Tappi Webinar 2023:

Advanced Inline TDS Measurement Technology for Brown Stock Washing Optimization with Advanced Process Control

Keijo Pyörälä, Vaisala

Rick van Fleet, Andritz

VAISALA

Webinar speaker introduction

Keijo Pyörälä is a Business Development Manager of Vaisala Liquid Measurements. He has over twenty years experience of in-line concentration measurements and process control optimization projects. He holds M.Sc. degree in Chemical Engineering and has been involved in number of global projects in different industries from pulp & paper, food & beverages to chemical & polymer and oil & gas industries all over the world.

Keijo Pyörälä, Vaisala

Rick Van Fleet is working at Andritz Process Optimization as Global APC Owner and has been developing new advanced process control solutions for fiberline optimizations over twenty years. Prior joining Andritz he has been a Fiberline Business Development Manager at BTG Americas, Inc. specializing in Pulping Process Control and over twenty years with Honeywell in Phoenix, AZ holding several titles including Product Manager, Global Strategic Marketing Solutions Leader-Pulping Honeywell Process Solutions. Currently he is located in Atlanta, GA.

Rick van Fleet, Andritz

Agenda

1 Introduction

2 Inline TDS measurement benefits for operation efficiency and economics

3 Wash loss measurements and impact to mill efficiency

4 Continuous inline TDS control examples

VAISALA

Safety, Efficiency and Better Decision-Making

Pioneering in pulp mill in-line liquor measurements

Vaisala K-Patents® process refractometer is **industry standard** in the traditional **chemical recovery** applications (black, green and white liquor) in kraft chemical pulp production.

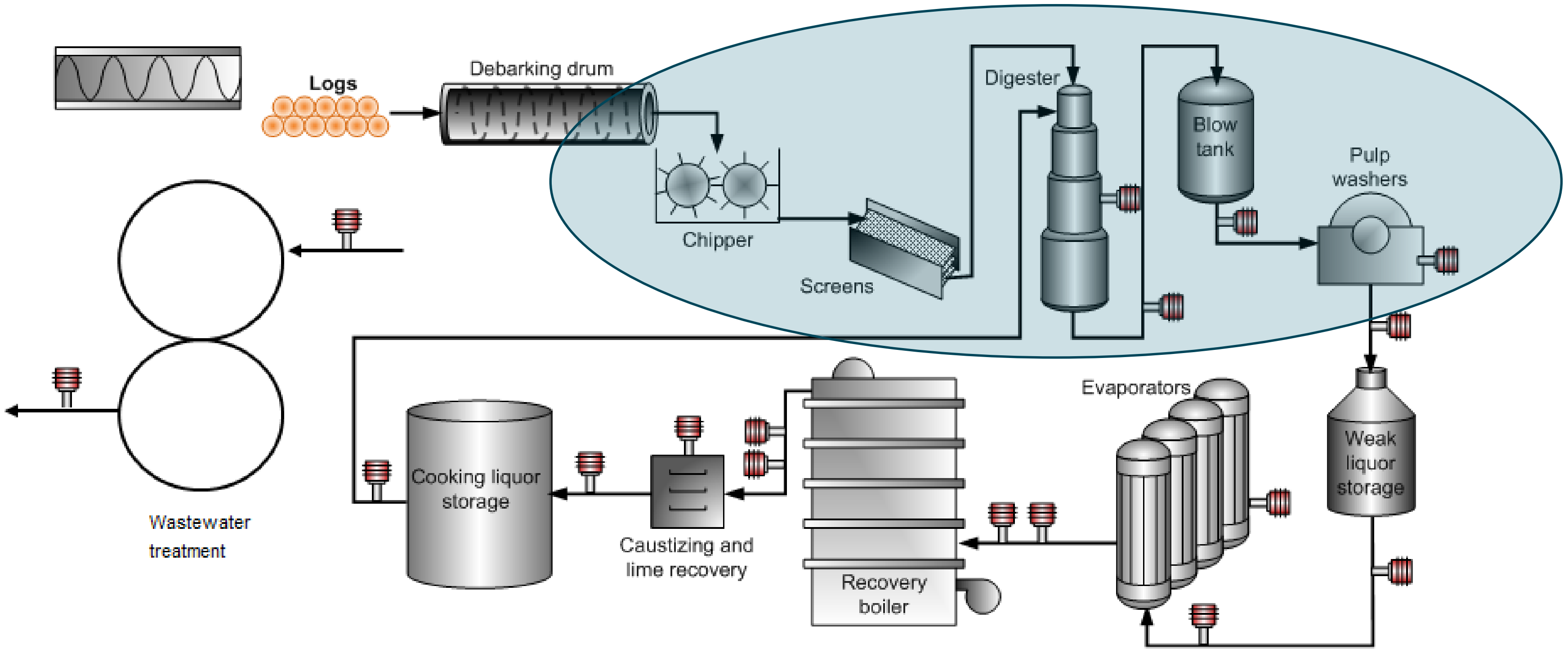
New applications in the **fiberline** have been developed to boost new sales in pulp mills:

- Brown stock (pulp) washing
- Oxygen delignification
- Continuous cooking optimization
- Batch digester optimization
- Wastewater treatment optimization

K-Patents SAFE-DRIVE™ refractometer in MetsäFibre Bioproduct Mill, Äänekoski, Finland.

Typical applications in chemical pulp mill

- **Brown stock washing application**: real-time measurement of Total Dissolved Solids (TDS) for ensuring economical viability the whole mill.
- Traditionally used methods were based in either off-line measurements or in the measurement of unsuitable parameters.
- Advanced process control to with reliable in-line measurement technology for higher process efficiency



Safe-Drive™ PR-23-SD Total Dissolved Solids Analyzer

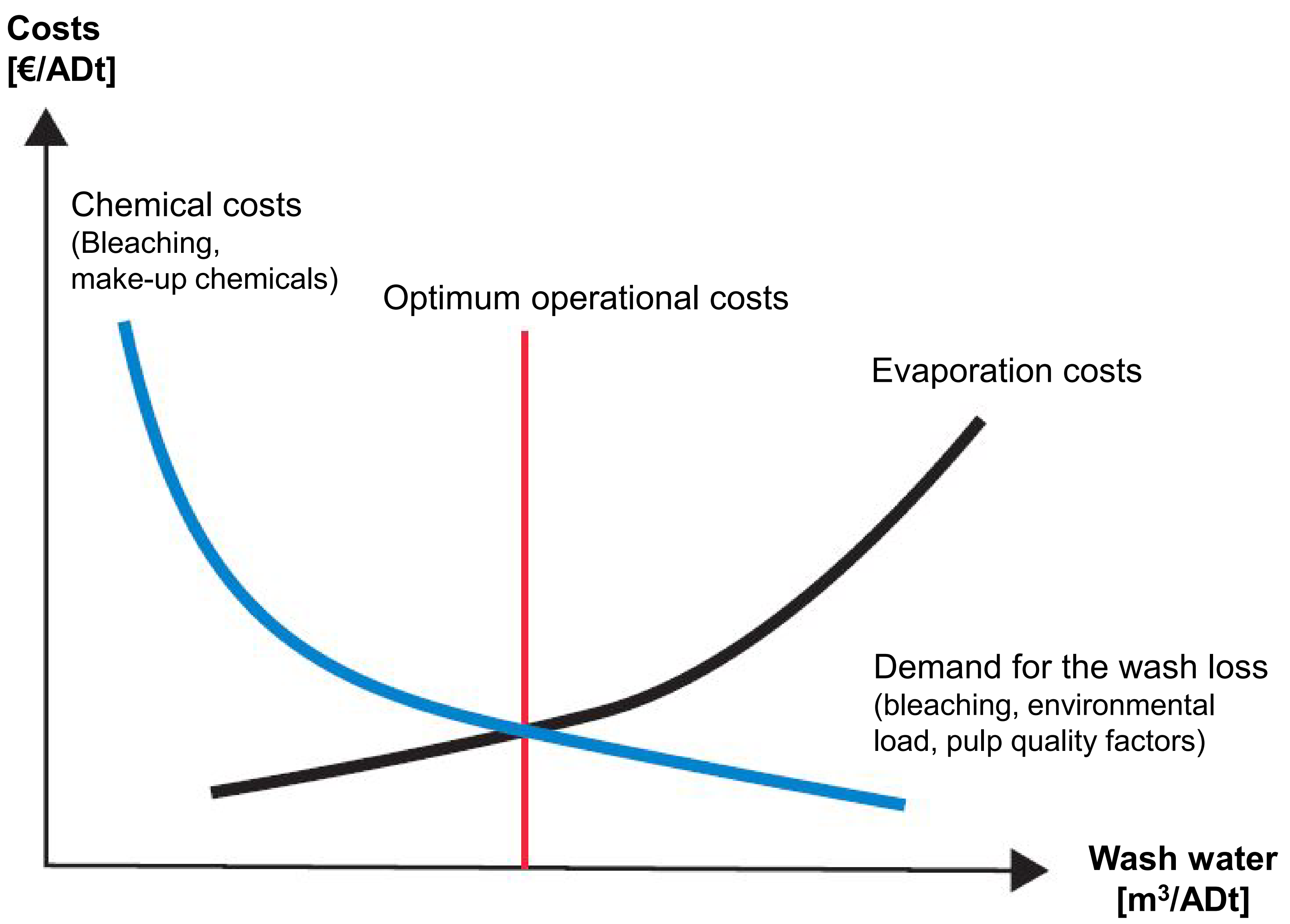
For Brown Stock Washing (BSW) optimization

- Accurate, reliable and continuous **TDS measurements**, for better control and continuous optimization of washing stages
- **Improved economics and environmental performance** of washing and the entire process

Brown Stock Washing Affects the economics and environmental load of the mill

- **Purpose**
  - **To remove dissolved inorganic and organic compounds from the pulp suspension:**
    - The organic fraction is a source of energy in the recovery boiler
    - The inorganic compounds are used for the regeneration of cooking chemicals
- **Outcome**
  - **An efficient washing line removes as much dissolved solids as possible while using the lowest amount of wash liquor or water**
    - Improves pulp quality
    - Improves subsequent processes (e.g. bleaching, waste water treatment), less chemical consumption
    - Decreases water consumption (higher mill capacity, less energy requirements for evaporation)

Use of Wash Water and Impact to Operation Costs



Measuring Washing Efficiency

- Washing efficiency is traditionally controlled in terms of **dilution factor** and **wash loss**

→ Dilution factor (DF) indicates the amount of water added during washing, and which ultimately dilutes the black liquor (m^3/Adt pulp)

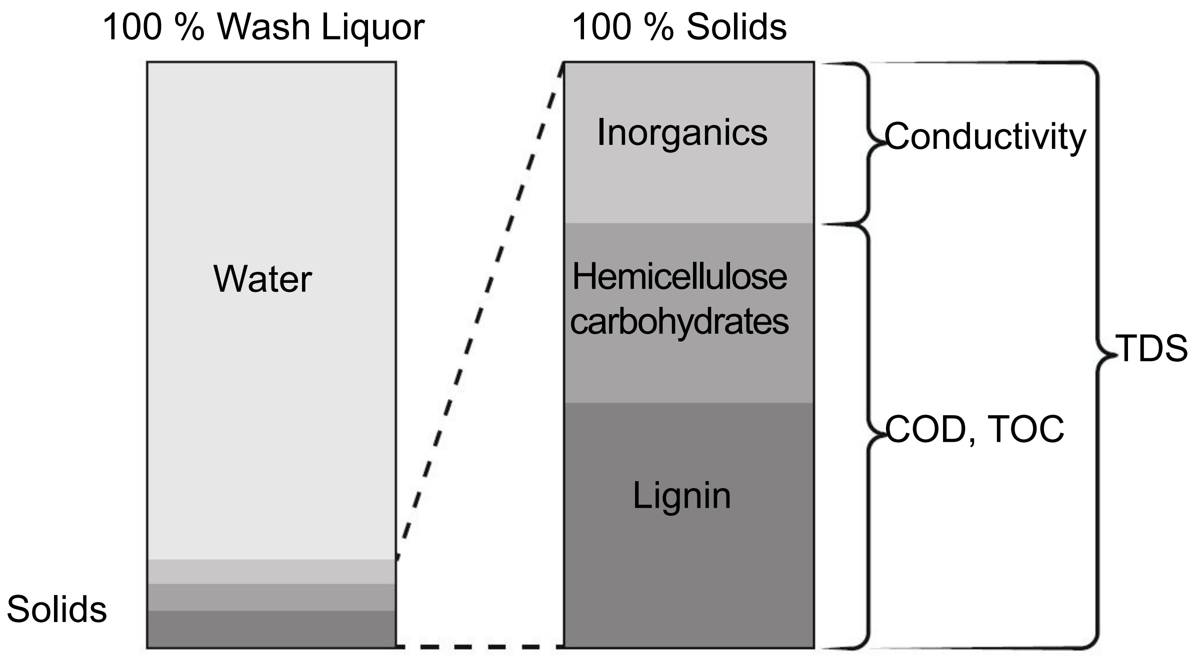
→ Wash loss is the amount of washable solids that could have been removed from the pulp suspension during washing. Often measured as:

- Total Dissolved Solids (TDS)
- Sodium, soda or salt-cake loss
- Conductivity
- Chemical Oxygen Demand (COD)
- Total Organic Carbon (TOC)

Fundamental of Wash Loss Measurement

- Monitoring and optimizing washing efficiency requires **accurate, reliable, continuous and real time wash loss measurements.**

- **Real wash loss measurements** should account for the dissolved organic and inorganic fraction in the pulp suspension.



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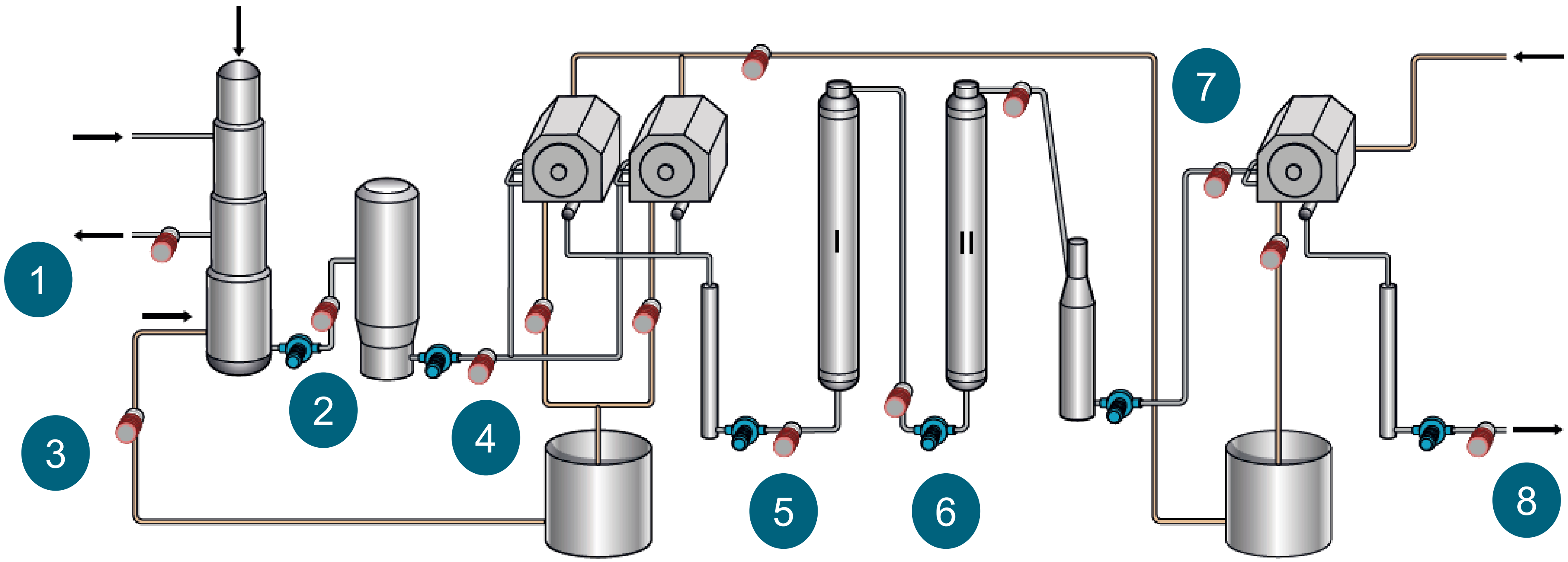
Continuous Fiberline TDS Control Optimization

- Continuous monitoring of individual washing process steps



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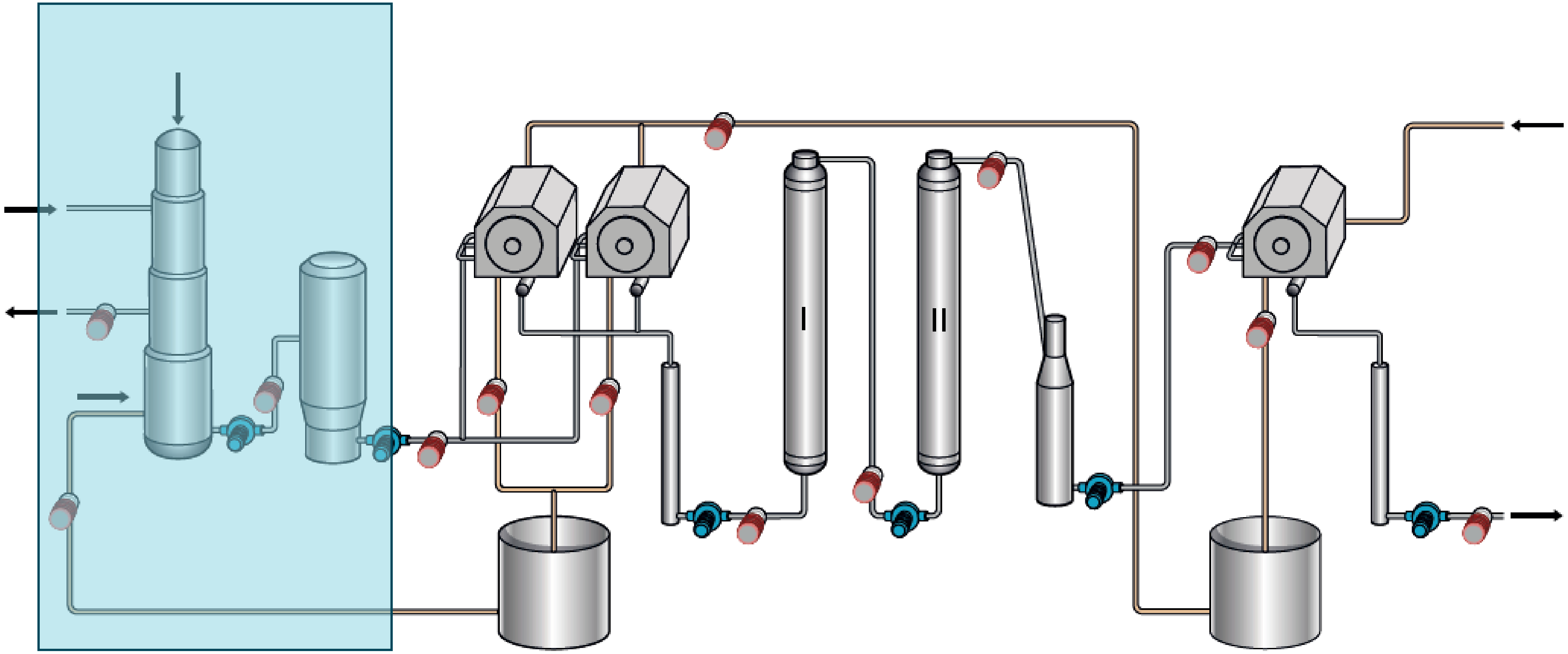
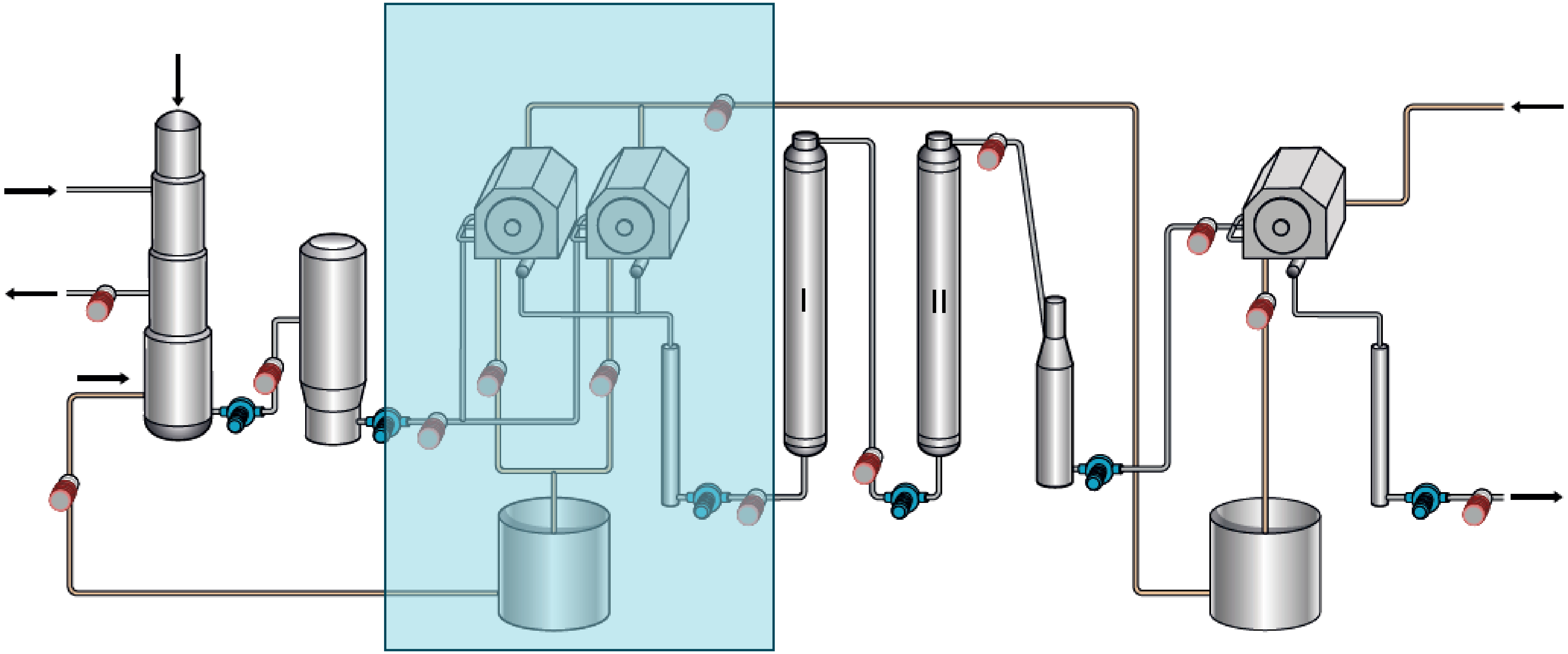
Continuous Fiberline TDS Control Optimization

- **Continuous digester TDS optimization cooking and washing extraction control**



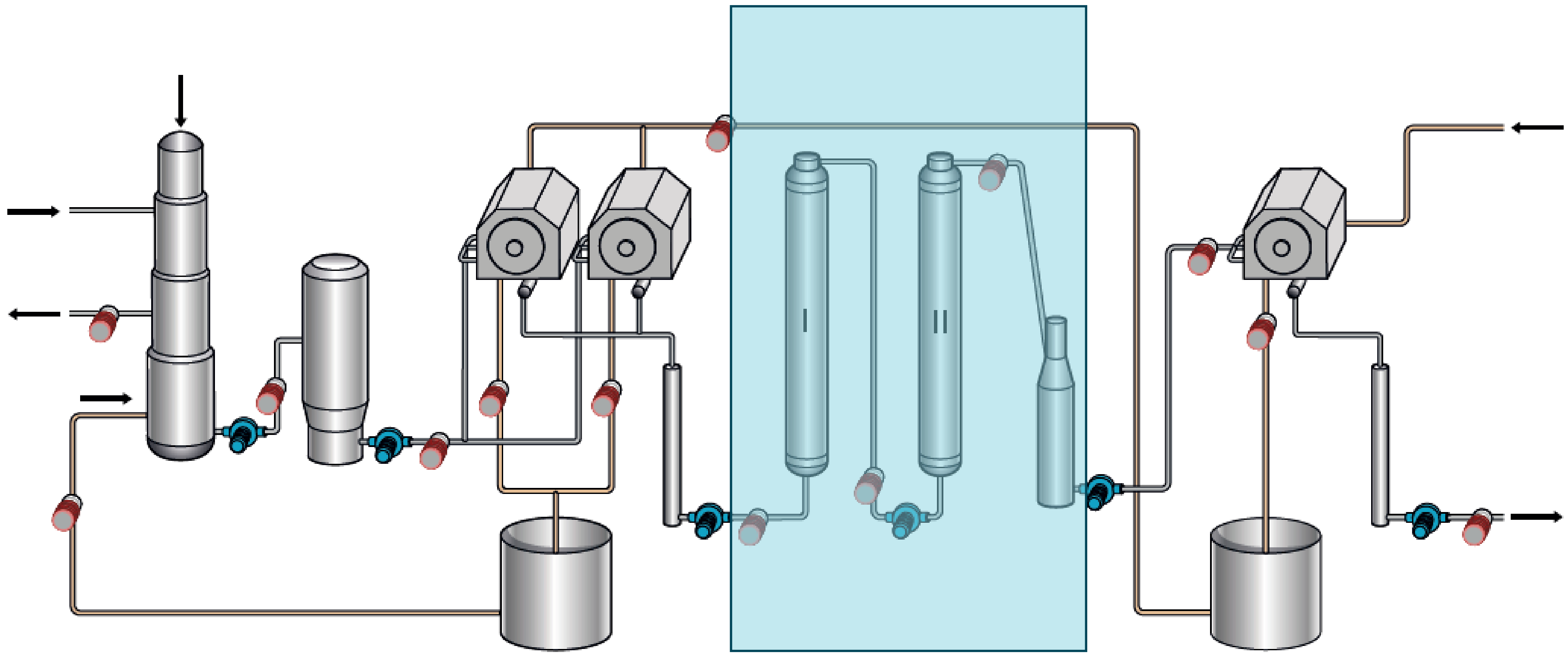
Continuous Fiberline TDS Control Optimization

- Continuous **brown stock washing TDS efficiency optimization** control



Continuous Fiberline TDS Control Optimization

- **Continuous oxygen delignification TDS kappa reduction optimization control**



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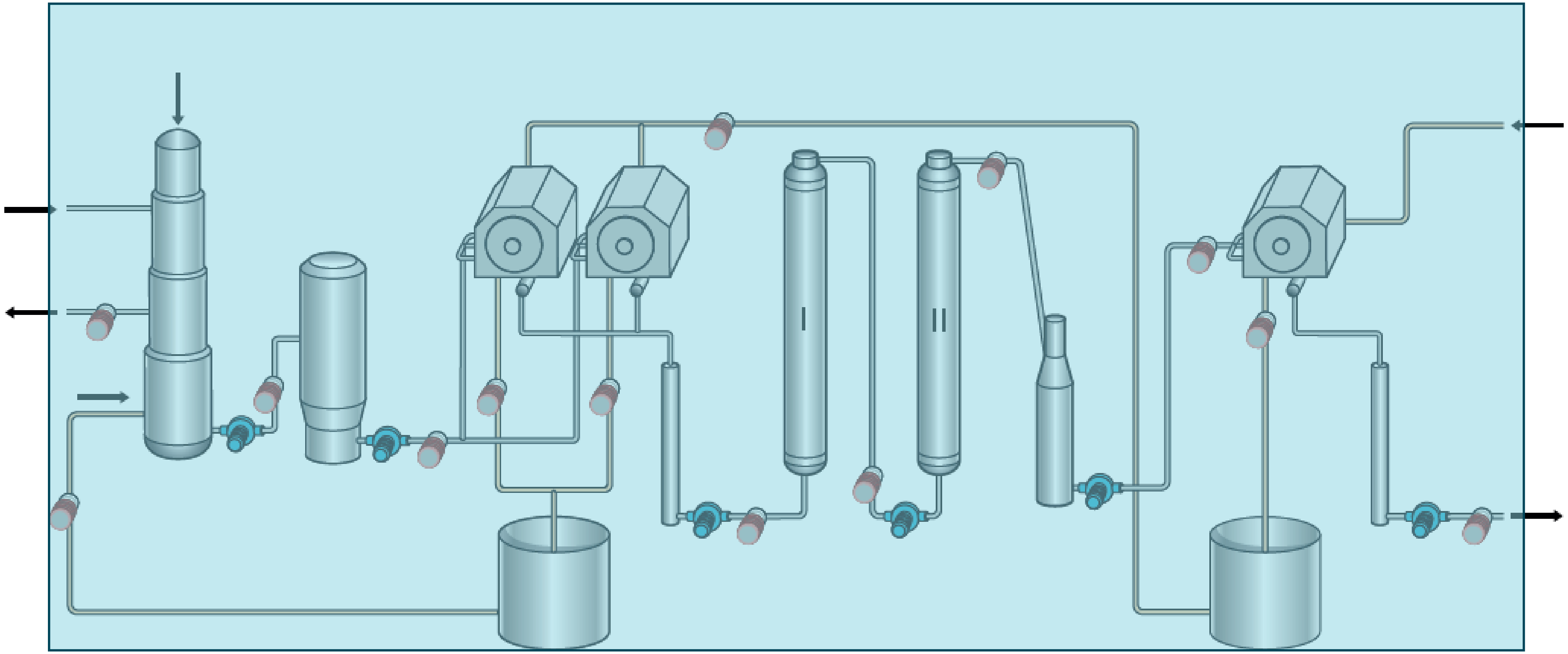
Continuous Fiberline TDS Control Optimization

- **Continuous fiberline TDS optimization** with advanced process control



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Features of Safe-Drive™ TDS Solids Analyzer PR-23-SD

- Indicates TDS in solution inline, suitable for all concentrations from 0 to 100%
- Measures precise exact concentration of washable liquid substances
- Detects organic materials with large molecular size, such as lignin
- Not influenced by COD caused by methanol
- In-line, real-time measurement, immediate response time, suitable for control
- Mounts directly in the pulp line
- Low operating costs, practically maintenance-free

Inline TDS Measurement BSW Optimization Benefits

- Enables monitoring the EFFICIENCY of the washing operation
- Low WASH LOSS in the pulp suspension, better pulp quality
- REDUCED amount of chemicals required in the bleaching stage
- REDUCED costs of effluent treatment plant, improved environmental performance
- IMPROVED pulp washing control with advanced process control

Inline TDS Measurement BSW Advanced Control Optimization Benefits

- Improved pulp quality
- Less formation of harmful organic compounds, less load to effluent treatment
- Improved recovery of cooking chemicals (Na and S) and wood based dissolved organic materials
- Increased recovery boiler efficiency
- Optimized use of energy
- Enhanced mechanical performance of the washers, longer life-time
- Improved process runnability
- Moderate initial investment; return on investment (ROI) typically less than a year

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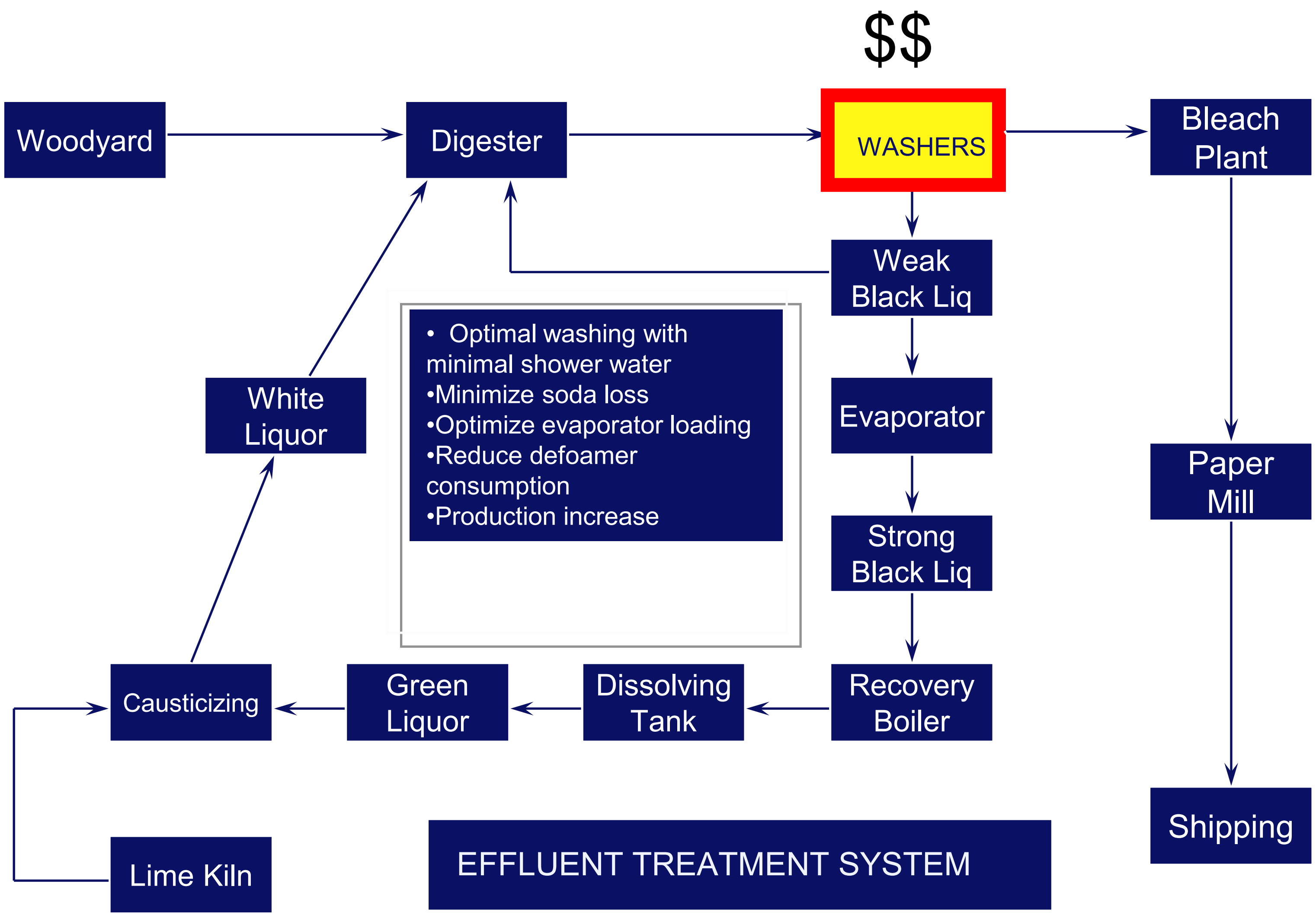
ANDRITZ AUTOMATION

BROWNSTOCK WASHING CONTROL - OPTIMIZED DILUTION FACTOR USING INLINE TDS MEASUREMENT

RICHARD VAN FLEET
04/04/2023

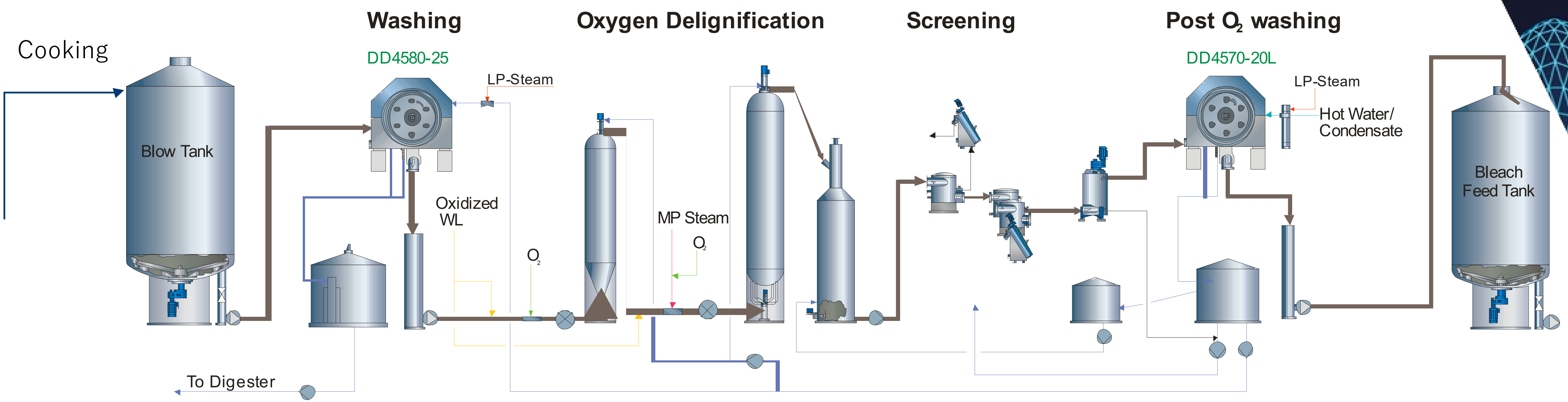
ANDRITZ
ENGINEERED SUCCESS

WHY CONTROL BROWNSTOCK WASHING?



- Optimal washing with minimal shower water
- Minimize soda loss
- Optimize evaporator loading
- Reduce defoamer consumption
- Production increase

WASHING THEORY – BROWNSTOCK WASHING



The brown stock washing operation refers to the separation of the dissolved wood solids and chemicals from the pulp before the bleaching process. It is carried out in multiple countercurrent stages.

BROWNSTOCK WASHING OBJECTIVES

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Produce clean pulp for bleaching or papermaking, by separating black liquor from blown digester pulp

Accomplish with an acceptable economic balance of:

Minimal carryover of spent cooking liquor and dissolved lignin in pulp (minimal "soda loss")

Maximum solids in weak liquor (H_2O must be evaporated- $$)

Minimal discharge to sewer (environmental permit issue)

Minimal use of hot process wash water (energy-$$)

WASHING THEORY

The pulp leaves the digester at 10% - 12% consistency. The liquor with the pulp is still very dark due to the high dissolved solids content.

PULP FLOW = FIBERS + (WATER + DISSOLVED SOLIDS)

DISSOLVED SOLIDS = ORGANIC + INORGANICS

WASHING THEORY – THE BIG PICTURE

THE TASKS:

1. Send the **CLEAN FIBERS** to the bleach plant
2. Send the **DISSOLVED SOLIDS** to the recovery island:
   - **ORGANIC** to be burned in the boiler to produce **ENERGY**
   - **INORGANIC** to be recovered in the recaust to produce **WHITE LIQUOR**

WASHING THEORY

Brown Stock Washing – The Big Picture

Most of the **dissolved solids** are in the water solution

A smaller part of the **dissolved solids** are bound to the fibers

- The solids in the water solution can be washed by displacement.
- The solids bound to the fibers can only be washed by diffusion and capillary flow – both dependent on time.

WASHING THEORY – DISSOLVED SOLIDS

ORGANIC

It is mostly lignin and other wood constituents

Usually expressed as COD (chemical oxygen demand)

The organic material dissolved in the cooking process consumes chemicals in the Oxygen Delignification and Bleach Plant.

1 kg of COD = 0.6 – 0.8 kg of ClO_2 (as TEC)

It can be burned to generate energy for the mill

WASHING THEORY – DISSOLVED SOLIDS

INORGANIC

The inorganic material is chemical carry-over from cooking and oxygen delignification.

It is mostly Na salts

The inorganic material carried over consumes chemicals in the acidic stages of the Bleach Plant.

Measured as amount of sodium (often Na_2SO_4 or Na_2O)

It can be recycled to produce white liquor for the digester

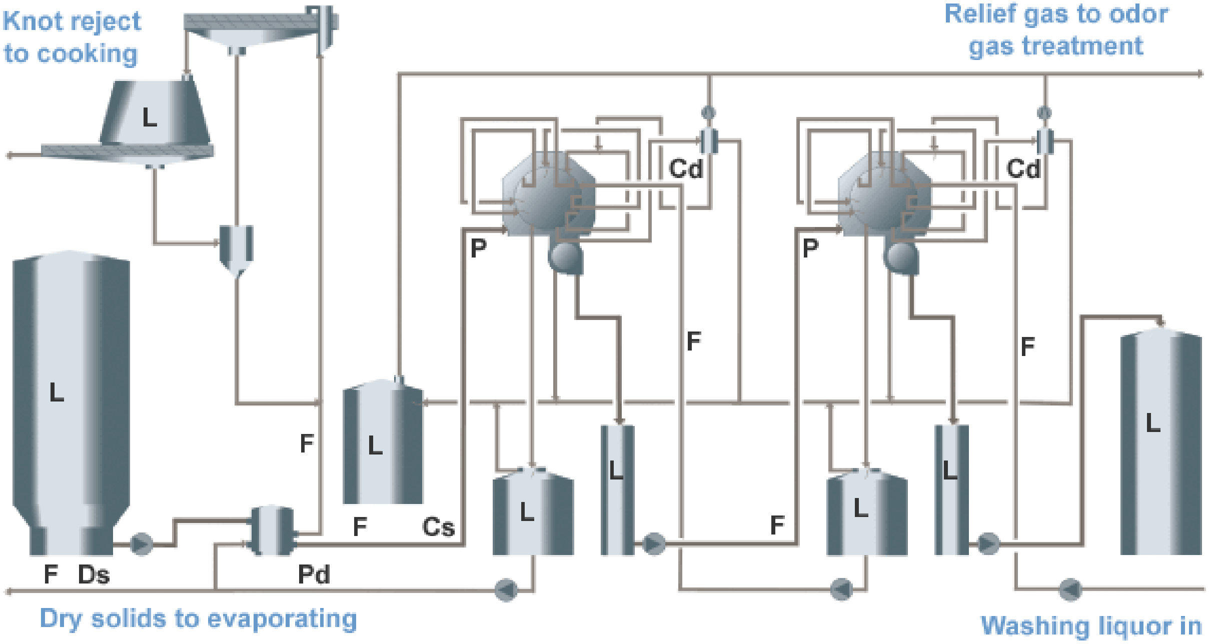
METRIS UX/X WASHING ACE™

Cost Optimization – Dilution Factor ⟷ Production Rate

Weak Black Liquor Solids Control

Conductivity/COD Control

Shower Flow Control



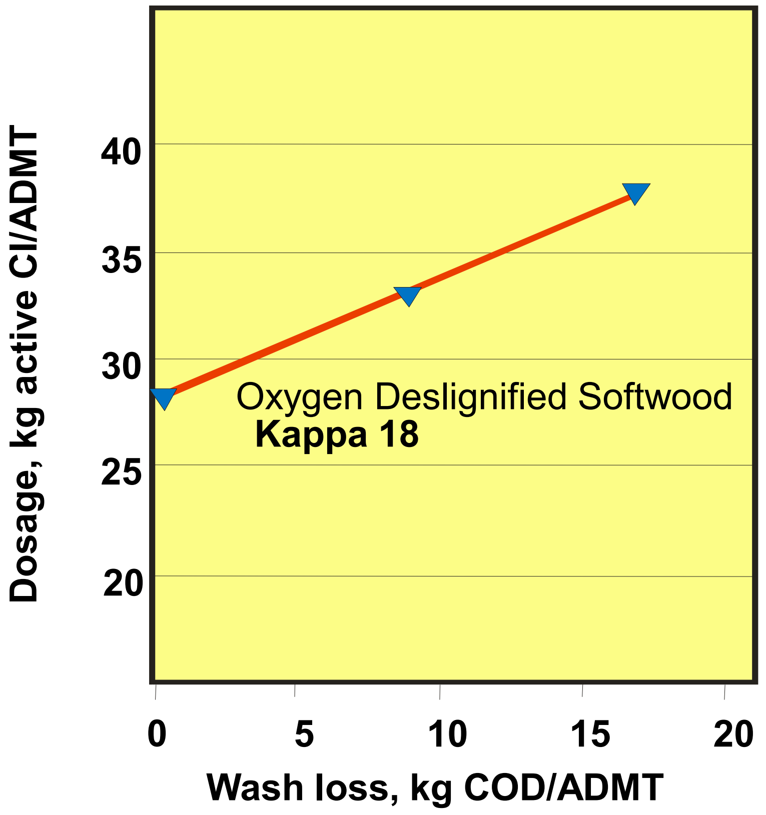
WASHING THEORY

Brown Stock Washing – Reasons to Wash

- **COST** - The organic material dissolved in the cooking process consume chemicals in the Oxygen Delignification and Bleach Plant.

- **COST** - Cooking or Oxygen Delignification dissolved solids consume bleaching chemicals

= REDUCTION IN CHEMICAL CONSUMPTION



Effect of wash loss on D_0 stage chemical consumption

WASHING THEORY - SUMMARY

Brown Stock Washing – Reasons to Wash

+ **COST** – The organics in the black liquor are burned in the recovery boiler generating power and steam to run the mill

+ **COST** – the chemicals in the black liquor are recovered in the recaust area and are used again in the cooking process.

= **RECUPERATING CHEMICALS AND WOOD COMPONENTS (ENERGY)**

WASHING THEORY - SUMMARY

Brown Stock Washing – Reasons to Wash

+ **OPERATIONS** – there will be less problems due to foaming (resins and fatty acids + metal ions + air), therefore there will be fewer operating problems and lower defoamer consumption.

+ **OPERATIONS** – less pitch (which occurs due to the wood extractives, and it varies with the wood type, production rate increase and water circuit closure)

= **LOWER DEFOAMER CONSUMPTION AND OPERATING PROBLEMS = HIGHER PRODUCTION**

TYPES OF BROWNSTOCK WASHERS

1. Counter-current washers: Counter-current washers are the most common type of brown stock washers and work by passing the pulp through a series of washing stages. The pulp flows in one direction, while the washing liquor flows in the opposite direction, allowing for efficient removal of impurities. Counter-current washers are relatively simple and cost-effective, but they require large amounts of water and energy to operate.
2. Rotary drum washers: Rotary drum washers consist of a large rotating drum that is partially submerged in a washing bath. The pulp is fed into the drum, which rotates continuously, allowing the pulp to be washed as it passes through the washing bath. Rotary drum washers are effective at removing impurities from the pulp, but they require more maintenance and are less efficient than counter-current washers.

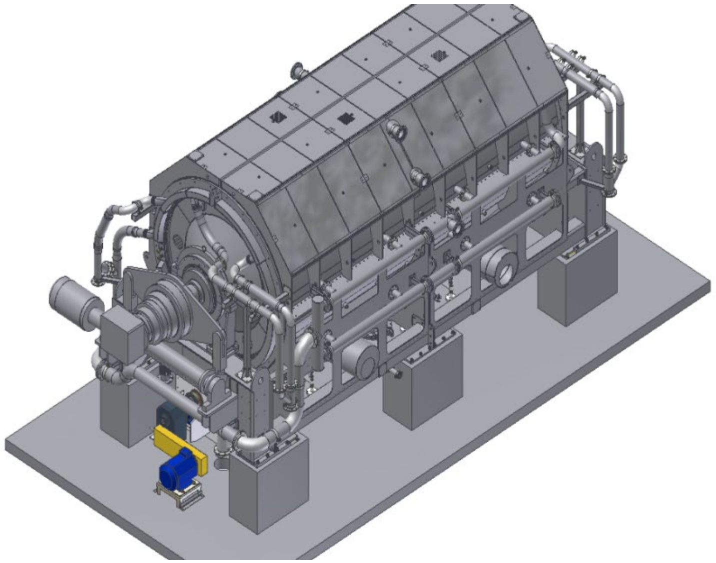
Each type of brown stock washer has its own advantages and disadvantages, and the choice of washer depending on the specific needs and requirements of the pulp mill.

WASHING THEORY

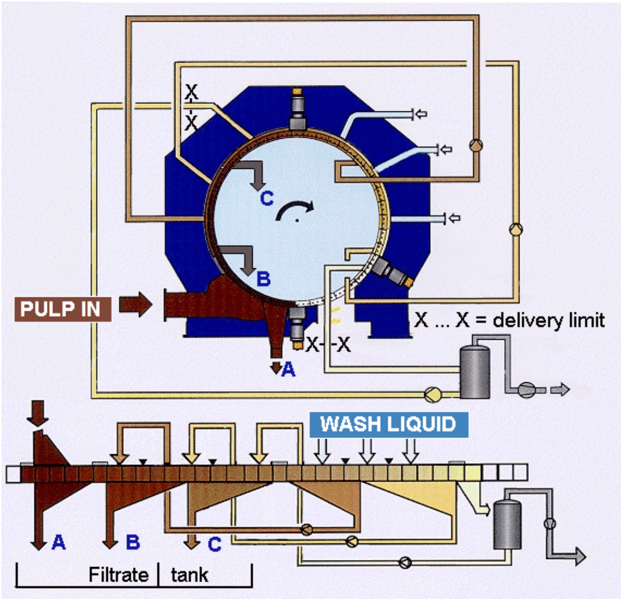
Brown Stock Washing – Amount of Washing

MULTIPLE STAGES

Andritz DD™, Drum Displacer, washers are multistage machines and can process up to 4 washing stages in one only machine. Other equipment usually require multiple pieces to perform the same amount of washing.



Stages of Washing
1. Thickening
2. Displacement
3. Extraction
4. Discharge



METRIS UX/X PROCESS CALCULATIONS

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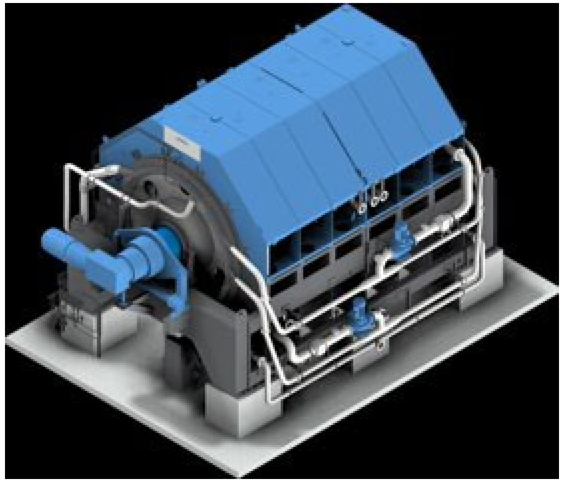
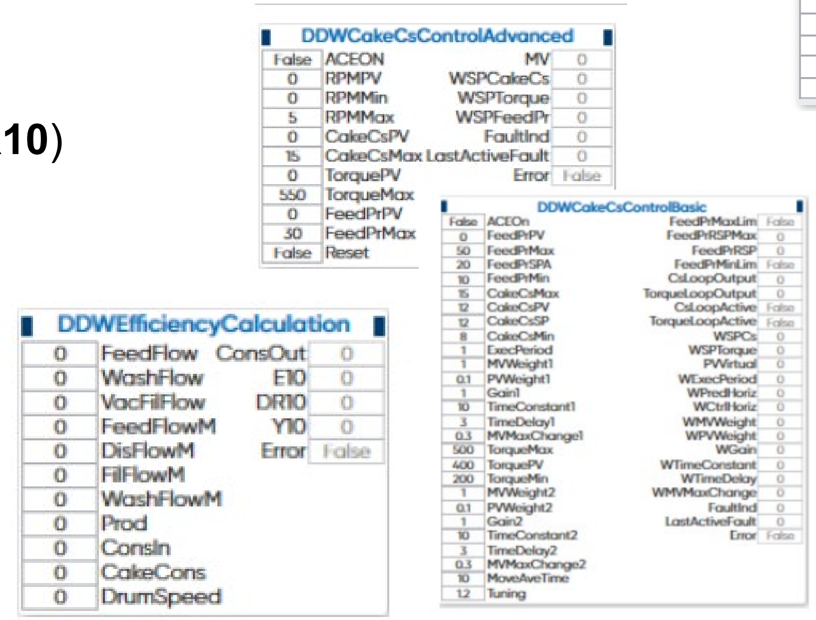
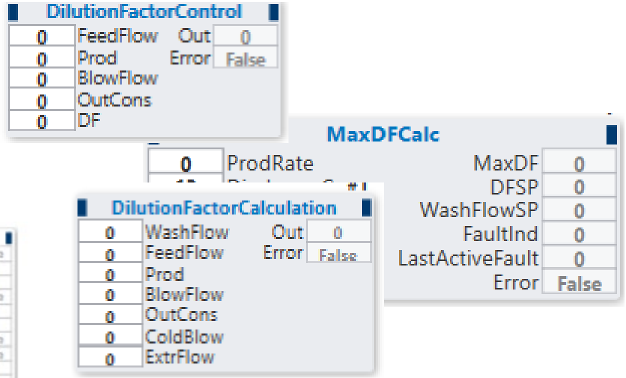
Efficiency Controls for Brown Stock Washers

- Realtime calculations to indicate washer performance and efficiency.
- Those indicators include:
  - Maximum Dilution Factor
  - Equivalent Displacement Ratio (**DR10**)
  - Equivalent Wash Yield (**Y10**).
  - DD Washer Cake Cs Control
  - DDW Efficiency Calculations





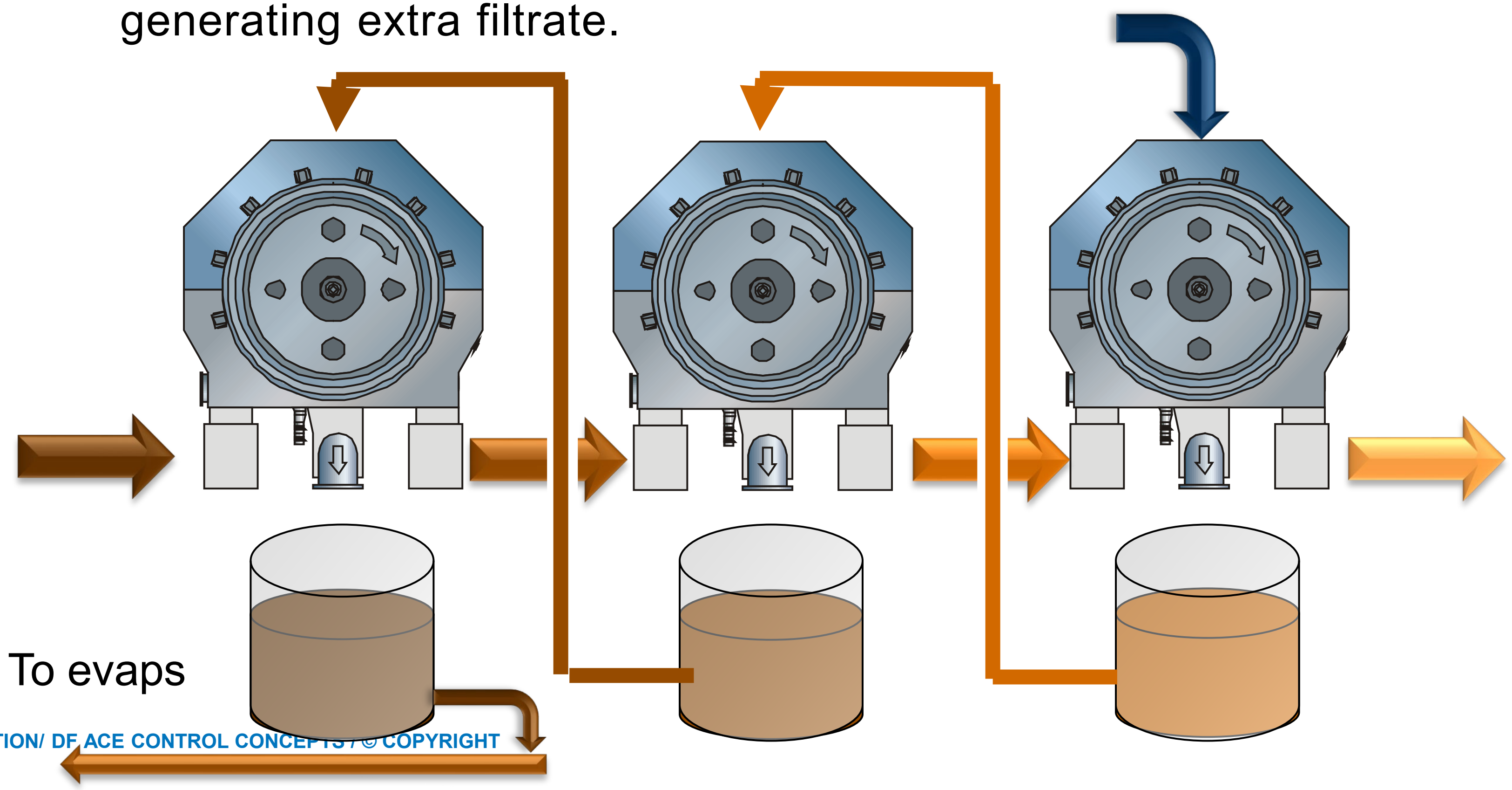


WASHING THEORY

Brown Stock Washing – Washing Water

COUNTERCURRENT WASHING

Mills with multi washing stages use the countercurrent concept, where the filtrate of one stage is used as wash water in the previous stage. This way the pulp is always washed with cleaner liquor without generating extra filtrate.



WASHING THEORY

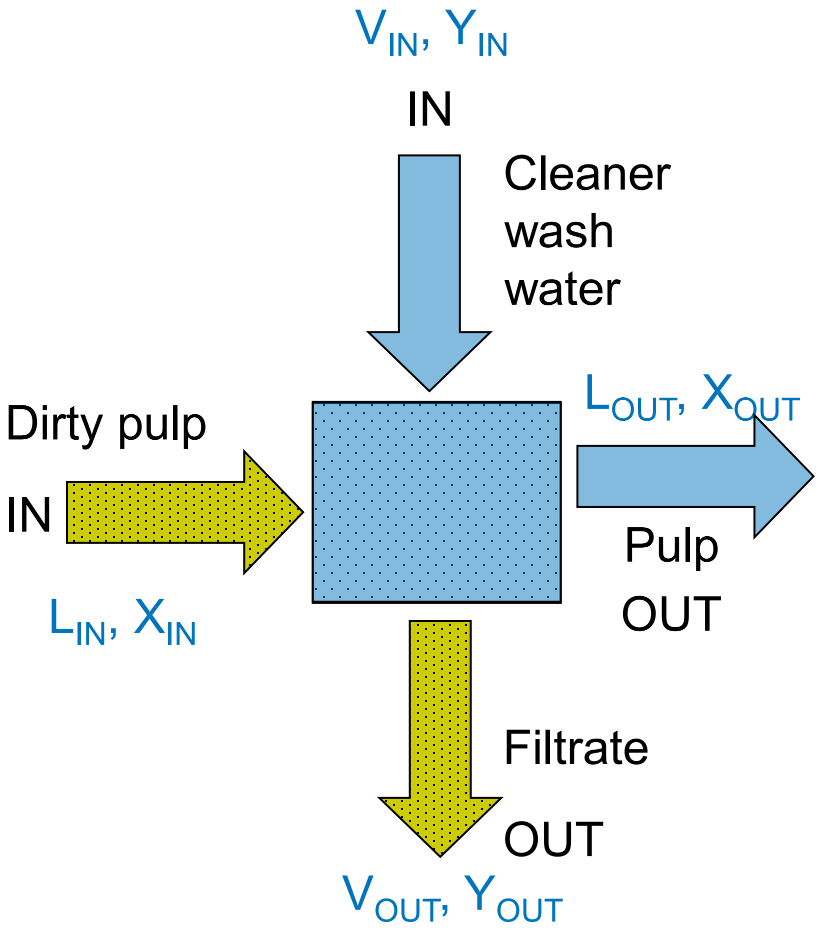
Dilution factor

The amount of "fresh" water that is used to wash the pulp.

It is the excess liquor used to wash in relation to the liquor going out with the Pulp.

Dilution Factor = wash liquor – liquor out with the pulp

Dilution Factor = $V_{IN} - L_{OUT}$



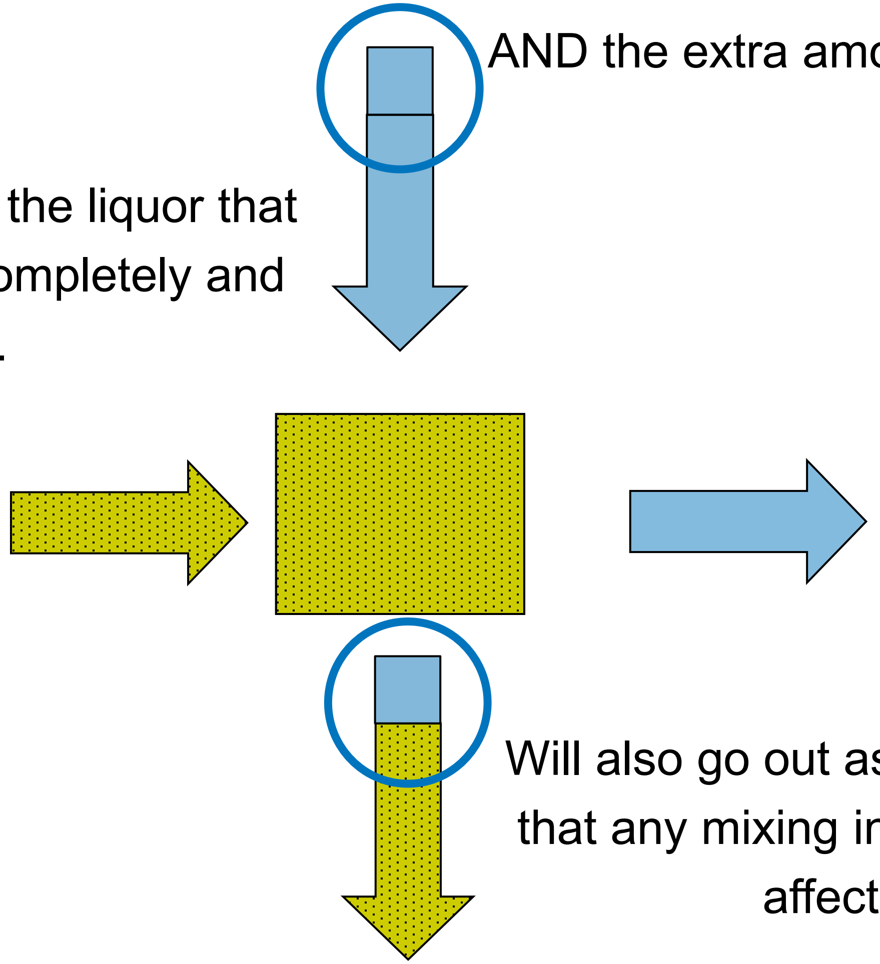
WASHING THEORY

Brown Stock Washing – Washing Efficiency

The idea is:

The wash water pushes the liquor that came in with the pulp completely and replaces it.

AND the extra amount added to wash



Will also go out as filtrate to guarantee that any mixing in the boundary won't affect the pulp

DILUTION FACTOR CALCULATION

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Example:
Given:

Pulp washer mat consistency = 12.5 %

Wash water shower flow per 100 lbs. of pulp = 21 gallons

Assume wash water SG = 1.0 (8.34 lbs./gal)

Calculate filtrate in mat

Consistency = 12.5%, therefore in 100 lbs. of pulp there is (1-12.5%) or 87.5 lbs. of liquor (and 12.5 lbs. pulp.)

Calculate shower flow weight per 100 lbs. pulp

21 gals * 8.34 lbs./gal = 175 lbs. wash water per 100 lbs. pulp

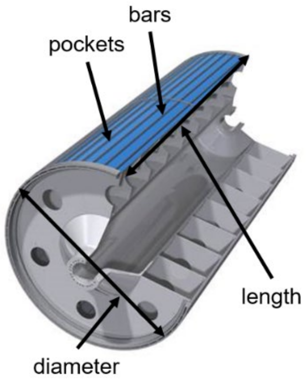
Calculate DF

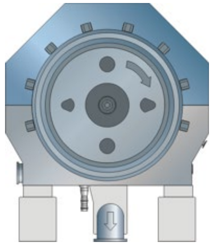
(175 lbs. water- 87.5 lbs. liquor in pulp)/ 87.5 lbs. liquor in pulp

DF = 1.0

METRIS UX/X PROCESS CALCULATION

- OnlineDFOptimizer block works to find the optimal DF(**OptimumDF**) based on cost function as well as operating conditions/constraints.

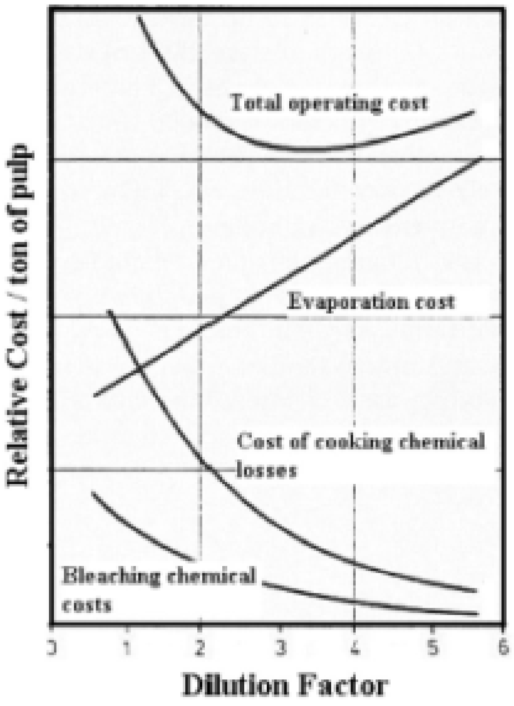




#1

OnlineDFOptimizer

1.4	CurrentDF	OptimalDF	0
10	FeedCons	OptimalCOD	0
13	DischargeCons	OptimalSolids	0
-2	DFMin	OptimalCost	0
5	DFMax	CurrentCOD	0
12	SolidsLimit	CurrentSolids	0
4.28	SteamPrice	CurrentCost	0
5.3	SteamEconomy	SugProdRate	0
0	ProdRate	FaultInd	0
0	ProdLimit	LastActiveFault	0
160000	X0Initial	Error	False
100	YInitial		
0	ExtraCOD		



DEFINITION

What is Advanced Process Control?

"Advanced Process Control, APC, is an enhancement of the basic process control aimed at delivering value to our customers in terms of throughput, quality and cost.

APCs utilize a variety of technology to optimize the process in response to business drivers with minimum resources without compromising throughput, quality and cost targets."

Digital Twin technology is an emerging technology that can also be utilized.

- A Digital Twin, DT, is a virtual model of a physical system that can be used to simulate and optimize the behavior of the system. In brown stock washing, a Digital Twin can be used to model the washing process and simulate the behavior of the system under different conditions.

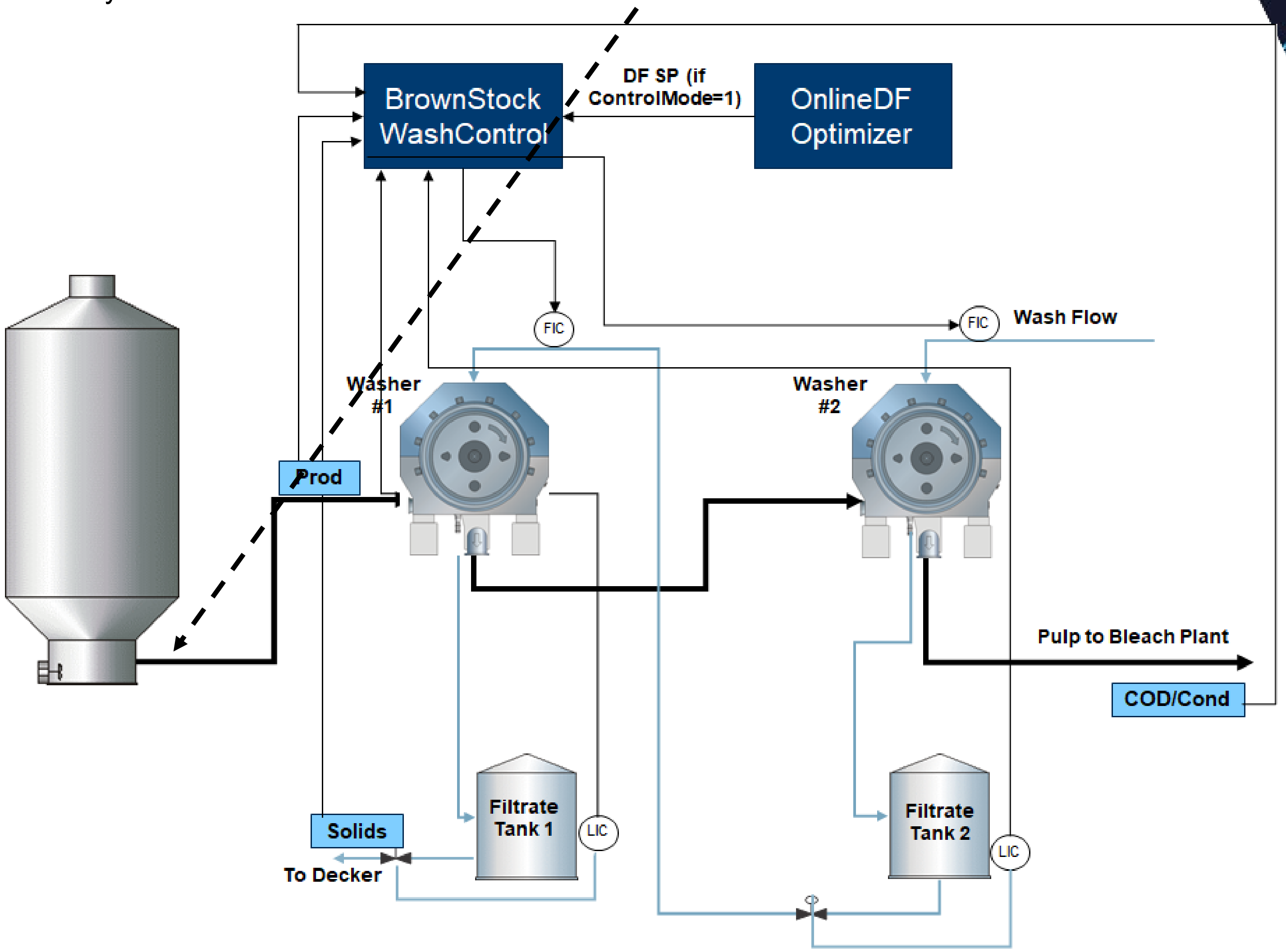
METRIS UX/X WASHING ACE BROWNSTOCK WASH CONTROL

This block is used for Brown stock washing control to take care of wash water set point for each stage of washers, keep weak black liquor solids higher than minimum limit, keep discharge liquor conductivity/COD lower than maximum limit and maintain filtrate tank level.

The control can be used in two modes. The control objective of the two modes are listed here:

1) DF Mode (ControlMode=1):
•Maintain the desired dilution factor. It will simultaneously adjust all shower flows when a new production SP is given and will bias the necessary shower flows in their preceding filtrate tanks, increasing or decreasing flow beyond a certain threshold. DF SP could be either from DCS or the Online DF Optimizer block.

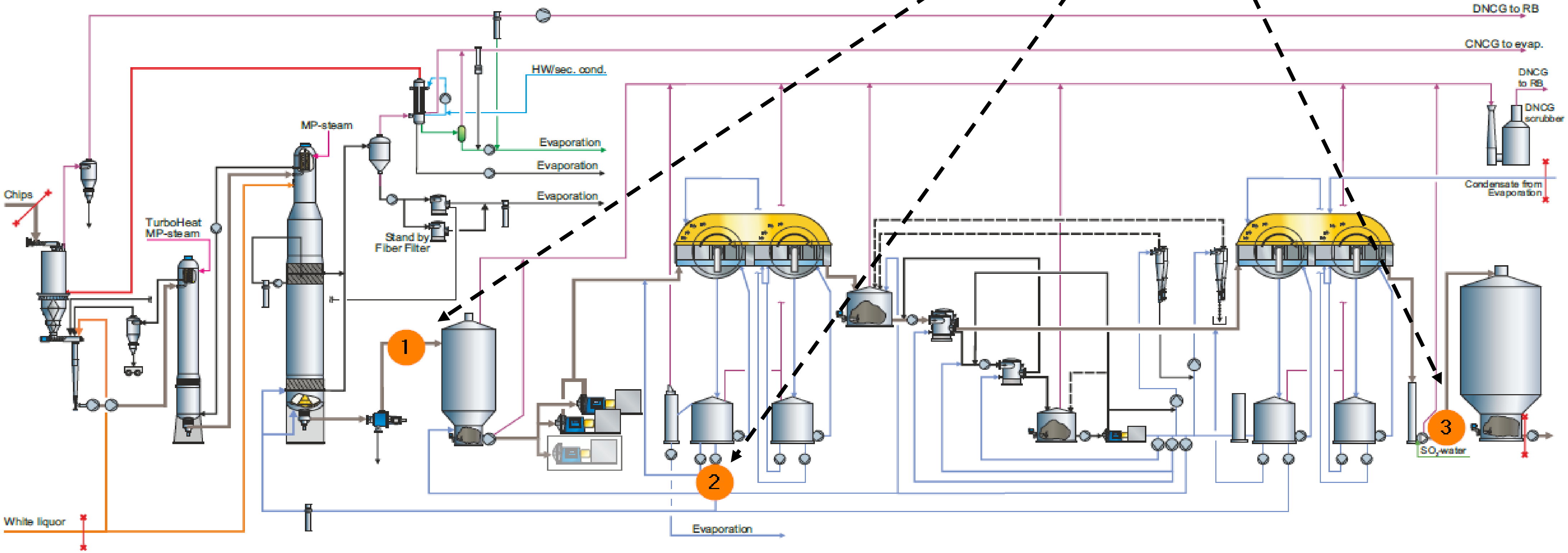
2) Solids Cond Mode (ControlMode=2):
•Keep conductivity and weak black liquor solids within the target range by adjusting the dilution factor.
While the control has two different modes, it would take care of filtrate tanks levels under both modes.



FIBERLINE PROCESS

PR-23

CONTROL OF THE OVERALL DILUTION FACTOR



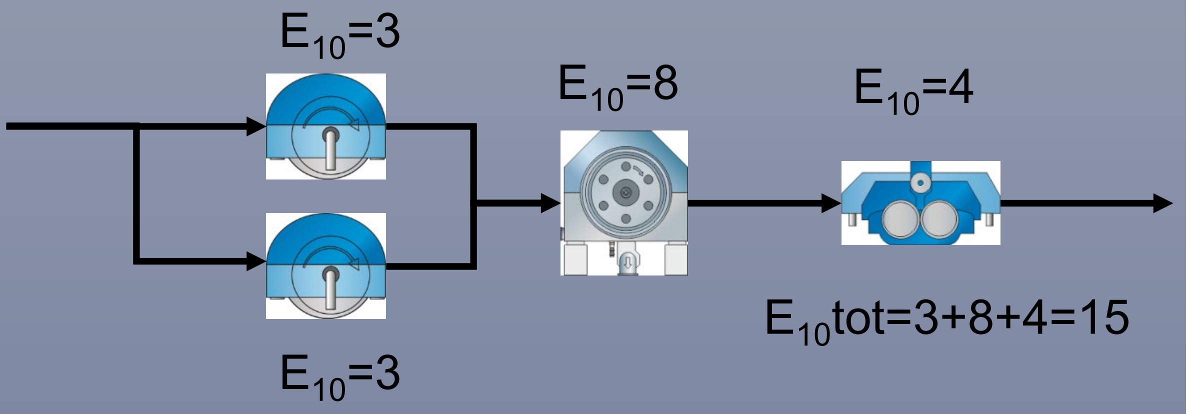
Position 1. Total Dissolved Solids exiting Digester
Position 2. Total Dissolved Solids to EVAPS
Position 3. Cleanliness of Pulp to Storage (COD)

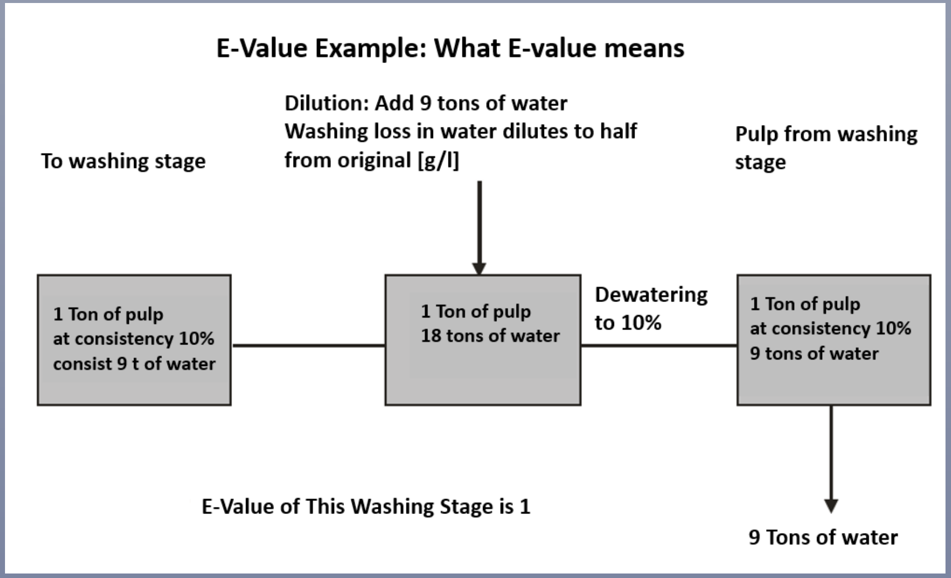
INTRODUCTION OF ONLINE DF OPTIMIZER

Washing Theory: Washing Efficiency E_{10} Calculation

Washing efficiency can be measured by different parameters. The most common is the efficiency factor, **E-value**

Useful tool of calculating and comparing different washing efficiencies is the **E_{10}-value**. It means **E-value** at constant 10% outlet consistency. Total E-value of the washing line can be calculated by adding separate E-values together.





INTRODUCTION OF ONLINE DF OPTIMIZER

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Washing Theory: Typical E_{10} Values, Feed and Outlet Consistencies for Different Type of Washers

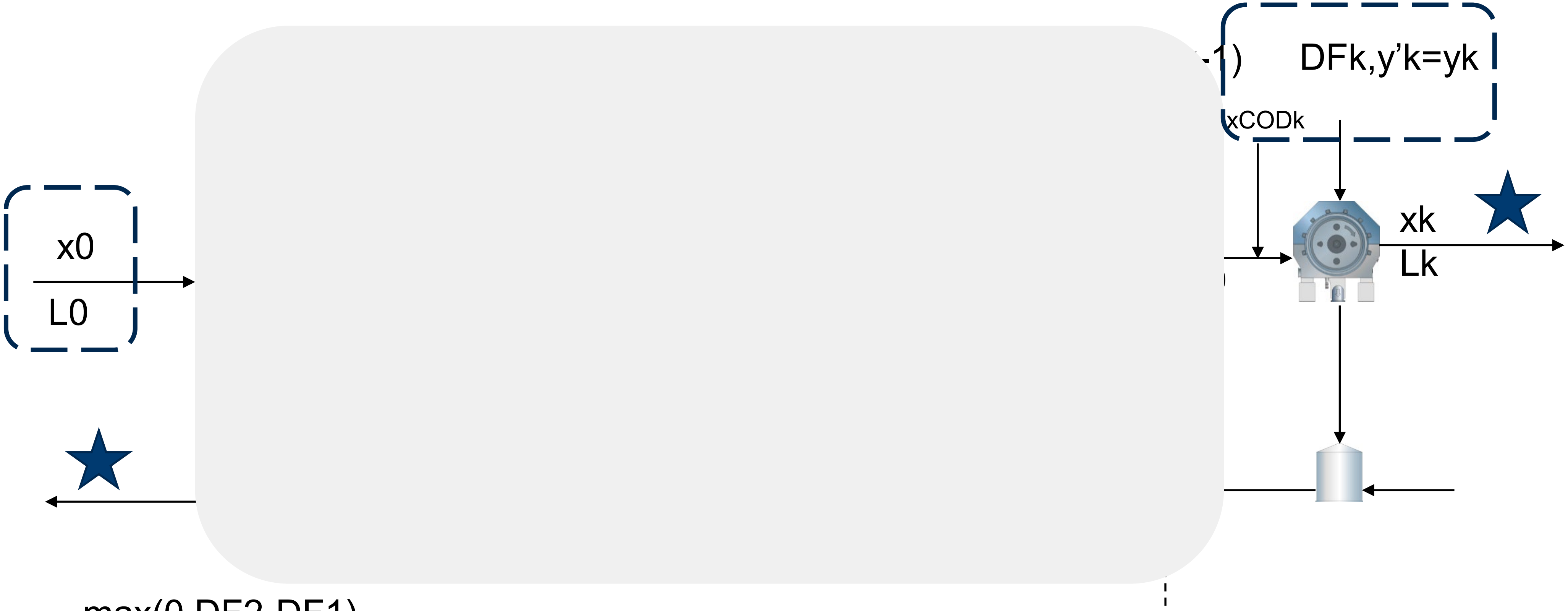
Washer type	Feed Consistency [%]	Outlet Consistency (before dilution) [%]	Typical E_{10} at DF 2,5[m^3/Adt]
Continuous Digester		10	3-4
Modified Batch Digester		10	1-2
Pressure Diffuser	10	10	4-6
1-Stage Diffuser ATM	10	10	3-5
2-Stage Diffuser ATM	10	10	7-8
Wash Press	3-9	28-35	3-5
Pressurized Filters	3-4	12-14	3-5
Vacuum Filter	1-2	12-14	2-4
1-Stage DD Washer	4-10	12-14	4-5
2-Stage DD Washer	4-10	12-14	9-10
3-Stage DD Washer	4-10	12-14	10-12
4-Stage DD Washer	4-10	12-14	12-15

The most common washing efficiency is the E-Value.

The most useful tool for comparing different Washing efficiencies is the E-10 Value which is defined by calculating the E-Value at a constant 10% consistency.

INTRODUCTION OF ONLINE DF OPTIMIZER

Washing Theory: Mathematical Methodology



max(0,DF2-DF1)

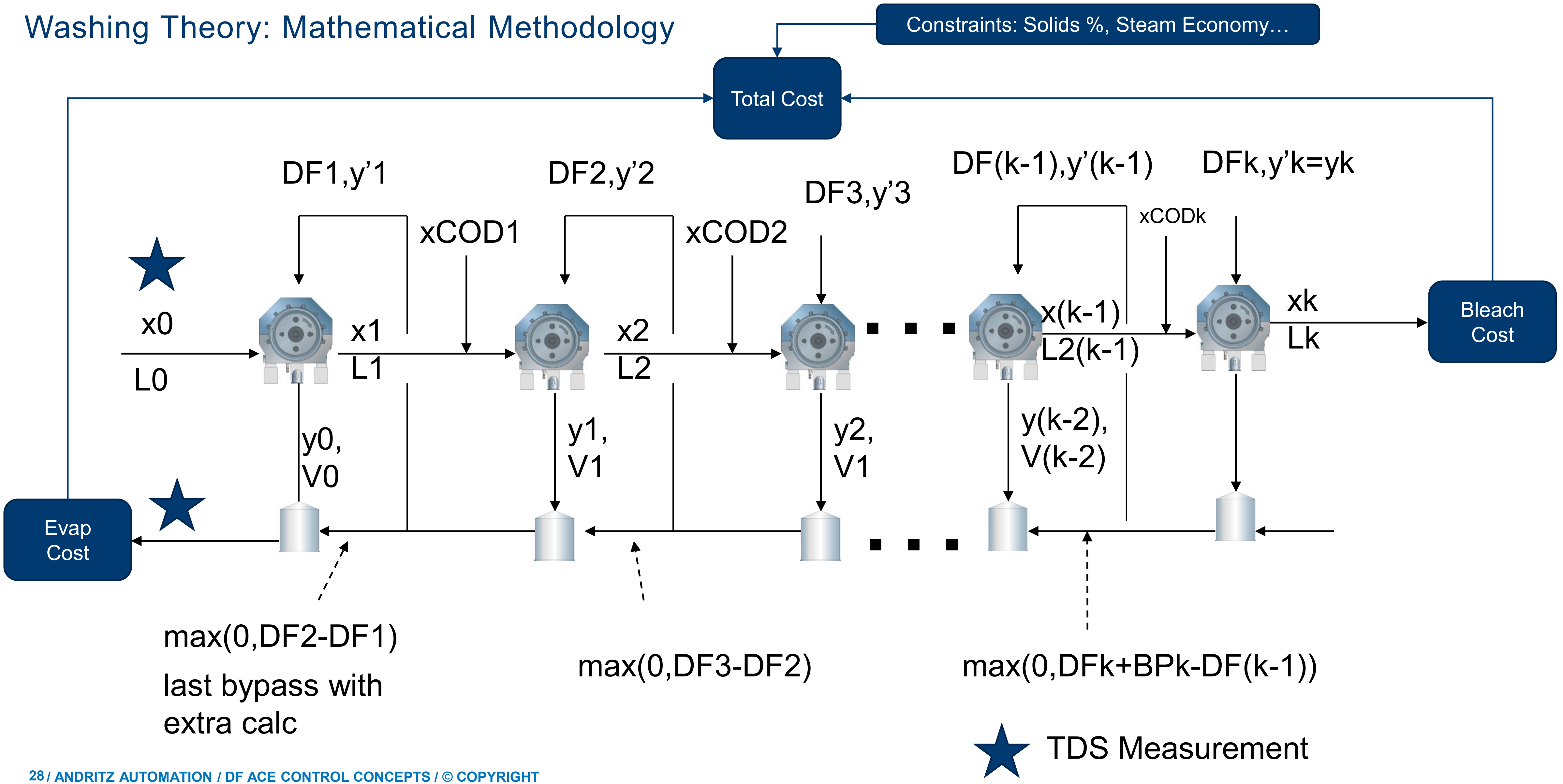
last bypass with
extra calc

max(0,DF3-DF2)

max(0,DFk+BPk-DF(k-1))

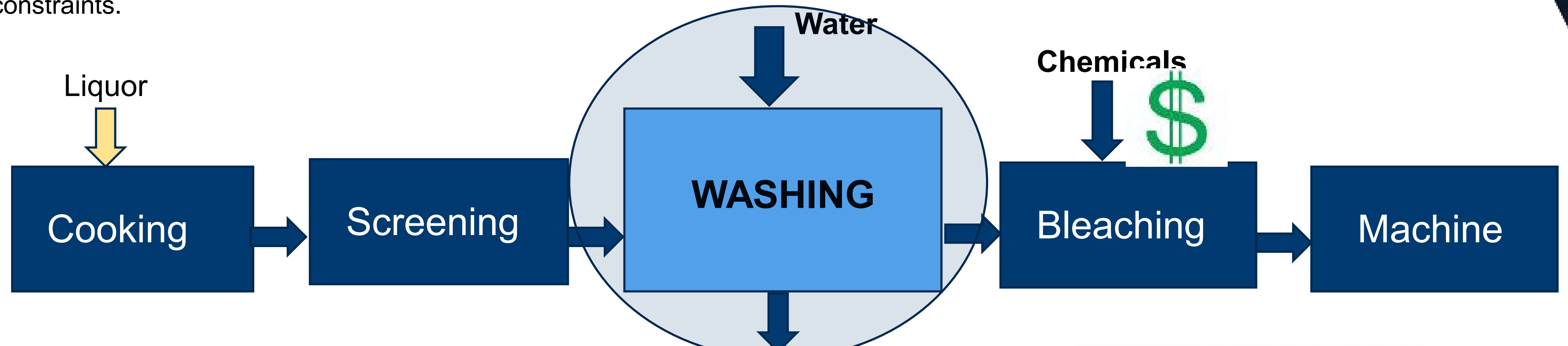
INTRODUCTION OF ONLINE DF OPTIMIZER

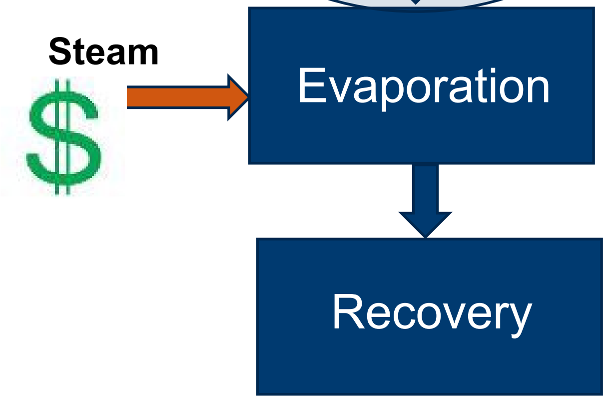
Washing Theory: Mathematical Methodology



METRIS UX/X WASHING ACE
ACE WASHING – ONLINE DF OPTIMIZER

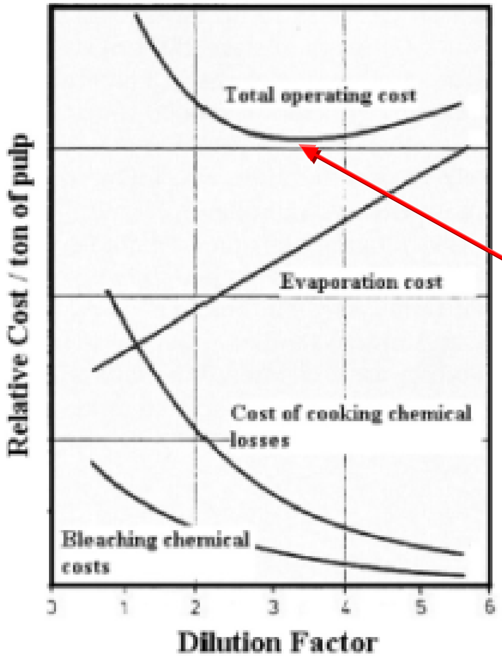
This block calculates the optimal DF based on cost function as well as operating conditions/constraints.





OnlineDFOptimizer

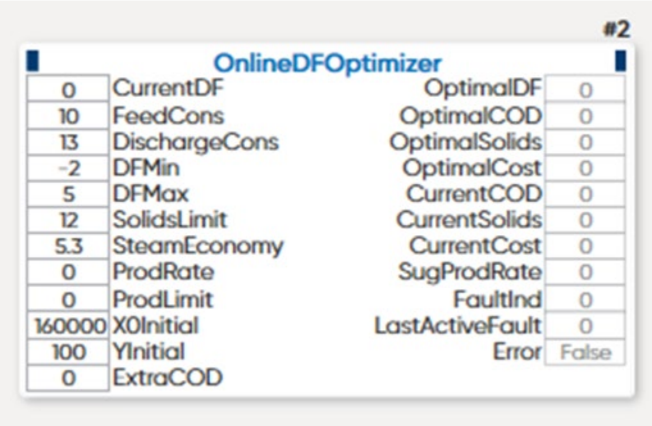
2.04407	CurrentDF	OptimalDF	1.22
9.07380	FeedCons	OptimalCOD	41.5305
11.93321	DischargeCons	OptimalSolids	12.0380
0.02	DFMin	OptimalCost	20.0913
5	DFMax	CurrentCOD	22.5316
12	SolidsLimit	CurrentSolids	11.37394
5.3	SteamEconomy	CurrentCost	13.2709
900	ProdRate	SugProdRate	900
1000	ProdLimit	FaultInd	0
139095	X0Initial	LastActiveFault	32
100	YInitial	Error	False
0	ExtraCOD		



Lowest Cost Target picked automatically by OptimumDF™

HOW WOULD THE BLOCK HELP ME?

How would the block help me?

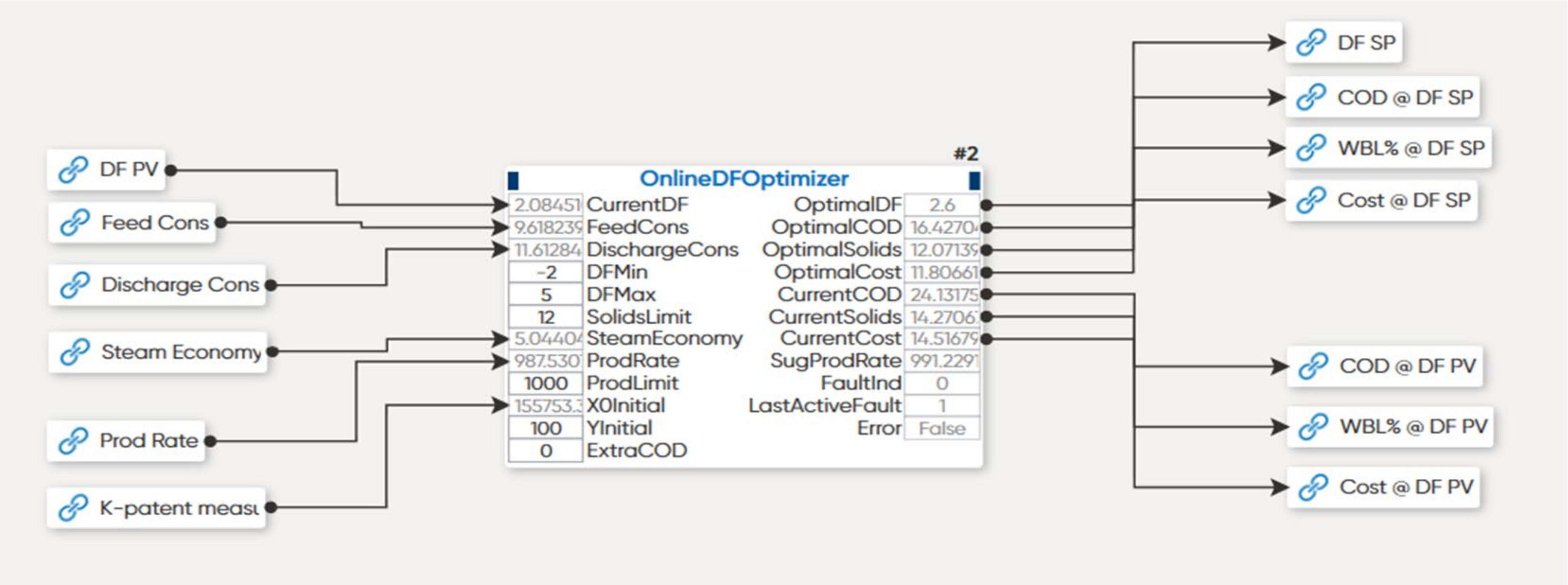


Scenario Studies:

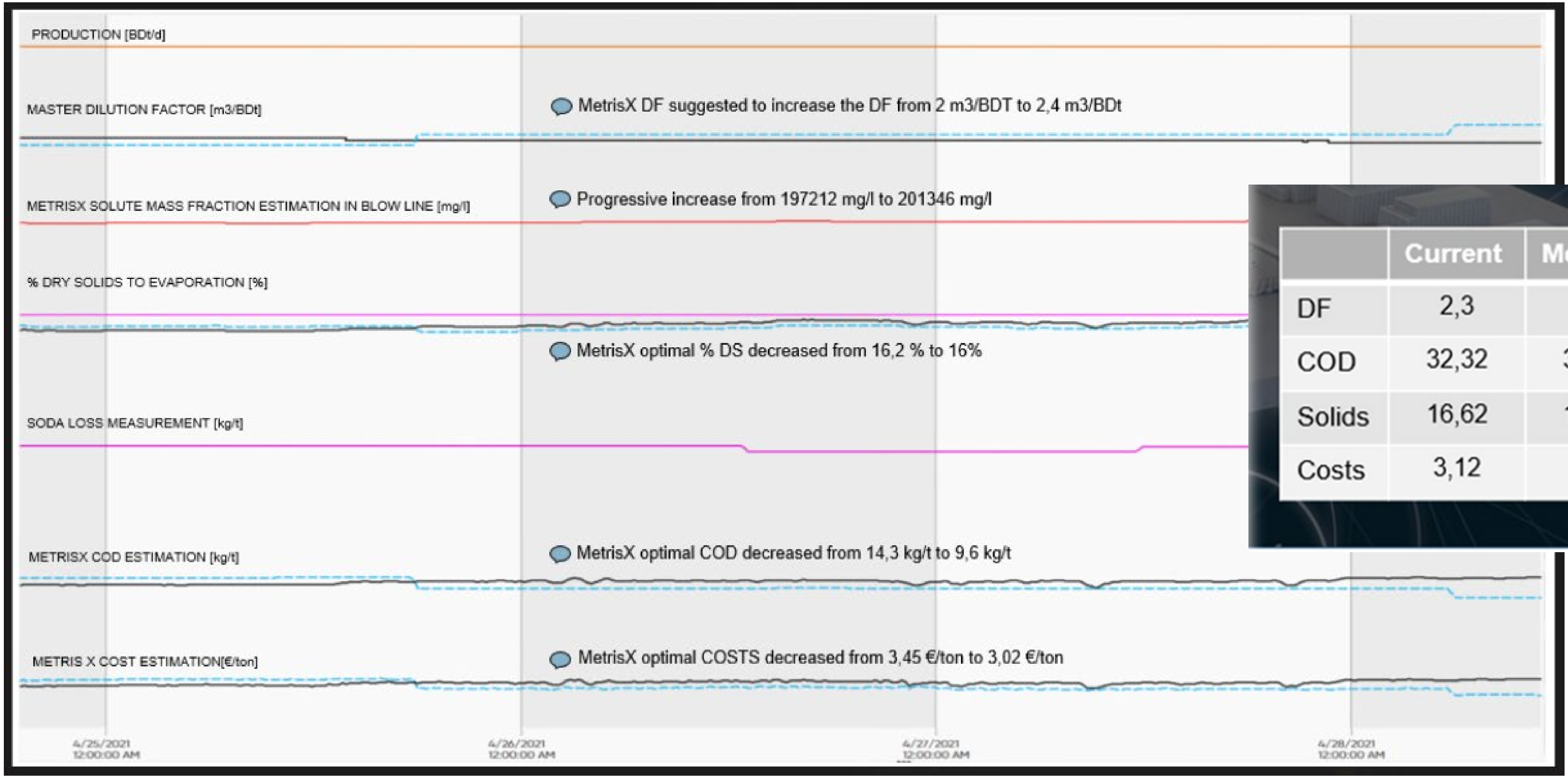
- What if steam economy drops? How would the block help me to deal with that?
- What if I want to increase my production? Does that make sense to sacrifice washing to get more pulp produced?
- What if mill put priority on bleach/Evap cost?

BROWNSTOCK WASHING OPTIMIZATION

CONFIGURATION EXAMPLE



MILL RESULTS – USE CASE



	Current	MetrisX	
DF	2,3	2,4	⇧
COD	32,32	30,45	⇩
Solids	16,62	16,49	⇩
Costs	3,12	3,12	=

CONTROL OBJECTIVES -SUMMARY

- Main targets
  - Stabilize filtrate balance
  - Stabilize all variables
  - Stabilize the Carry over (COD, sodium) from washing
  - Stabilize Weak Black Liquor Solids
  - Help minimizing the use of wash water
- Measurements
  - Normal wash liquid flow measurements,
  - Buffer and filtrate tank level measurements, and
  - Total Dissolved Solid measurements
- Controlled variables
  - Total Dilution Factor in all washers [m3/ADt]
  - Corrects the overall system including the Cooking Dilution Factor [m3/ADt]