Poor sensor and sampler installation
  - Review and adjust, small change can have drastic result
- Variable dilution header pressure – multiple demand
  - Use pressure control or similar strategy on dilution
- Poor control strategy / controller tuning
  - Review and adjust, many strategies available and proven in use
- Process dynamics like large demand flow turndown velocity
  - Be aware of loop behavior to various disturbances, as well as recipe needs
- Poor level control tuning of pulp storage chests
  - Target steady (70% full) level in towers to minimize work of the Cs loop
- Limited instrument calibration range
  - Production range variations can mean calibrating across demand flows

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