AMAZON
PAPYRUS CHEMICALS

Pulp Training for Non-Pulp & Paper Professionals

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Training Objectives

- **Understand Pulping Process**
- **Minimize Environmental Footprint**
  - *Improve Resources Management*
    - *Reduce Raw material usage*
    - *Lower Energy & Water Usage*
- **Reduce Production Cost**
  - *Key parameters*

Pulping Process - *Forest to Pulp Machine to Paper*

- Raw Materials
- Raw Material Preparation
- Pulping Processes – *Chemical/Mechanical/Semi-Chemical*
- Kraft Pulping Process - *Paper/Dissolving*
- Brown Stock Washing
- Oxygen delignification
- Bleaching Process
- Pulp Dryers
- Issues in Pulp Mills

Points to Ponder

- This training is meant for a Training and best practices used in Asia and elsewhere.
- We have participants with diversified experience.
- I am not a *teacher/professor*!
- I am not a *Pulping Guru*!
- I am not a chemist!
- I want to share my 34 years of experience in the pulp/pulp mills on the six continents.
  - *Also want to use this experience to learn from your best experience/s in a pulp mill to gain a business.*

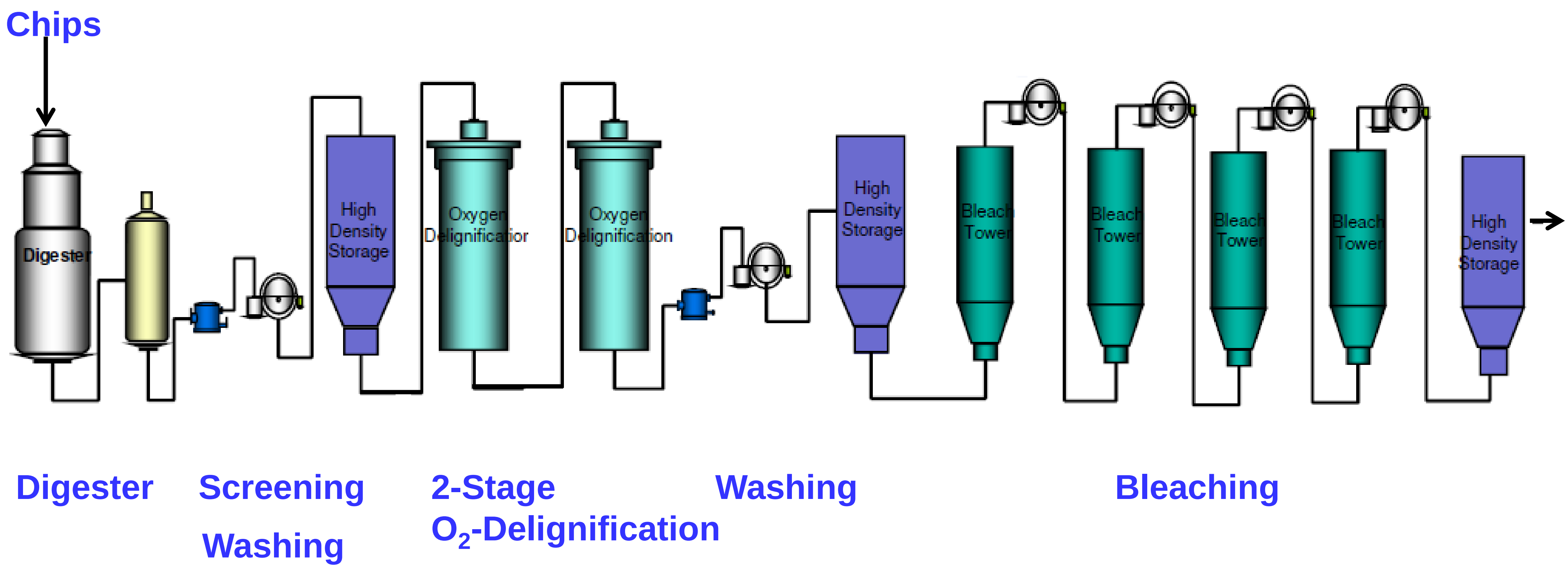
Ask More Questions!

Enjoy Your Time with Good Learning Experience!

We Will Work It Out!

Fiber Line Overview

(Ref: Kavaerner now Valmet)



Types of Pulping Processes

- **Chemical**
  - Kraft
    - *Paper grade*
    - *Dissolving grade*
  - Soda
  - Sulfite
    - *Paper grade*
    - *Dissolving grade*
  - Neutral Semi-sulfite (NSSC)
  - Alkaline sulfite

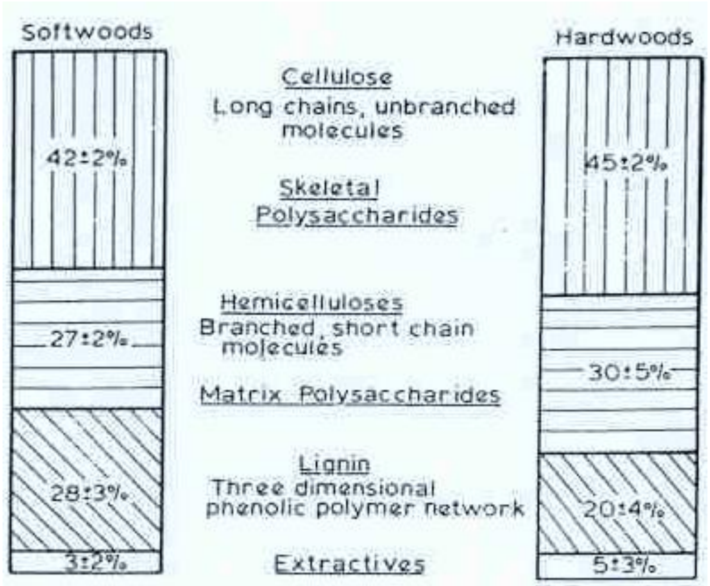
- **Mechanical**
  - Stone/Pressure Ground Wood
  - Refiner Mechanical Pulp *(RMP)*
  - Thermo-Mechanical Pulp *(TMP or BTMP)*
  - Alkaline Peroxide Mechanical Pulp *(AMPM)*
  - Bleached Chemi-Thermo Mechanical Pulp *(BCTMP)*

Chemical Pulping

- Digester operations
- Brown stock washing
- Oxygen delignification
- Bleaching
- Pulp Dryer
- Environmental Sustainability – *Improved Resources Management*

Raw Material Types
Cellulosic

- **Hardwoods**
  - *Eucalyptus, Poplar, Subabul, Casurina, Acacia, Birch, Aspen and Maple*
- **Softwoods**
  - *Pine-Red, Southern and Radiata, Spruce, and Douglas Fir*
- **Non-woods**
  - *Bagasse, Wheat/Rice Straw, Bamboo, Kenaf and Corn Stalk*



Different raw materials produce different pulp quality!

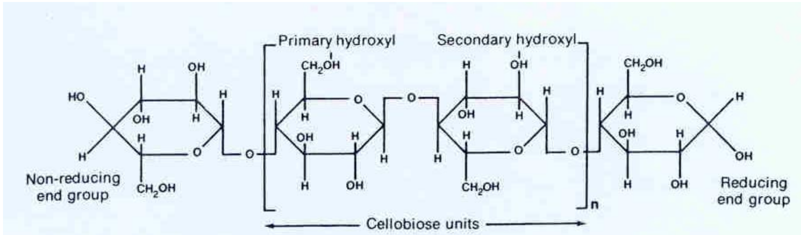
Fiber lengths/strengths are also different for each type of fibers.

Wood Chemistry

CELLULOSE
(40-45%)

HEMICELLULOSE
(20-28%)

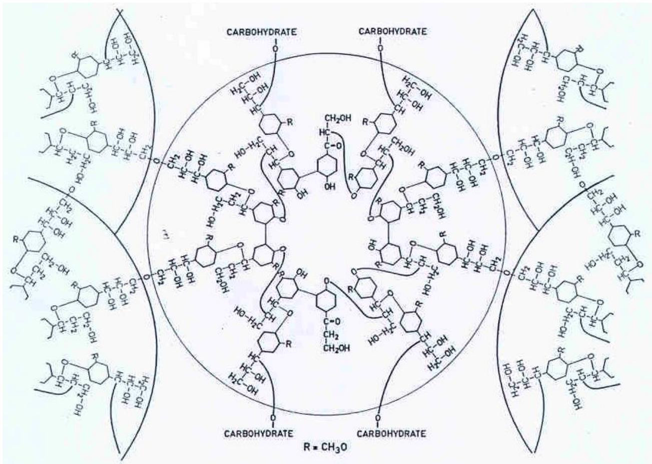
} Carbohydrates = Pulp



LIGNIN
(15-28%)

EXTRACTIVES (= Pitch Problem)
(2-8%)

OTHERS
(1-3%)



Lignin

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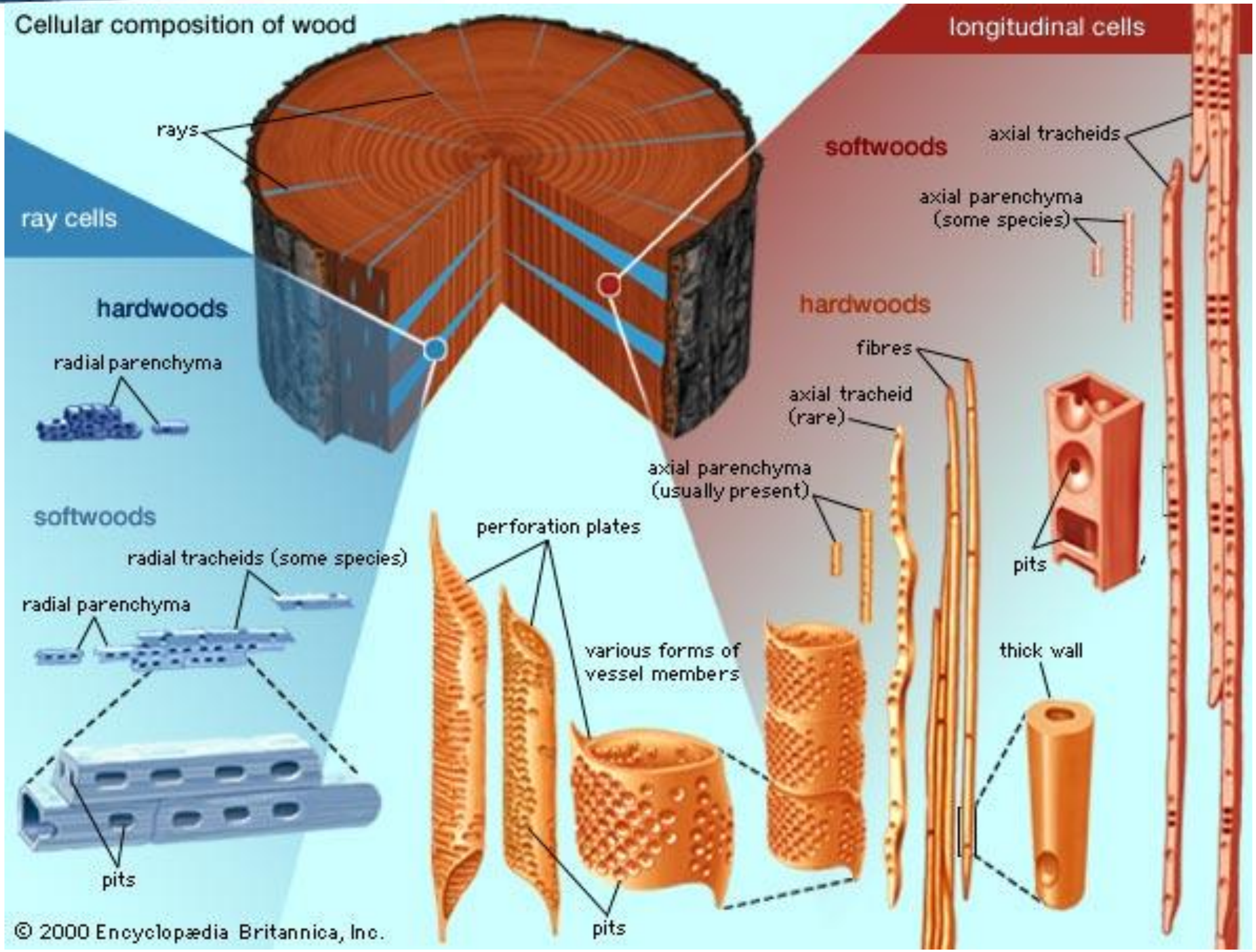
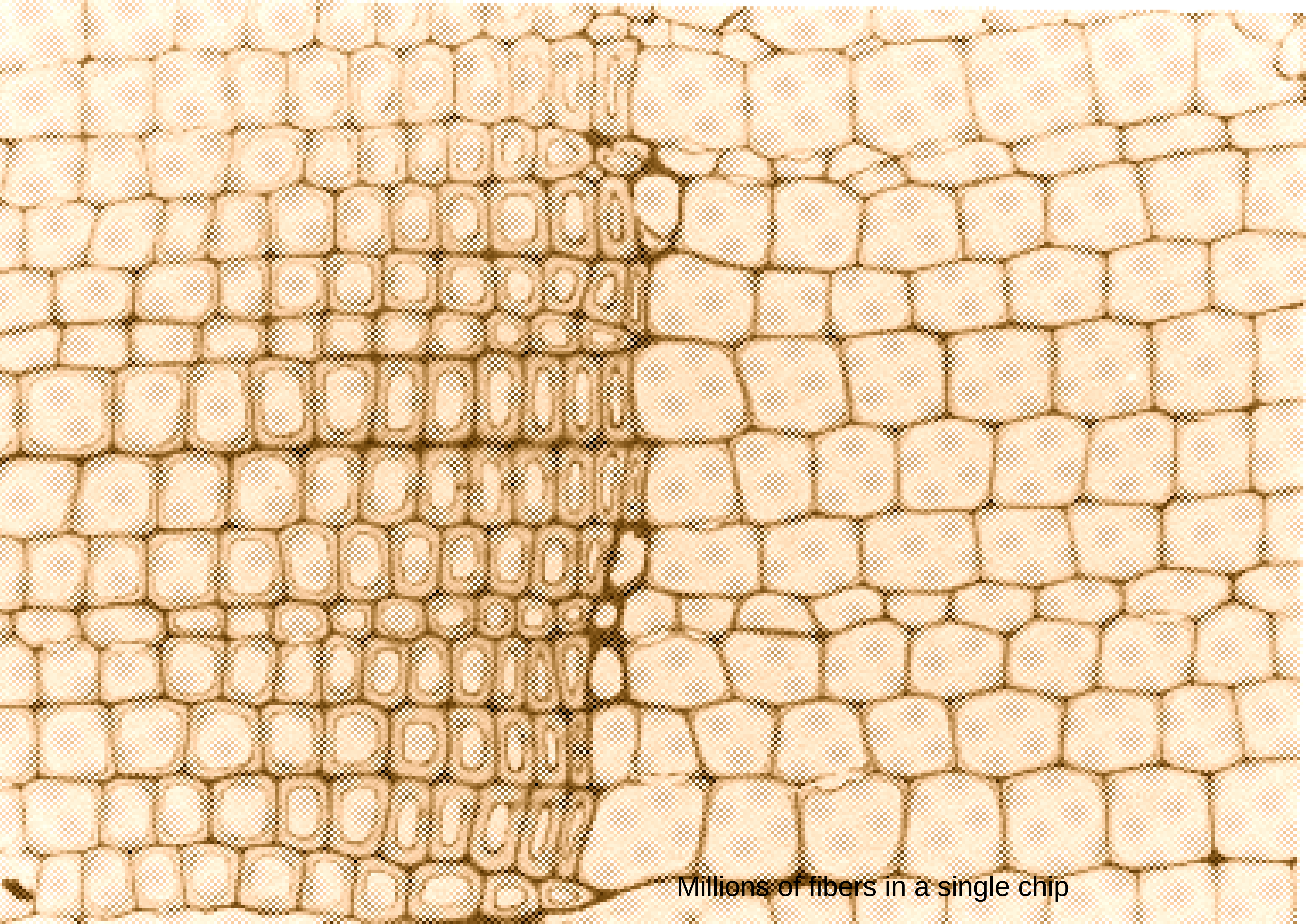
Understanding Woods
Wood/Fiber Matrix

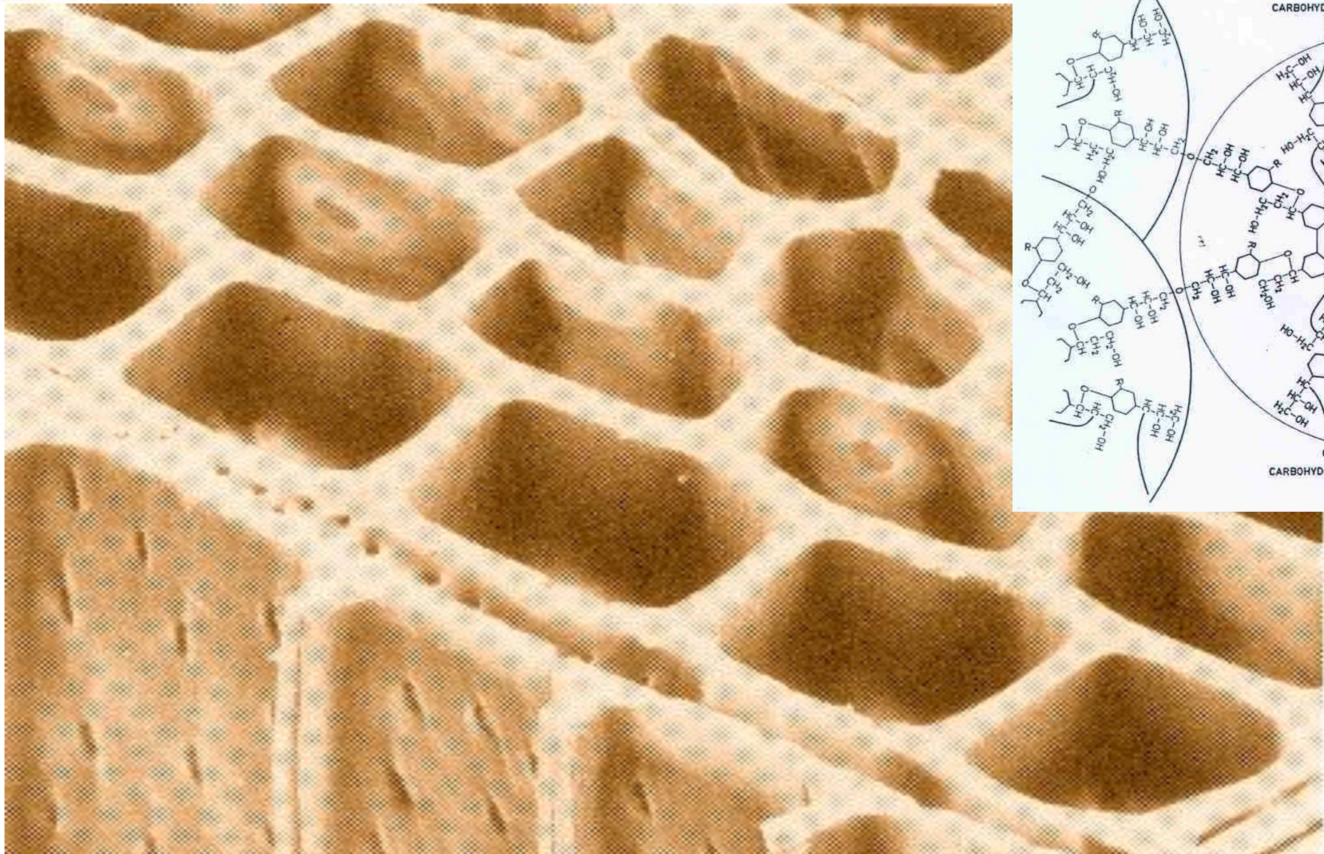


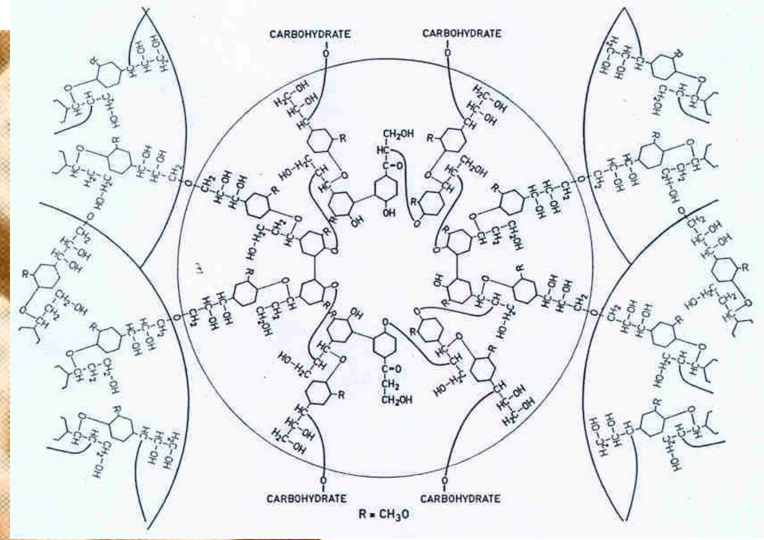
(Ref: Taken from Web)



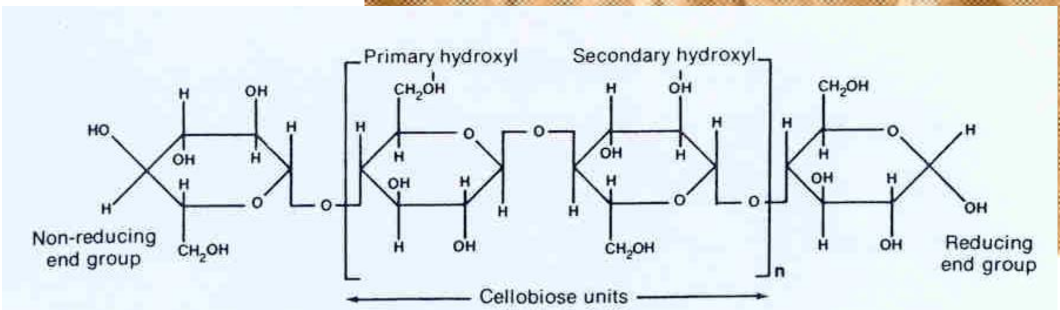
Millions of fibers in a single chip

Fiber Matrix



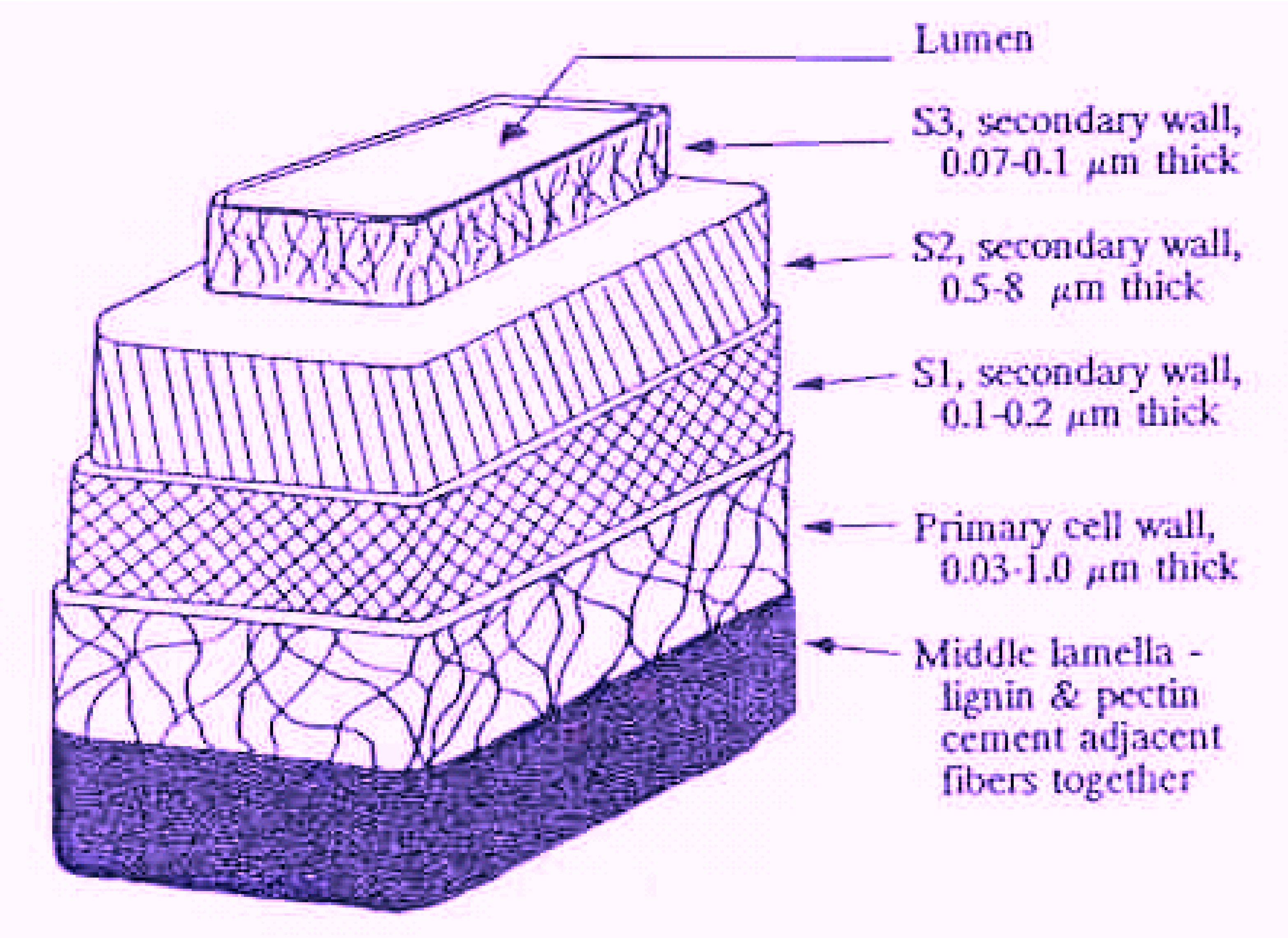


Lignin



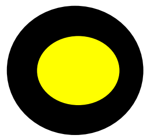
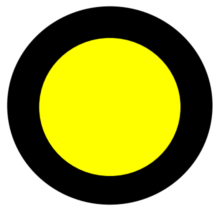
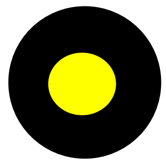
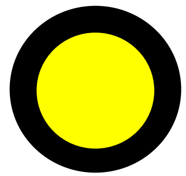
Single Fiber Cell

Typical Soft Wood Fiber



Morphological Comparison

Eucalyptus

	Eucalyptus	SCAN-Birch/NHW	MTHW	Acacia
Fiber length (mm)	0.55 - 0.80	0.80 - 1.30	0.65 - 1.20	0.50 - 0.70
Width (µm)	12 - 16	18 - 22	14 - 20	15 - 20
Fiber Cross Section				
Coarseness(mg/100m)	7 - 9	9 - 12	16 - 18	7 - 8
# of fibers per gram (million)	18 - 25	13 - 15	17 - 20	18 - 27
Wall thickness (µm)	2.0 - 3.5	2.5 - 4.0	3.5 - 4.5	2.0 - 3.0
Fines content (%)	8 - 12	6 - 8	12 - 17	7 - 10

Kraft Pulping Process

- Wood is broken into chips
- Chips are screened to eliminate fine material and oversized chips
- Chips are steamed to eliminate air
- White Liquor containing primarily $NaOH$, Na_2S and Na_2CO_3, is blended with chips
- Typically liquor-to-wood ratio is 3.5-5 tons/ton of wood
- Cooking is done at elevated temperature under pressure (155 -170ºC)
- Fiber is separated from spent liquor in washers

Chips

Key Chip Dimensions

- **Width**
  - Affects packing density
    - Productivity and processing
- **Length**
  - Affects fiber length
- **Thickness**
  - Affects rate of liquor penetration
  - Can plug digester screens

Chip Quality for Different Processes

Chip parameters	Pulping Process		
	Kraft	Sulfite	Refiner Mechanical
Length, mm	15-25 (NC)	25-35 (C)	C
Width, mm	NC	NC	NC
Thickness, mm	2-4 (VC)	2-4 (C)	NC
Chip density	NC	NC	C
Bark contents, %	C	VC	C
Contaminants	C	C	VC
Chip damage	C	VC	N.A.
Moisture content	NC	NC	VC

NC: Not concerned, C: Concerned, VC: Very concerned

Kraft Cooking Terms

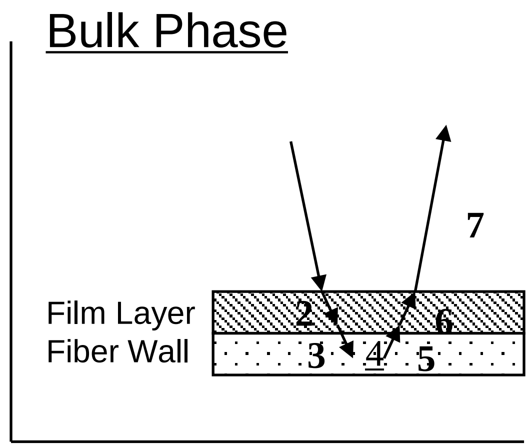
- Active chemicals: *Caustic (NaOH) & sodium sulfide (Na_2S)*
- Chemical Expression: *grams/liter (gpl) as Sodium Oxide (Na_2O)*
- Active Alkali (A.A. as gpl): *NaOH + Na_2S*
  - *Dissolves lignin*
  - *But attacks Cellulose and Hemi-cellulose at the same time*
- Sulfidity (%): Na_2S ÷ (NaOH + Na_2S) x 100
  - *Helps to protect cellulosic fiber*
- Effective Alkali (E.A.): *NaOH + 1/2 Na_2S*
  - *Actual chemical usage during cooking*

$$NaOH + H_2O \leftrightarrow Na^+ + OH^- + H_2O$$
$$Na_2S + H_2O \leftrightarrow 2Na^+ + S^{2-} + H_2O$$
$$S^{2-} + H_2O \leftrightarrow HS^- + OH^-$$

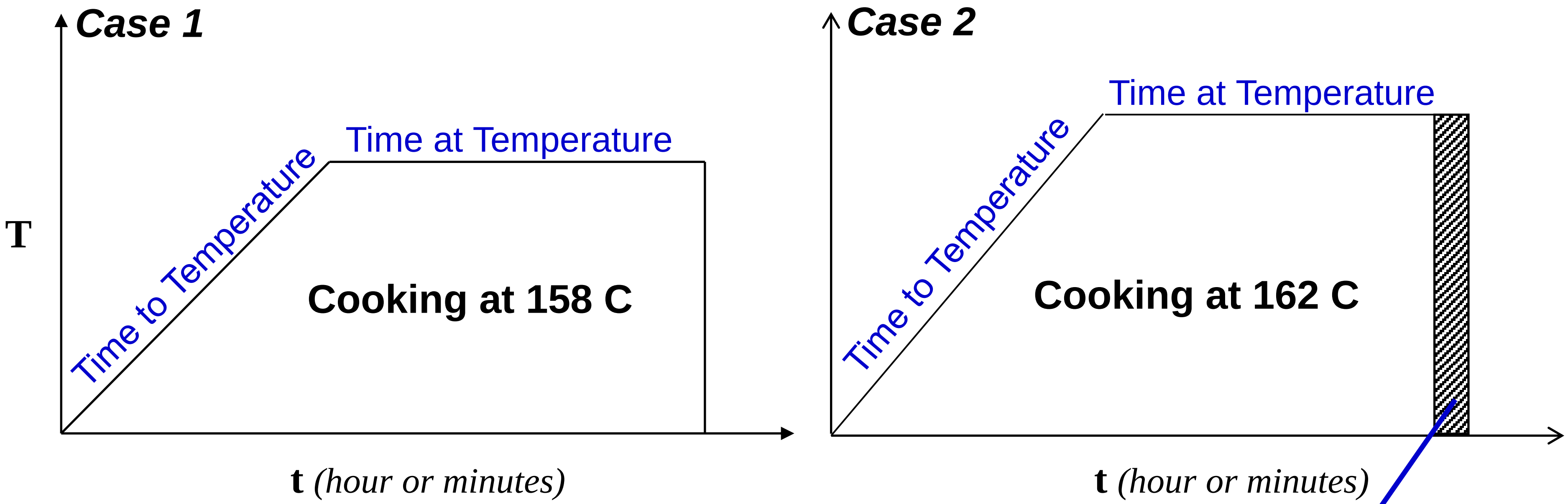
- Chemical to Wood Ratio: *Chip moisture, black liquor, A.A. ÷ O.D. Wood*
  - *This Ratio can be 4:1 with some of the AA replaced with chemically adjusted black liquor*
- H-factor - *Time –Temperature relationship*
- **Kappa Number (K#)** *– Degree of delignification*

Alkali Usage During Cooking

- Neutralization of different organic acids
  - *Original wood acids*
    - *The moisture in wood/chips is highly acidic.*
  - *Produced (during cooking) by hydrolysis*
- Reaction with lignin
- Reaction with resins/extractives in the wood
- Dissolution of carbohydrates
  - *Cellulose*
  - *Hemi-cellulose*
- Adsorption by the fibers
- Residual alkali
  - *Keep residual lignin soluble*



H-factor



Time to Temperature in both the cases remain the same.

Time saving

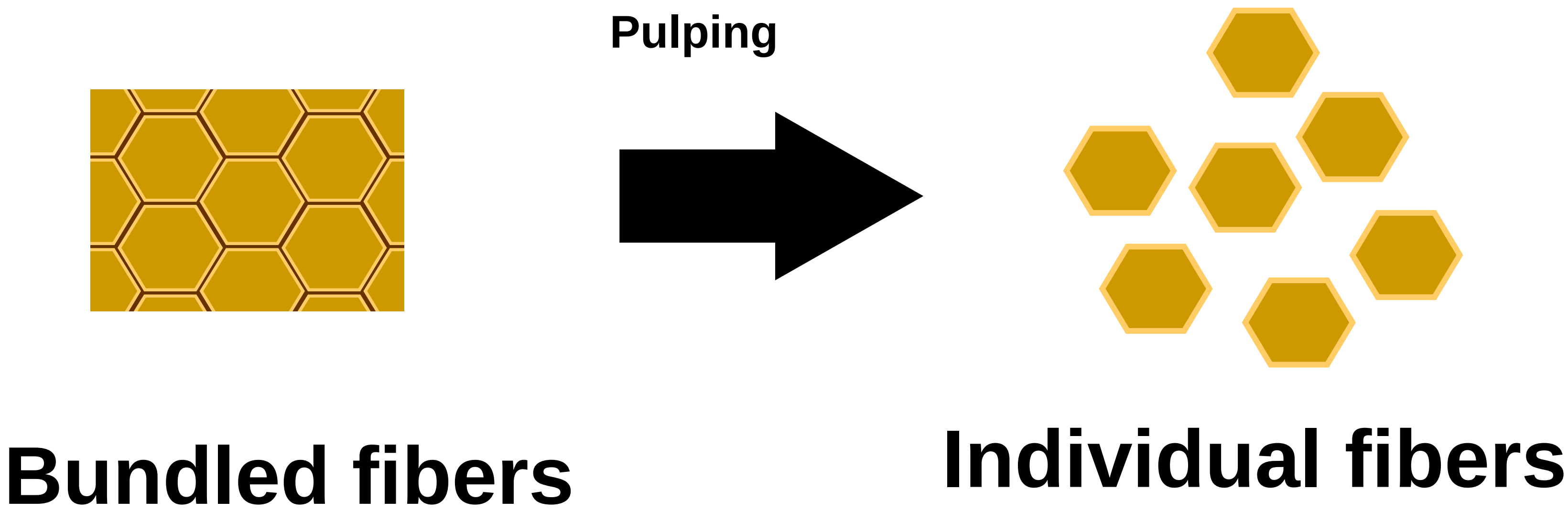
= More Production

(While keeping all other parameters the same)

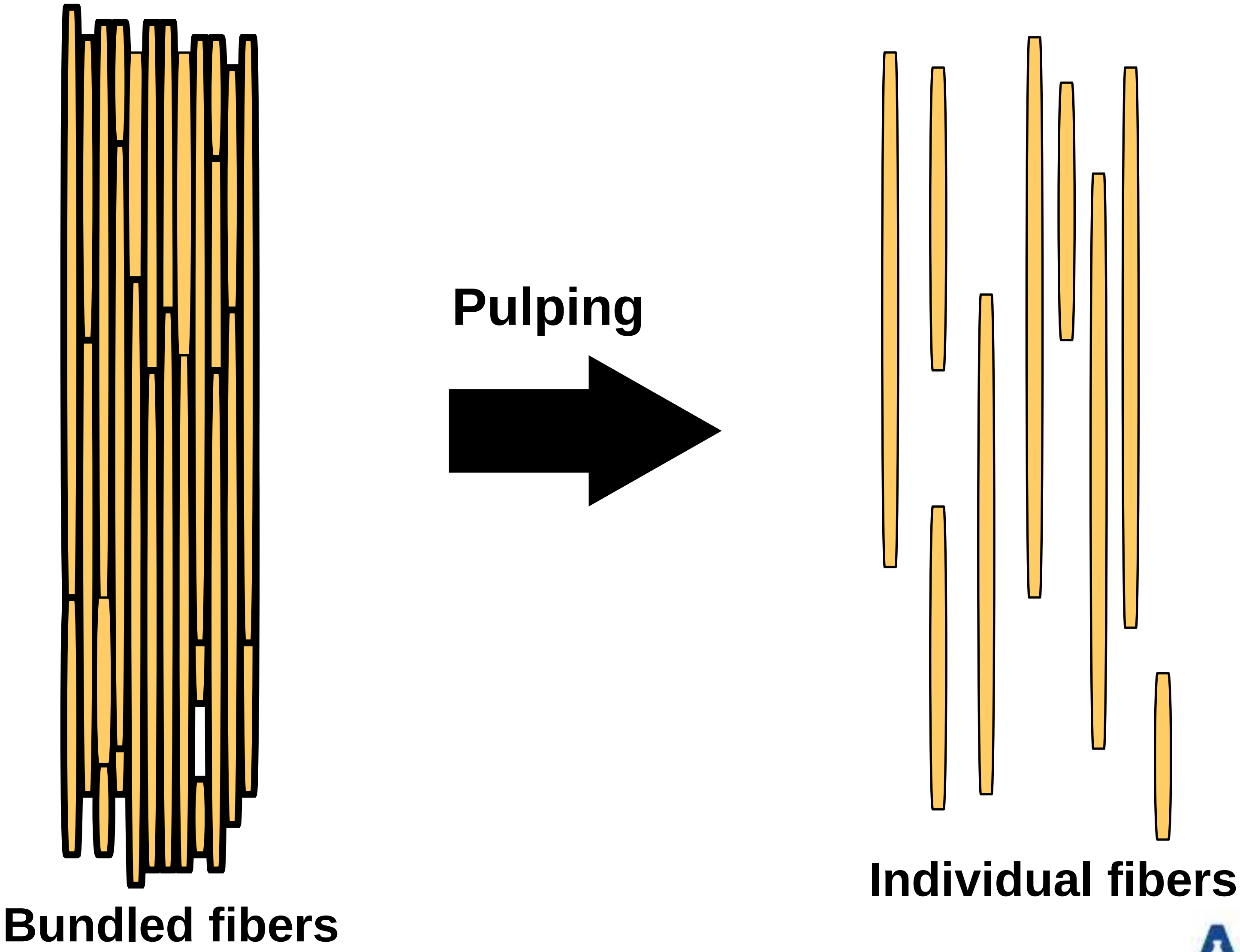
Kraft Pulping

- The steps in the cooking process are
  - ***Chip filling***
  - ***Packing with steam***
  - ***Alkali charge (Hot alkali) –*** *Based on OD wood and targeted K#*
  - ***Impregnation - with white liquor***
  - ***Heating*** *(Indirect steaming)* ***–*** *to desired temperature*
  - ***Cooking –*** *Maintain desired temperature for certain time based on targeted K#*
  - ***Hi-Heat Washing***
  - ***Displacement or discharge***
- In a continuous digester, the chips move down the body in plug flow

Cross-Sectional View of Fibers before and after Pulping



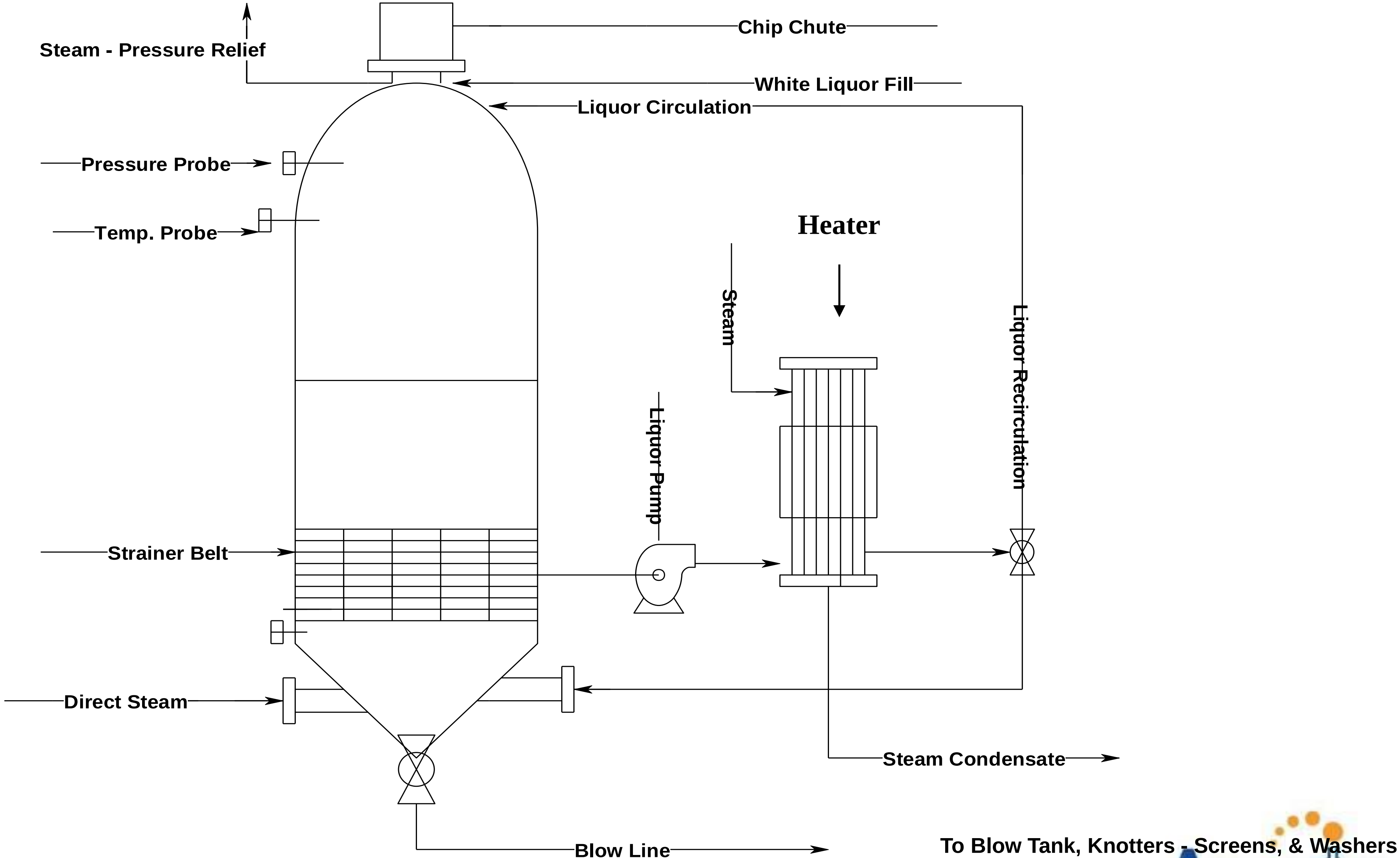
Schematic Microscopic Side View of Fibers Before and After Pulping



Kraft – Types of Cooking

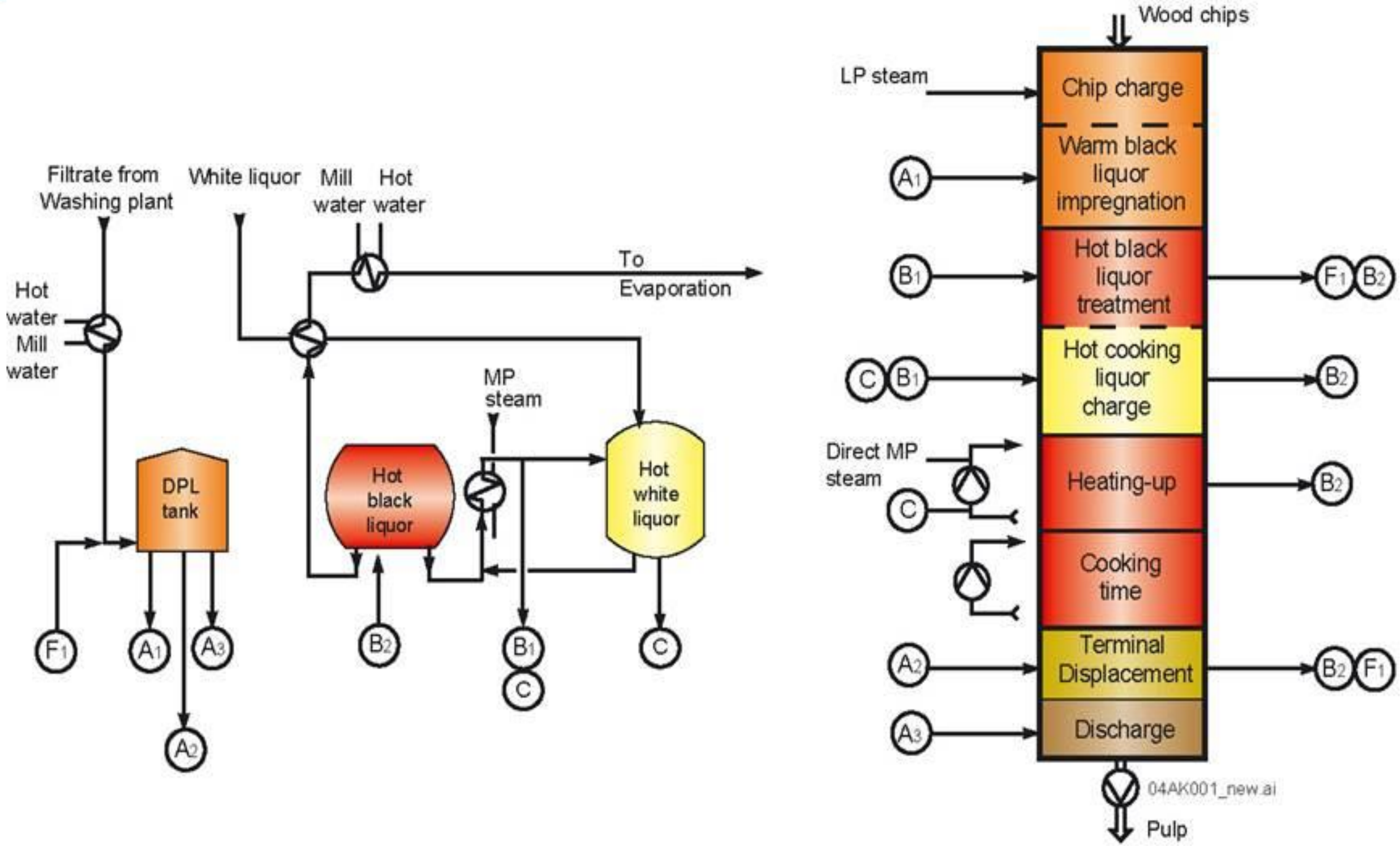
- **Batch cooking**
  - Conventional
  - Modified batch cooks
    - *Superbatch & RDH cooking*
- **Continuous cooking**
  - Modified continuous cooks
    - *Compact cooking,*
    - *EMCC,*
    - *Lo-Solids*
    - *Compact – G1 & G2*

Typical Kraft Batch Digester



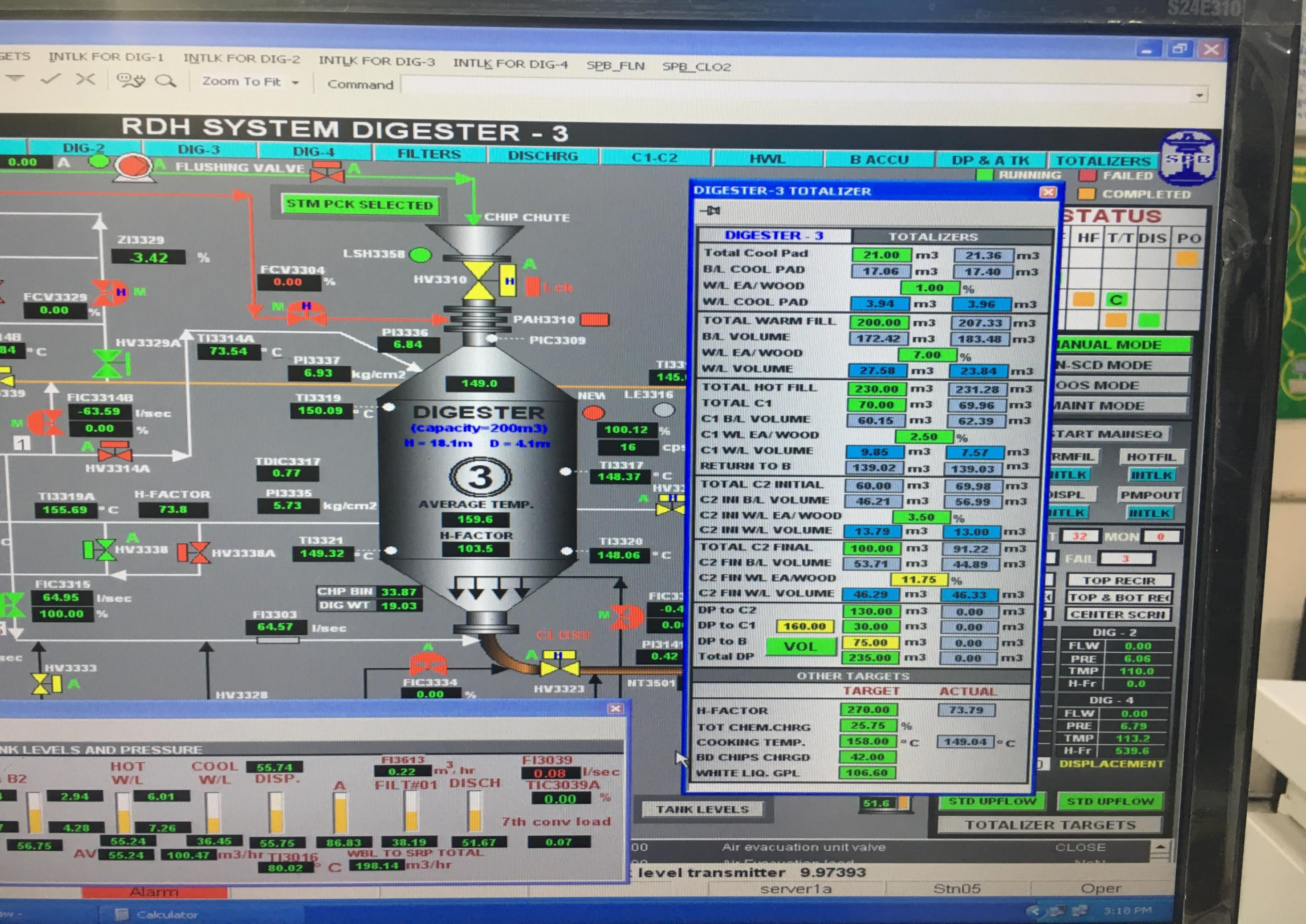
Super Batch Digester

Simple flow sheet



(Ref: Valmet)

Note – human gives an idea of size of Batch digester



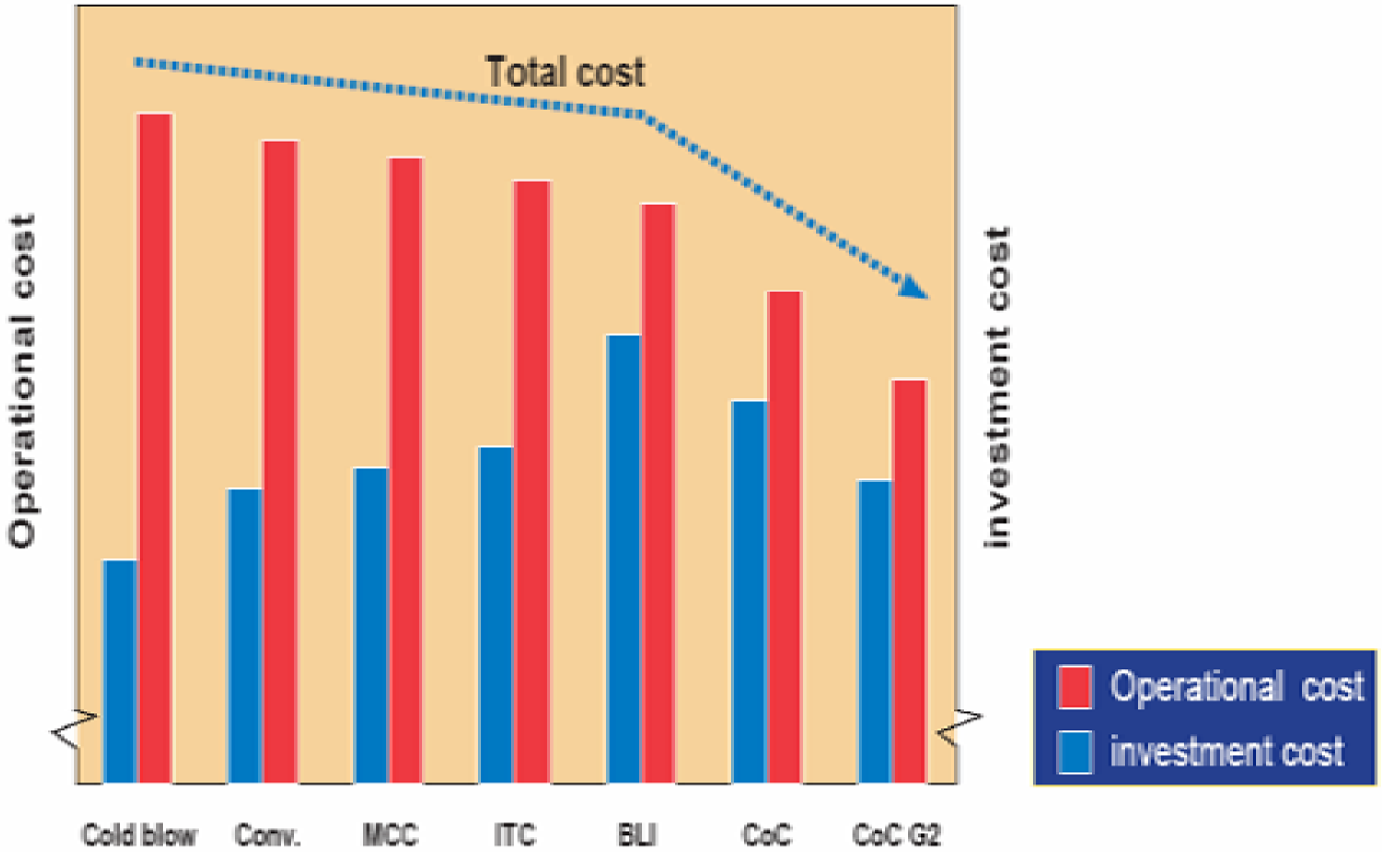
INTLK FOR DIG-1
INTLK FOR DIG-2
INTLK FOR DIG-3
INTLK FOR DIG-4
SPB_FLN
SPB_CLO2
Zoom To Fit
Command
RDH SYSTEM DIGESTER - 3
DIG-2
DIG-3
DIG-4
FILTERS
DISCHRG
C1-C2
HWL
B ACCU
DP & A TK
TOTALIZERS
RUNNING
FAILED
COMPLETED
FLUSHING VALVE
STM PCK SELECTED
CHIP CHUTE
ZI3329 -3.42 %
LSH3358
FCV3304 0.00 %
HV3310
FCV3329 0.00 %
PAH3310
PI3336 6.84
PIC3309
HV3329A
TI3314A 73.54 °C
PI3337 6.93 kg/cm2
149.0
FIC3314B -63.59 l/sec 0.00 %
TI3319 150.09 °C
DIGESTER
(capacity=200m3)
H = 18.1m D = 4.1m
LE3316
100.12 %
16
HV3314A
TDIC3317 0.77
TI3317 148.37 °C
TI3319A 155.69 °C
H-FACTOR 73.8
PI3335 5.73 kg/cm2
AVERAGE TEMP.
159.6
H-FACTOR
103.5
HV3338
HV3338A
TI3321 149.32 °C
TI3320 148.06 °C
FIC3315 64.95 l/sec 100.00 %
CHP BIN 33.87
DIG WT 19.03
FI3303 64.57 l/sec
HV3333
HV3328
FIC3334 0.00 %
HV3323
CLOSE
DIGESTER-3 TOTALIZER
DIGESTER - 3
TOTALIZERS
Total Cool Pad 21.00 m3 21.36 m3
B/L COOL PAD 17.06 m3 17.40 m3
W/L EA/WOOD 1.00 %
W/L COOL PAD 3.94 m3 3.96 m3
TOTAL WARM FILL 200.00 m3 207.33 m3
B/L VOLUME 172.42 m3 183.48 m3
W/L EA/WOOD 7.00 %
W/L VOLUME 27.58 m3 23.84 m3
TOTAL HOT FILL 230.00 m3 231.28 m3
TOTAL C1 70.00 m3 69.96 m3
C1 B/L VOLUME 60.15 m3 62.39 m3
C1 WL EA/WOOD 2.50 %
C1 W/L VOLUME 9.85 m3 7.57 m3
RETURN TO B 139.02 m3 139.03 m3
TOTAL C2 INITIAL 60.00 m3 69.98 m3
C2 INI B/L VOLUME 46.21 m3 56.99 m3
C2 INI W/L EA/WOOD 3.50 %
C2 INI W/L VOLUME 13.79 m3 13.00 m3
TOTAL C2 FINAL 100.00 m3 91.22 m3
C2 FIN B/L VOLUME 53.71 m3 44.89 m3
C2 FIN WL EA/WOOD 11.75 %
C2 FIN W/L VOLUME 46.29 m3 46.33 m3
DP to C2 130.00 m3 0.00 m3
DP to C1 160.00 30.00 m3 0.00 m3
DP to B VOL 75.00 m3 0.00 m3
Total DP 235.00 m3 0.00 m3
OTHER TARGETS
TARGET
ACTUAL
H-FACTOR 270.00 73.79
TOT CHEM.CHRG 25.75 %
COOKING TEMP. 158.00 °C 149.04 °C
BD CHIPS CHRGD 42.00
WHITE LIQ. GPL 106.60
STATUS
HF T/T DIS PO
MANUAL MODE
OOS MODE
MAINT MODE
HOTFIL
INTLK
PMPOUT
TOP RECIR
CENTER SCRN
DIG - 2
FLW 0.00
PRE 6.06
TMP 110.0
H-Fr 0.0
DIG - 4
FLW 0.00
PRE 6.79
TMP 113.2
H-Fr 539.6
DISPLACEMENT
STD UPFLOW
STD UPFLOW
TOTALIZER TARGETS
TANK LEVELS
TANK LEVELS AND PRESSURE
HOT W/L
COOL W/L
55.74 DISP.
FI3613 0.22 m3/hr
FILT#01 DISCH
FI3039 0.08 l/sec
TIC3039A 0.00 %
7th conv load
2.94
6.01
4.28
7.26
56.75
55.24
36.45
55.75
86.83
38.19
51.67
0.07
AV 55.24
100.47 m3/hr
TI3016 80.02 °C
WBL TO SRP TOTAL 198.14 m3/hr
Air evacuation unit valve CLOSE
level transmitter 9.97393
server1a
Stn05
Oper
Alarm
Calculator
3:18 PM

Continuous Digester

Liquor extraction area

(Ref: Kavaerner now Valmet)

Continuous Cooking Development
Investment VS Production Cost



(Ref: Kavaerner now Valmet)

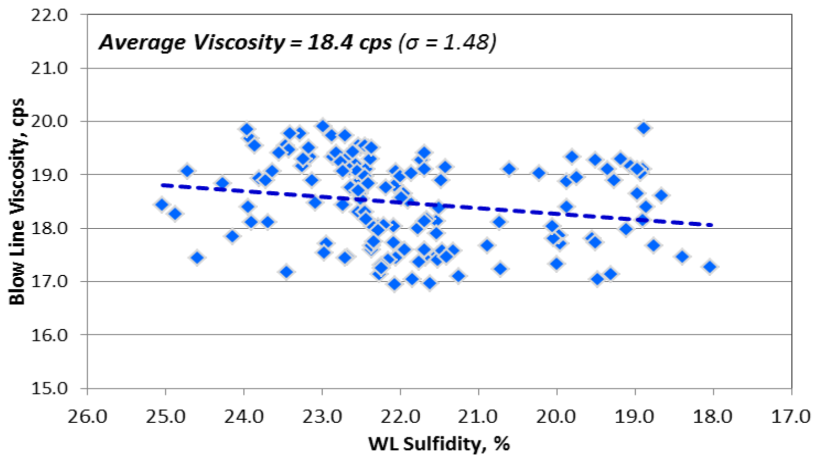
Advantages of Continuous Cooking

- Minimized production cost
- High yield
- Low reject
- Easy to bleach
- Low steam consumption
- Low power consumption
- Less equipment to maintain

Kraft Pulping Variables

There are several variables that impact kraft cooking:

- **Wood chips**
  - *Species – Hardwood/Softwood/Non-wood*
  - *Bulk density (kg/m³)*
  - *Chip quality*
    - *Accept chips (85%)*
    - *Chip thickness, (< 7 mm)*
  - *Moisture content (%)*
  - *Age of the chips (# of days)*



- **Cooking liquor**
  - *Active Alkali charge, % of OD wood*
  - *Sulfidity (%)*
  - *Liquor concentration (gpl)*

Kraft Pulping Variables

- **Cooking Parameters**
  - *Temperature of the cook (Maximum temperature)*
  - *Chemical reactions of white liquor*
  - *Liquor to wood ratio*
  - *H-Factor (Time and Temperature relationship)*
- **Target Parameters**
  - *Degree of delignification* ***Kappa #***
  - *Knots/rejects (%)*
  - *Yield (%)*
  - *RAA/REA at the end of the cook (gpl)*

Kappa Number (K#)

- The Kappa number is a measurement of the **residual lignin** on/in cooked fibers
- The Kappa number is not determined for high yield mechanical pulps
- The Kappa number is related and derived from the old “K” or potassium permanganate number

Pulp Yields

- Decline as the Kappa number declines
- Decline as the pulp brightness increases
- Decline as digester rejects increase
- Are reduced as wood ages
- Decline as carbohydrate dissolution occurs
- Decline as more extractives are removed
- Increase as rejects decrease
- Increase as the kappa number increases

Effect of Time During a Kraft Cook

- Lignin and carbohydrates are dissolved resulting in a yield decrease

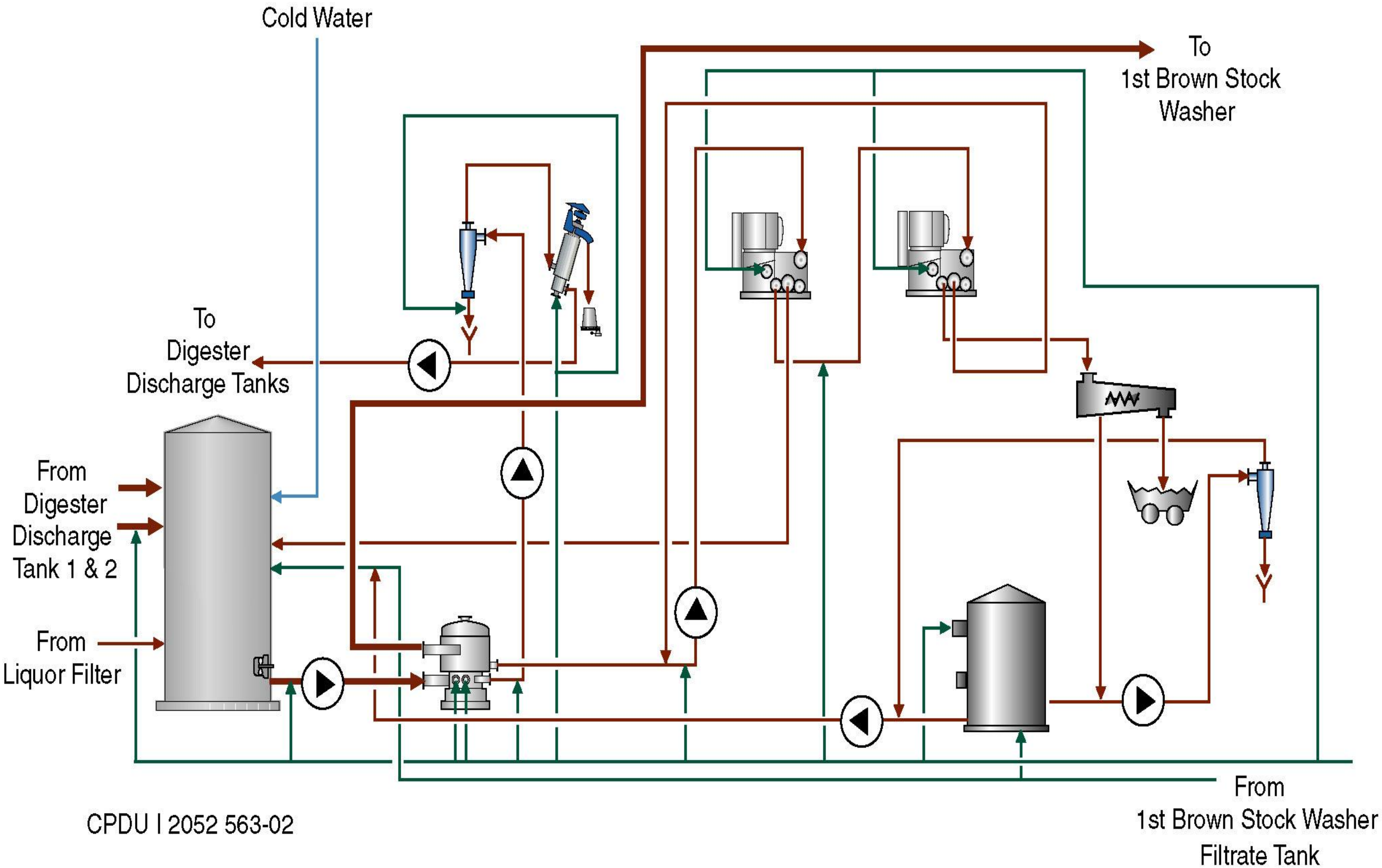
- Carbohydrate dissolution is rapid, but is essentially complete halfway through the cooking cycle

- Lignin dissolution is slower in the beginning of the cooking cycle, but continues until the end of the cook

Digester - Chemical Additives

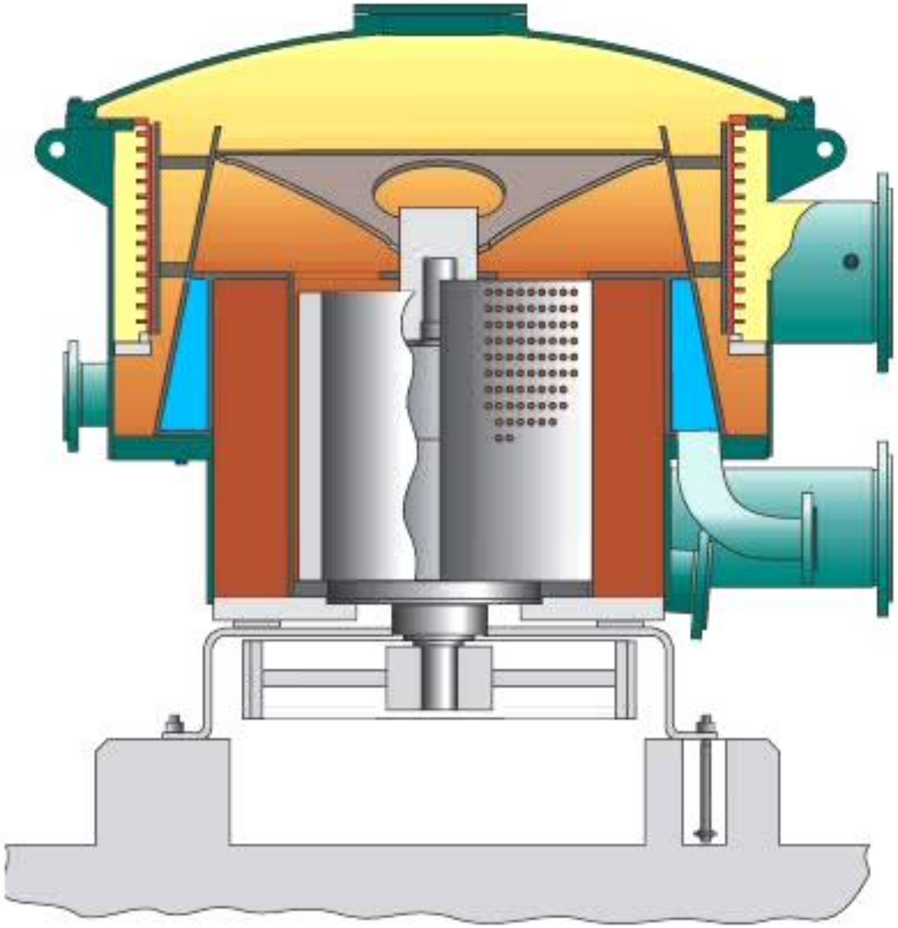
- **Cooking aids**
  - *Digester additives in small amounts act as catalysts to improve yield and accelerate delignification*
  - *Anthraquinone (AQ) is a catalyst to improve breakdown of lignin*
  - *Penetrants/surfactants improve wetting of chips*
  - *Combinations of AQ + penetrants*
- **Scale control**
  - *Commonly calcium carbonate scale appears in heaters and/or strainers*
- **Pitch/Extractive control**
  - *Surfactants/dispersants may be used to disperse pitch*

Pulp Screening



(Ref:Web…Not known exactly)

Screening – Combi Screen
Inbuilt Primary Screen and Knotter



(Ref: Kavaerner now Valmet and/or Others)

Screening
Knots

Higher Knot rejects

Normal Knot rejects

Washing

- The purpose of brown stock washing is to displace and remove dissolved solids (both inorganic and organic) from the pulp. The two primary reasons we need washed pulp are:
  - *Residual liquor will contaminate pulp going to the paper machines.*
  - *We need to recover the maximum amount of spent cooking chemicals and dissolved wood solids from the fiber with minimum dilution, making chemical pulping economical.*

Excessive Foaming on Washer

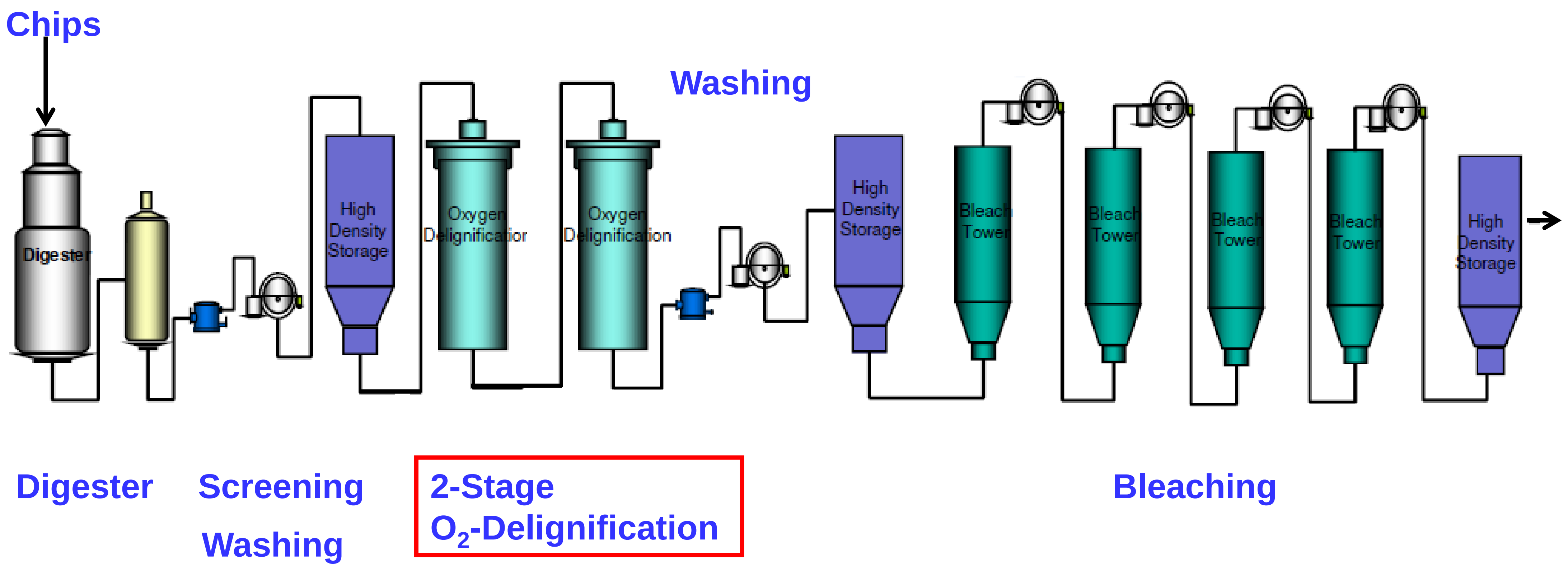
Poor Washing, Increased Alkali Carryover

Excessive Foaming on Washer…#2

Poor Washing, Increased Alkali Carryover

Fiber Line Overview

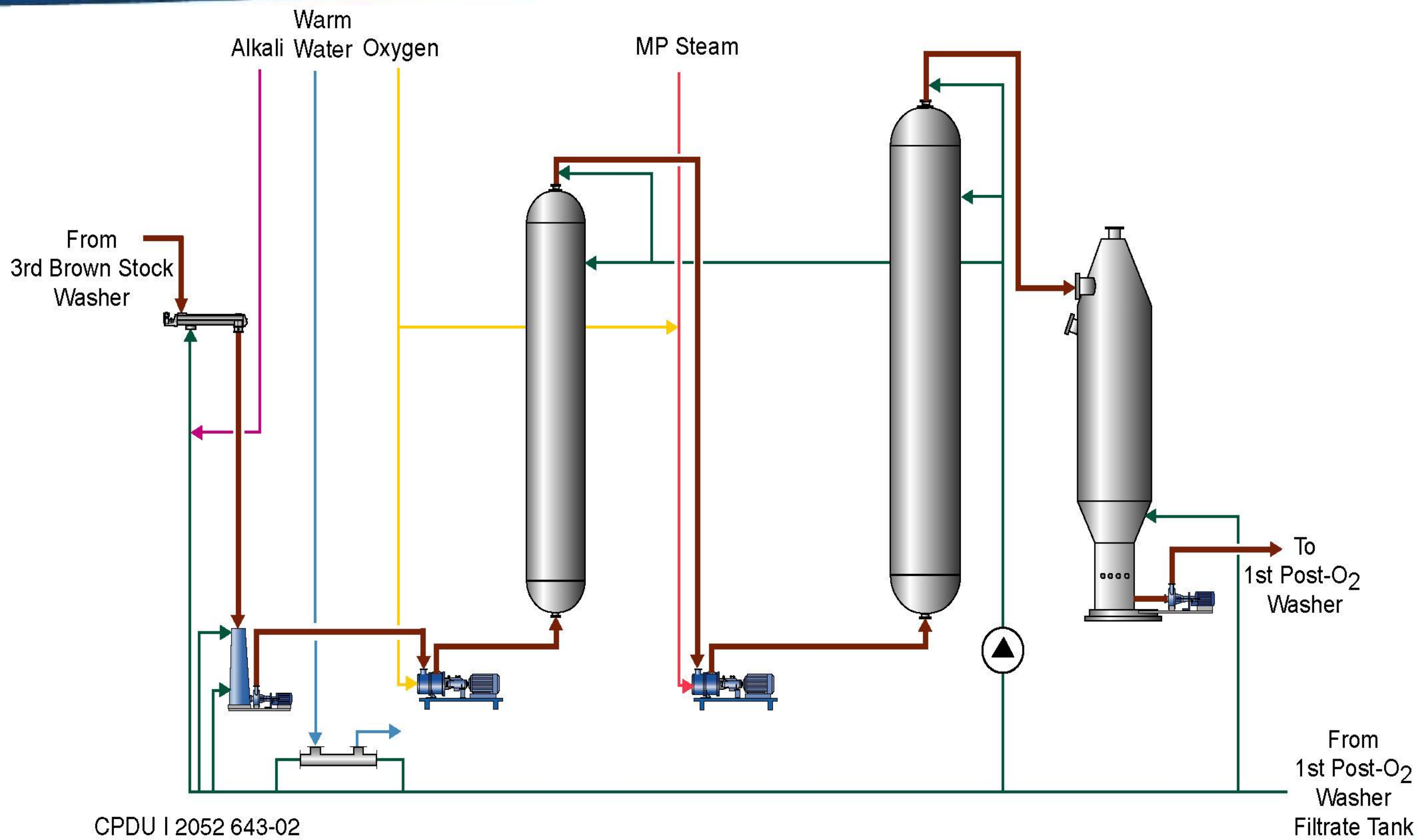
(Ref: Kavaerner now Valmet)



Oxygen Delignification - Purpose

- Extended lignin removal
- Minimize pulp degradation (cellulose loss)
- Reduce the amount of lignin to the bleach plant
- Minimize environmental load
- Increase capacity

Oxygen Delignification
(Simple flow diagram)



(Ref: Andritz/Valmet??

Typical O_2 Stage Process Conditions

Pulp consistency %	10-14
Temperature	90-110°C
Pressure	2.5-6.0 Bar
Reaction Time, min	20-80
pH	10-11.5
Oxygen,% on pulp	1.5-2.2
NaOH,% on pulp	1.5-3.5
$MgSO_4$,% on pulp *(mostly for softwood)*	0.1 as Mg
Kappa Number	40-75% reduction of an incoming K#

Bleaching Process

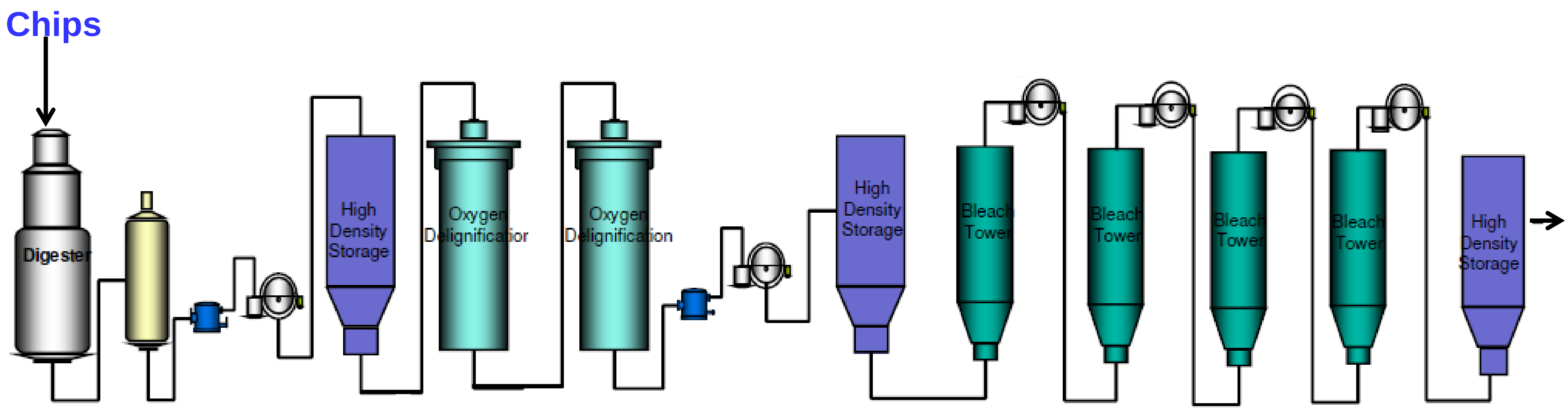
- Bleaching is a chemical process applied to pulp to **eliminate materials that absorb light**.

- Most common measurement is ***brightness***.

- Brightness is: **the % reflectance of light at a wavelength of 457 nm**.

Fiber Line Overview

(Ref: Kavaerner now Valmet)



Digester

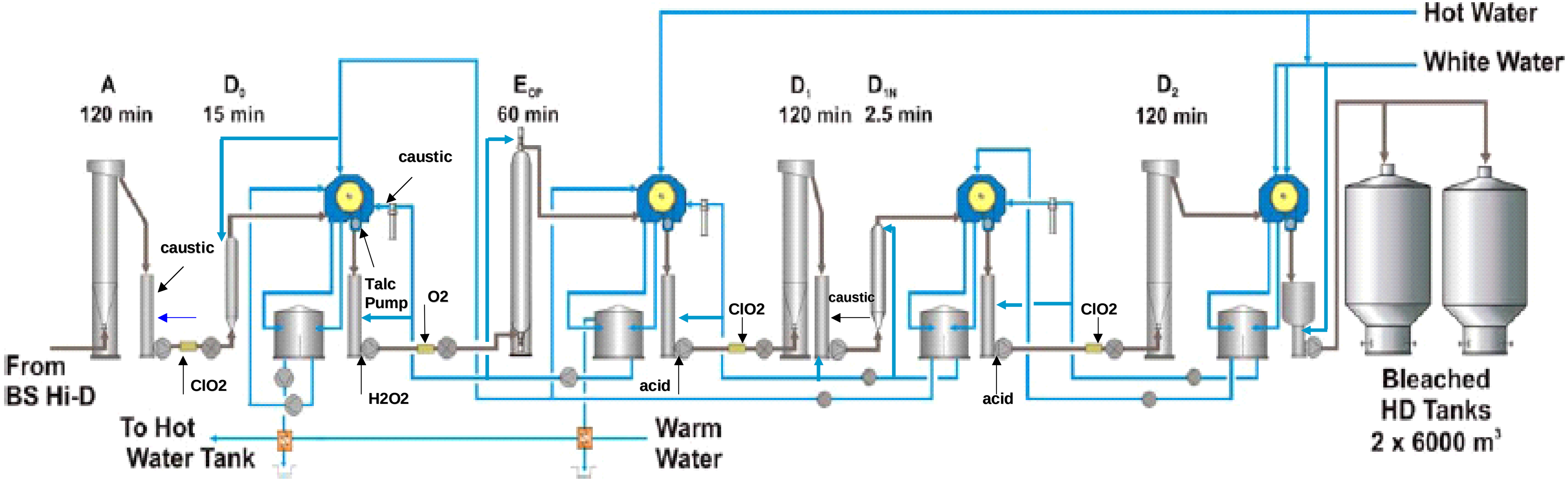
Screening Washing

2-Stage O_2-Delignification

Washing

PULP BLEACHING

Bleaching Sequence
(Ref. Andritz)



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The Task of the Bleach Plant

- Produce a pulp with stable brightness
- Produce a pulp with good viscosity, strength, and cleanliness
- Rid the pulp of quality variations
- Remove or chemically change the resin and dirt components
- Reduce and remove shives
- Remove bound transition metals
- Remove solid particulates through screening
- Adjust pulp viscosity

Brightness at Various Stages

Approximate Brightness Ranges *(% ISO)*

unbleached Kraft pulps	20-30
unbleached Kraft pulp (with O2 delig)	44-48
NSSC	40-50
unbleached sulfite, SGW	50-65
typical newspaper	55-60
writing papers	**85-90+**

Bleaching Terms

Symbol	Chemicals used
C/D or C_D	Chlorine + Chlorine Dioxide
E_O	Caustic Extraction w/ Oxygen added
EOP	Caustic + Oxygen + Peroxide
OP	Oxygen + small amount Peroxide
PO	Peroxide + small amount Oxygen
D_0	initial Chlorine Dioxide stage
Z	Ozone bleaching
D_1	initial Chlorine Dioxide stage
D_n	Chlorine Dioxide stage *(neutral pH dilution stage)*

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Dissolving Grade Pulp

Dissolving Grade Pulp - Agenda

- **Dissolving grade pulp**
  - *Demand trend*
  - *Drivers for demand*
  - *End use*
  - *Fibers in textile industry*
- **Understanding Dissolving Grade pulping process**
  - *Issues related to process*
  - *Targets for pulp quality*
- **Rayon conversion process and issues**

What is Dissolving Grade Pulp?

- **Dissolving pulp** (also called *dissolving cellulose*) is a bleached wood pulp that has a high cellulose content (> 90%). It is produced chemically from the pulpwood, in a process that has a low yield (30 - 35% of the wood). This pulp has special properties, such as a high level of brightness and uniform molecular-weight distribution
- Dissolving pulp is made from the sulfite process or the Kraft process with an acid pre-hydrolysis (PH) step to remove hemicelluloses.
- The sulfite process produces pulp with cellulose content up to 92 percent. It can use ammonium, calcium, magnesium or sodium as a base. The pre-hydrolysis sulfate process produces pulp with cellulose content up to 96 %.

Fiber Consumption in Textile Industry

(Ref.: Poyri Management Consulting Oy at http://www.paperadvance.com/process/special-features/176-dissolving-pulp-the-great-come-back.html)

Fiber Type	Synthetic (Oil)	Cotton	Other Natural	Viscose	Total
Million Tons	43.0	23.5	4.5	5.0	75.0
%	57.5	31.5	6.0	6.7	100.0

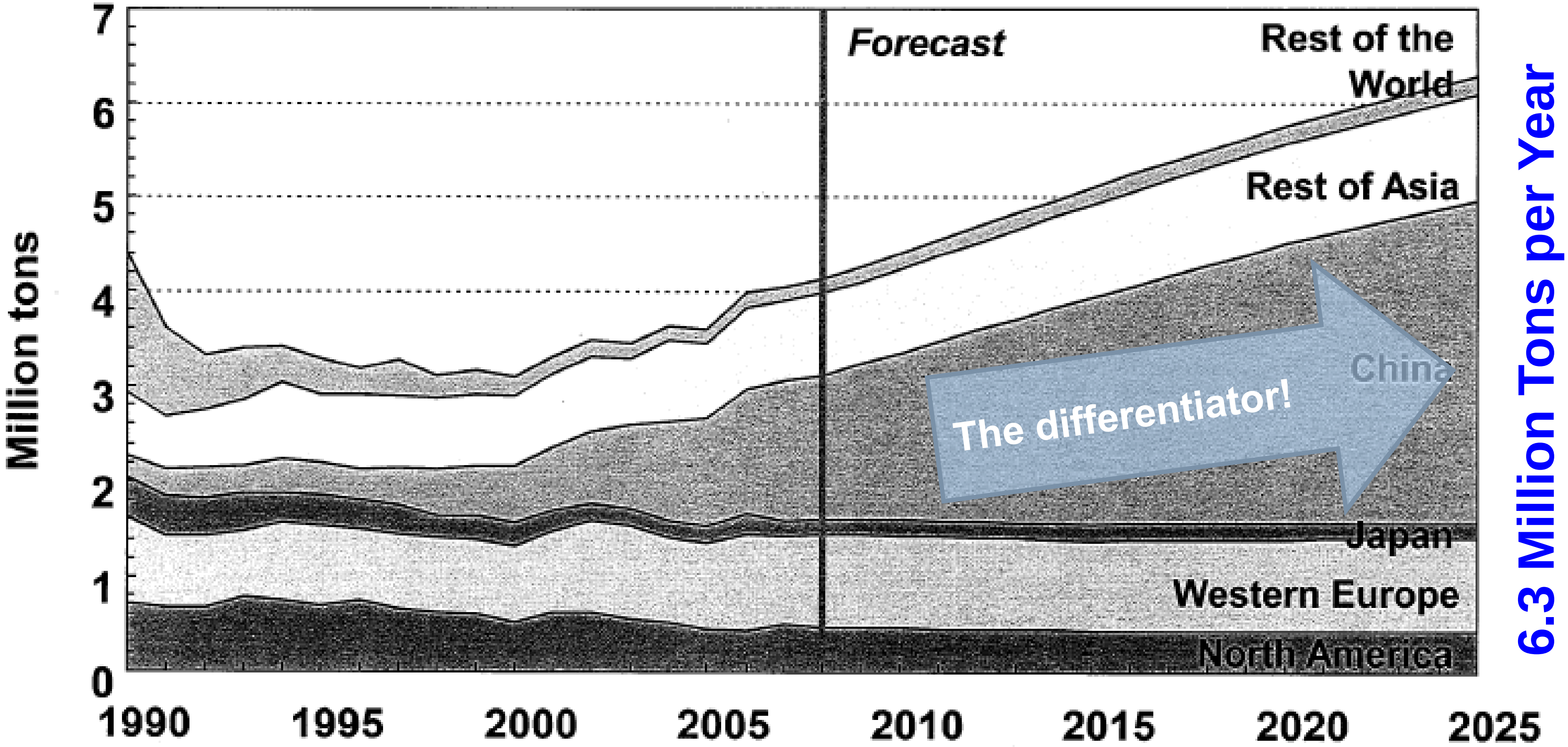
- 11% increase in Viscose fiber with 1% reduction in synthetic fiber
- 6% increase in Viscose fiber with 1% reduction in cotton output

Staple VS Synthetic Fibers

"Unlike ***SYNTHETIC FIBERS***, which are petroleum based, and therefore neither moisture absorbent nor biodegradable, **DISSOLVING GRADE PULP** and VISCOSE STAPLE fiber meets consumers demand for ***absorbency, biodegradability*** ***and*** ***sustainability***."

DP Demand – *China the Driver!*

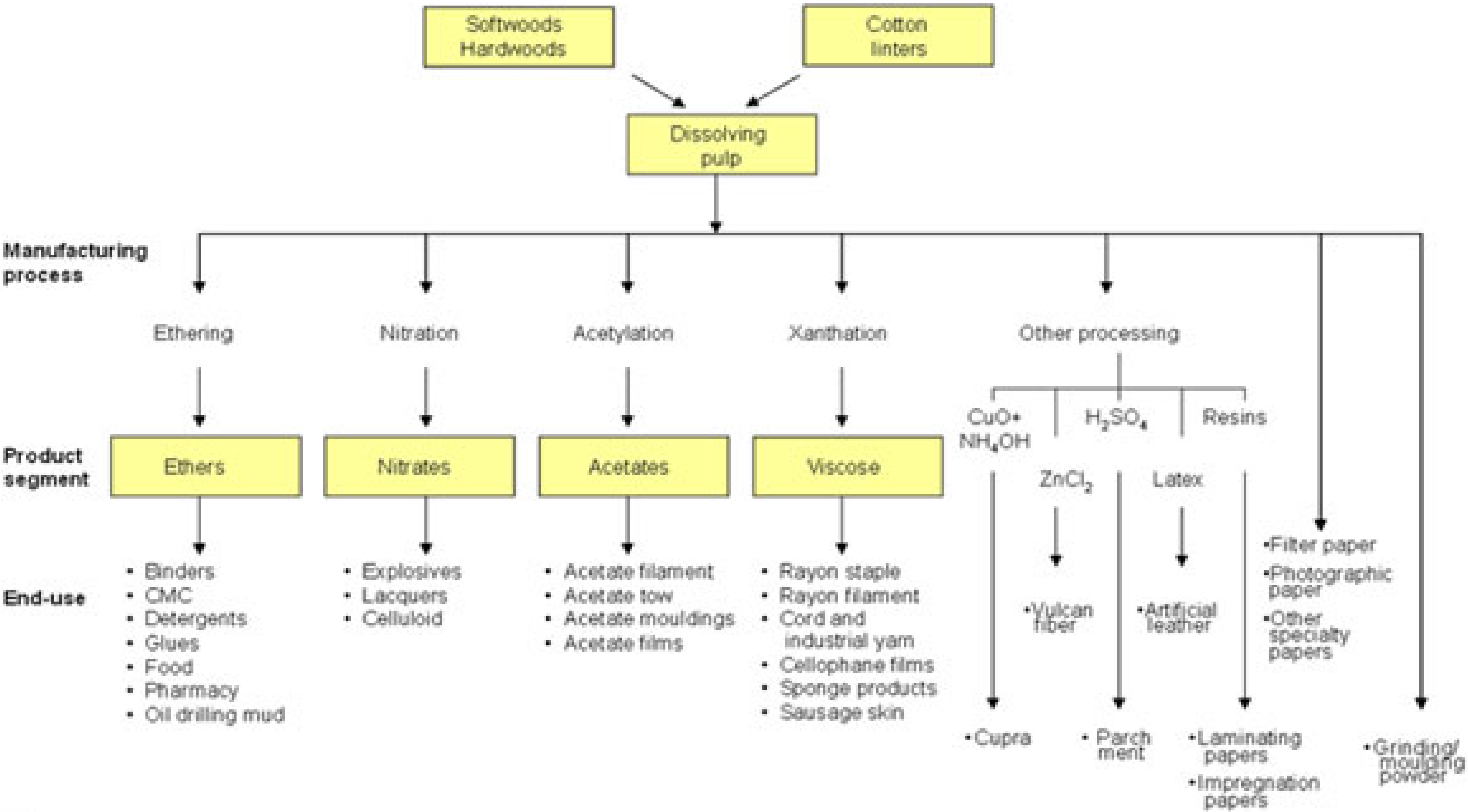
(Ref.: RISI 2011)



China production = ~1.9 MM TPY

End Use/Products of DG Pulp

(Ref: From web. Source unknown)



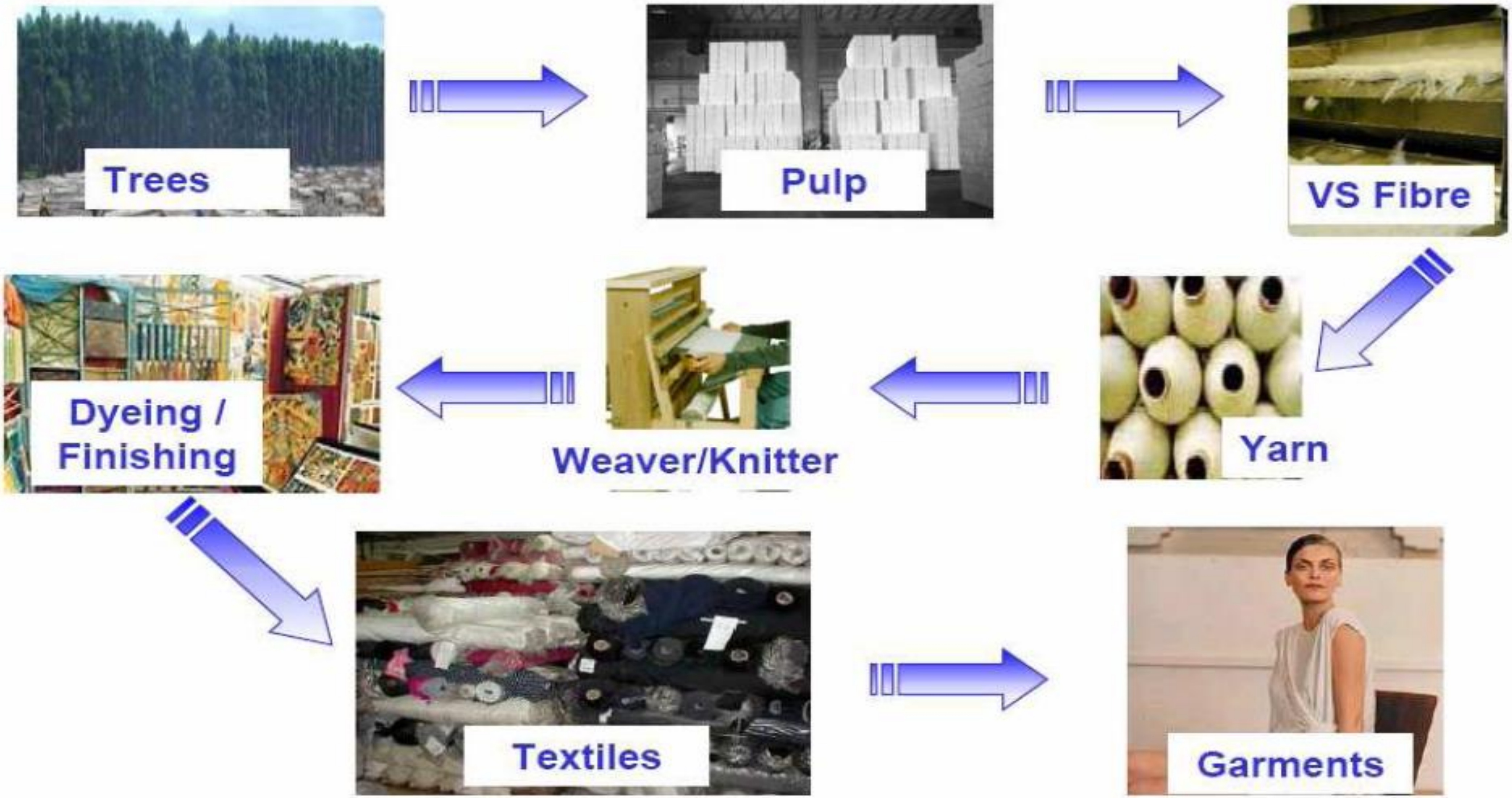
Ethers *(CMC, HC, & HEC)*

(Ref: From web. Source unknown)

- Food applications
- Pharmaceuticals
- Detergents
- Cosmetics
- Paper sizing
- Kitchen wipes

DP - Value Chain

(Ref: From web. Source unknown)



Viscose Staple Fiber

(Ref: From web. Source unknown)

Commodity Grade
- Viscose Staple
- Non-wovens

Specialities
- Lyocell
- Filament
- Other Applications

Specialities
- Acetate Tow

DG Pulping

Suitable Pulping Processes

- **Kraft**
- ~~Soda~~
- **Sulfite**
- ~~Neutral Semi-sulfite (NSSC)~~
- **Alkaline sulfite**
- ~~CTMP~~
- ~~APMP~~

Raw Material Types

- Hardwoods
- Softwoods
- Non-woods
  - *Different nonwood raw material provides different pulp quality!*
  - *Kenaf and hemp can provide pulp quality as good fiber as is from softwood!*

Wood Chemistry

CELLULOSE
(40-45%)

HEMICELLULOSE
(20-28%)

} Carbohydrates = Kraft Pulp

LIGNIN
(15-28%)

EXTRACTIVES
(2-8%)

(= Pitch Problem)

OTHERS
(1-3%)

Wood Chemistry & DG Pulp

CELLULOSE (40-45%) (= Dissolving Grade Pulp)

~~HEMICELLULOSE~~ (20-28%)

~~LIGNIN~~ (15-28%)

~~EXTRACTIVES~~ (2-8%) (= Pitch/Process Problem)

~~OTHERS~~ (1-3%)

Dissolving Grade Pulp

Different Types of Digesters

Type of digester	Raw Material	Process
~~Tumbling type batch digester~~	~~Non-woods~~	~~Soda/Kraft/sulfite~~
~~Rotary spherical digester~~	~~Non-woods~~	~~Soda/sulfite~~
~~Pandia continuous cooking~~	~~Wheat straw/bagasse~~	~~Soda/Kraft/sulfite~~
Conventional batch digester	Wood	Kraft/sulfite
Super batch cooking process	Wood	Kraft/Displacement
RDH cooking system	Wood	Kraft/displacement
~~EMCC (Extended modified continuous cooking)~~	~~Wood~~	~~Kraft~~
~~Lo-solids continuous cooking~~	~~Wood~~	~~Kraft~~
Compact cooking	Wood	Kraft

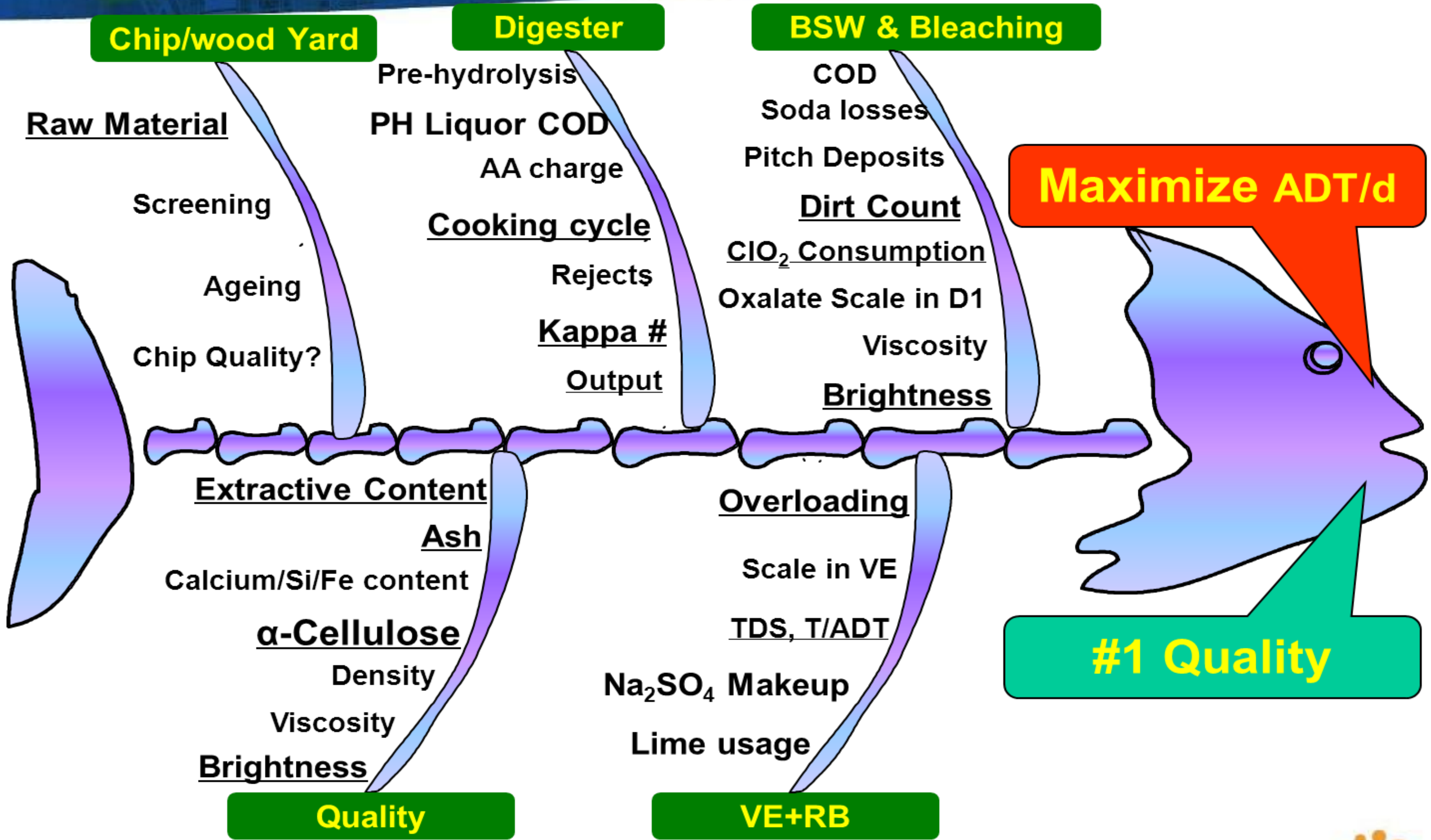
Water Quality for DP Process

-	pressure	MPa (g)	>0.35
-	pH		6.5-8.0
-	turbidity as SiO_2	mg/l	<25
-	colour (as Pt)	mg/l	<5
-	total iron as Fe	mg/l	<0.1
-	manganese as Mn	mg/l	<0.05
-	chlorides as Cl^-	mg/l	<20
-	total hardness as $CaCO_3$	mg/l	<100
-	COD content	mg/l	0

Comparison of Outputs

Parameter	Bleached Kraft Pulp	Dissolving Kraft Pulp
Raw Material	Acacia/MHW	Eucalyptus
Wood : Pulp ratio	4:1	3.9-4.2 :1
Log Unit Consumption (GT/ADT)	4.3	6.9
AA Charge, % on BD	17	21
Kappa No	12	5-6
Total Time Cooking (Min)	270	385
Yield(%)	42	33
Pulp/Day (ADT)	675	475

Key Challenges for DG Pulp Mills



Dissolving Pulp Quality
(Eucalyptus/Sulfite)

Property	Unit	Value
-cellulose	%	**93%**
Ash content	%	**0.01**
Calcium (as Cao)	ppm	**12**
Iron (as Fe)	ppm	**1**
Acid insolubles	ppm	**33**
S10		**6.28**
S18	%	**2.61**
Resin (DCM)	%	**0.02**
Copper #	ppm	**0.64**
Viscosity	cps	**27.3**
Brightness	%	**93.9**
Dirt count	Ppm	**5**
Density	g/m^3	**0.49**

Dissolving Pulp Quality
(Eucalyptus/Kraft)

Property	Unit	Value
Brightness	%	**88-90.5**
Viscosity	ml/g	**400-500**
-cellulose	%	**94.5**
R18	%	**96.5**
R10	%	**92.0**
Extractives (DCM)	%	**<0.1**
Ash	%	**<0.12**
Metals – Fe	ppm	**<10**
Ca	ppm	**<100**
SiO_2	ppm	**<80??**
Mn	ppm	**<0.5**
Cu	ppm	**<1.5**
Dirt count	Ppm	**<5**

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Key Factors in Process Optimization

Raw Material
- Species
- Accept
- Over thick
- Over size
- Bark

Cooking
- H-factor
- Alkali
- Sulfidity
- Temperature
- Scaling
- **Kappa#**
- **Output**
- **Yield**

Washing &ODL
- Washer type
- COD
- O_2-Charge
- OXWL
- Temp/Pre.
- K# reduction
- Viscosity
- Brightness
- COD
- Soda loss

Bleaching
- End pH
- Temperature
- Active Cl_2
- O_2/H_2O_2
- Consistency
- Washing
- Viscosity
- Brightness
- Dirt count
- Yiel

Chemical Recovery
- Evap. cap.
- Runnability
- Scaling/ΔT
- Overloading
- **TDS/BLS**
- Na_2SO_4
- C.E.
- WL TSS
- Lime mud dryness

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Mechanical Pulping

Pulping Process - Mechanical

- Chemical
  - Kraft
    - *Paper grade*
    - *Dissolving grade*
  - Soda
  - Sulfite
    - *Paper grade*
    - *Dissolving grade*
  - Neutral Semi-sulfite (NSSC)
  - Alkaline sulfite

- **Mechanical**
  - Ground Wood
    - *Stone Ground Wood*
    - *Pressurized Ground Wood*
  - Refiner Mechanical Pulp *(RMP)*
  - Thermo-Mechanical Pulp *(TMP or BTMP)*
  - Chemical Mechanical Pulp
    - *Alkaline Peroxide Mechanical Pulp (AMPM)*
    - *Bleached Chemi-Thermo Mechanical Pulp (BCTMP)*

Wood Chemistry
Mechanical Pulp = Retain Maximum

- **Mechanical Pulping Concept – Retaining everything**

CELLULOSE
(40-45%)

Carbohydrates = Pulp

HEMICELLULOSE
(20-28%)

LIGNIN
(15-28%)

EXTRACTIVES
(2-8%)

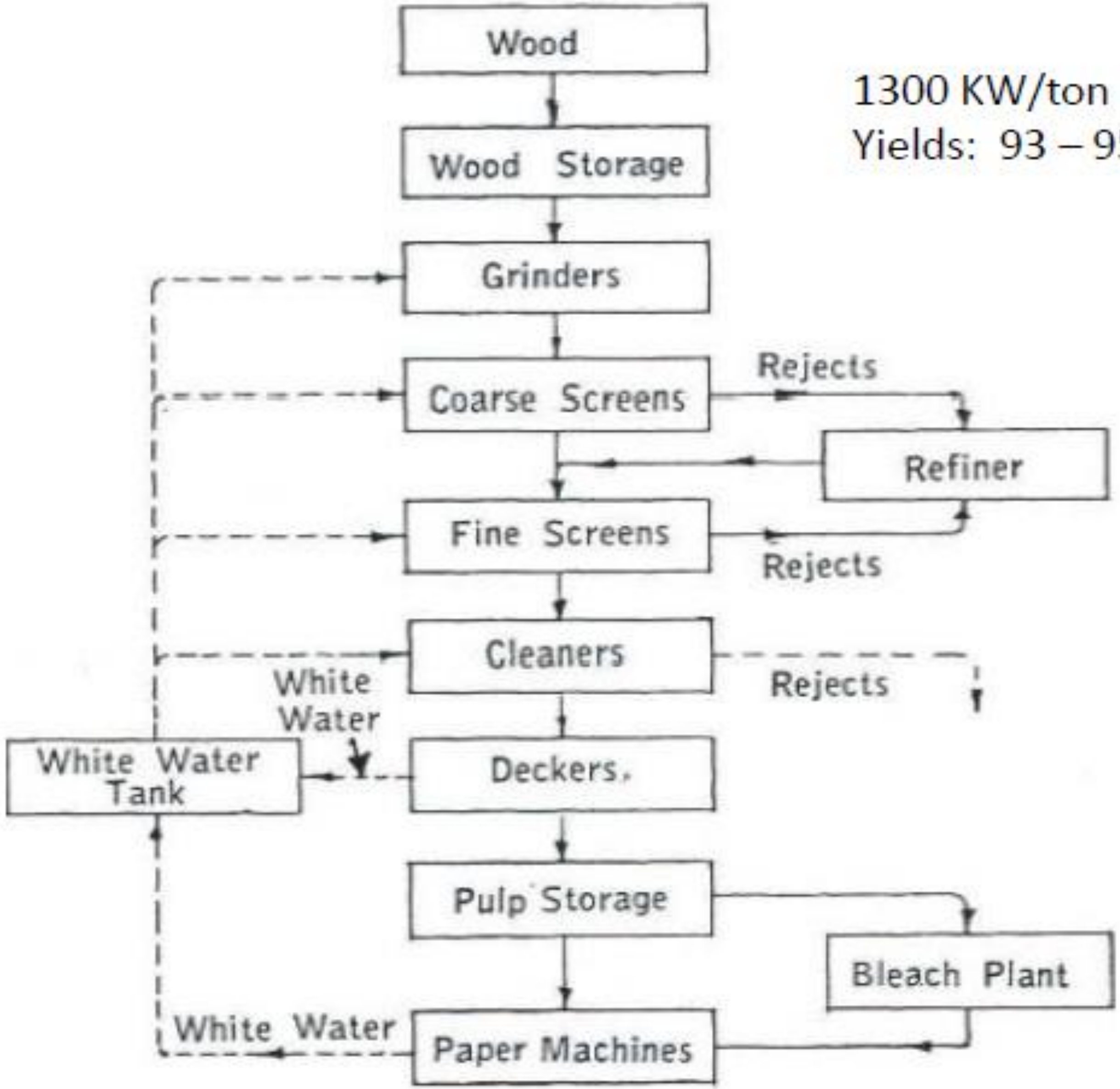
OTHERS
(1-3%)

Chip Quality for Different Processes

Chip parameters	Pulping Process		
	Kraft	Sulfite	Mechanical
Length, mm	15-25 (NC)	25-35 (C)	C
Width, mm	NC	NC	NC
Thickness, mm	2-4 (VC)	2-4 (C)	NC
Chip density	NC	NC	C
Bark contents, %	C	VC	C
Contaminants	C	C	VC
Chip damage	C	VC	N.A.
Moisture content	NC	NC	VC

NC: Not concerned, C: Concerned, VC: Very concerned

Stone Ground Wood

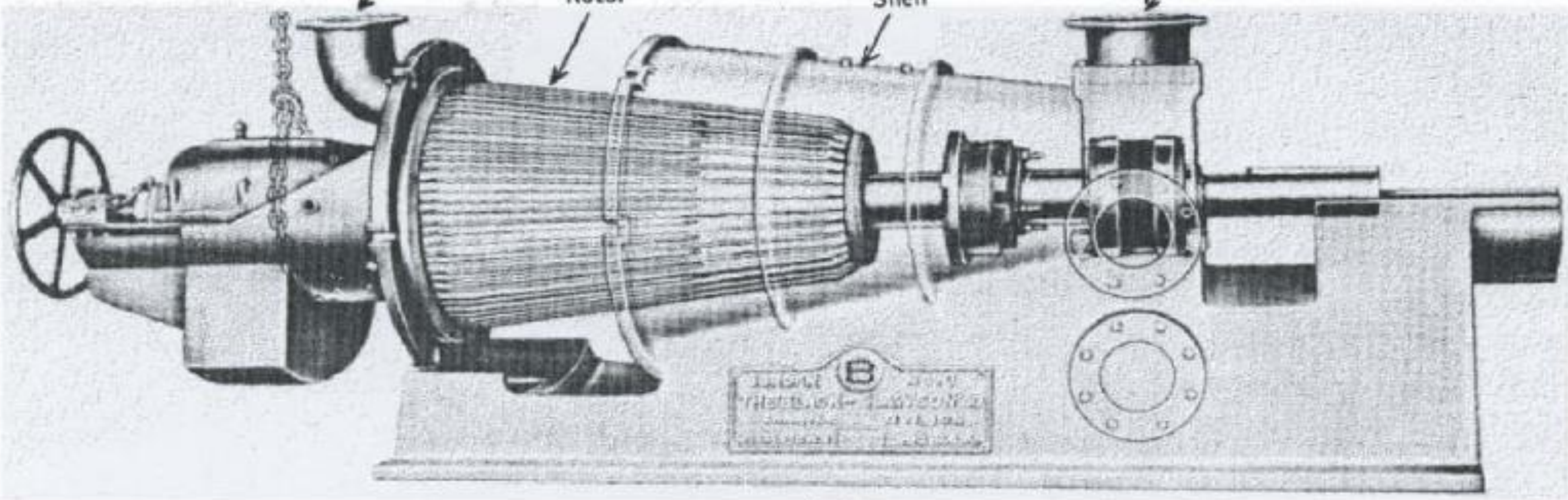


1300 KW/ton
Yields: 93 – 95%

Refiner Mechanical Pulp (RMP)

- Chips are used.
- Power requirements are 1600-1800 kWh/ton.
- Disk refiners are up to 1.5 m in diameter and rotate at 1800 rpm with 60 Hz power; this gives a velocity at the periphery of up to 140 m/s.
- The plates containing the metal bars must be replaced every 300-700 hours or low quality pulp is produced and energy use increases.
- Refining is usually carried out in two stages. The first is at 20-30% consistency to separate the fibers, while the second is at 10-20% consistency to alter the surface of the fibers for improved fiber bonding in the final paper.

Refiner



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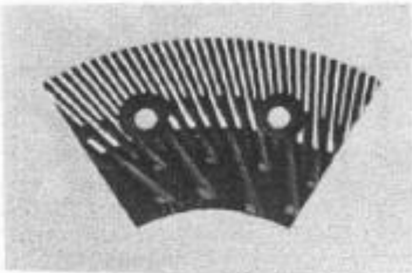
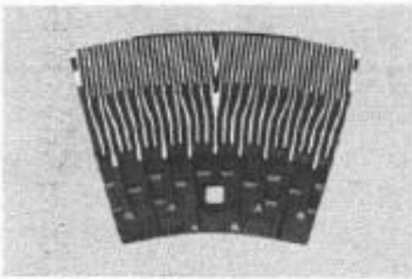


Fiber Development — Medium Bar



Double-Disc Refiner

Fiberboard

RMP

Thermo-Mechanical Pulp (TMP)

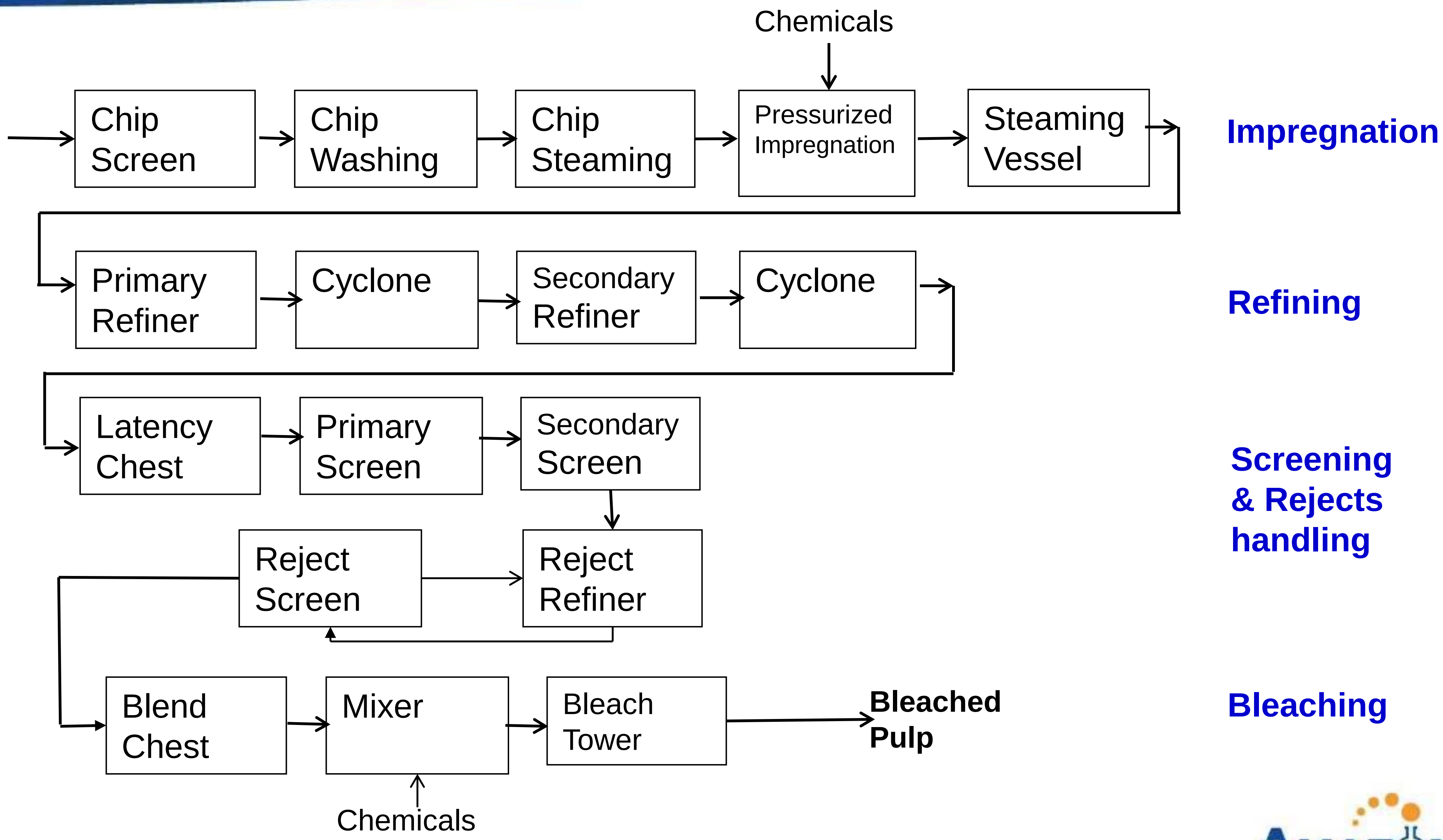
- Most important mechanical pulping method.
- The TMP process is very similar to the RMP process except that pulp is made in special refiners that are pressurized with steam in the first stage of refining. First stage: Elevated T (110-130°C, just below the glass transition temperature of lignin 140°C, enhance fibrillation) & P. second stage: Ambient T, P
- Higher pulp strength. Energy req. 1900-2900 kWh/ton
- An even consistency of 20-30% is ideal
- The pulp yield is 91-95%

Neutral Semi-Sulphite Chemical Pulp (NSSC)

- High pulp yields are obtained (75-85%).
- Cooking liquors contain Na_2S0_3 plus Na_2C0_3 (10-15% , act as a buffer); the liquor pH is 7-10.
- Cooking time is 0.5-2 h at 160-185°C.
- The residual lignin (15-20%) makes paper from this pulp very stiff.
- Subsequent refining energy of the pulp is 200-400 kWh/ton

Kraft green liquor semi-chemical process

BCTMP or APMP



Key Factors in Mechanical Pulping

Raw Material
- Wood Species
- Chip Size
- Bulk density
- Moisture content
- Chip temperature
- Sulphonate content
- Plate Age

Primary Variables
- Hydraulic Pressure
- Transfer screw Speed
- Dilution Water Flow Rate

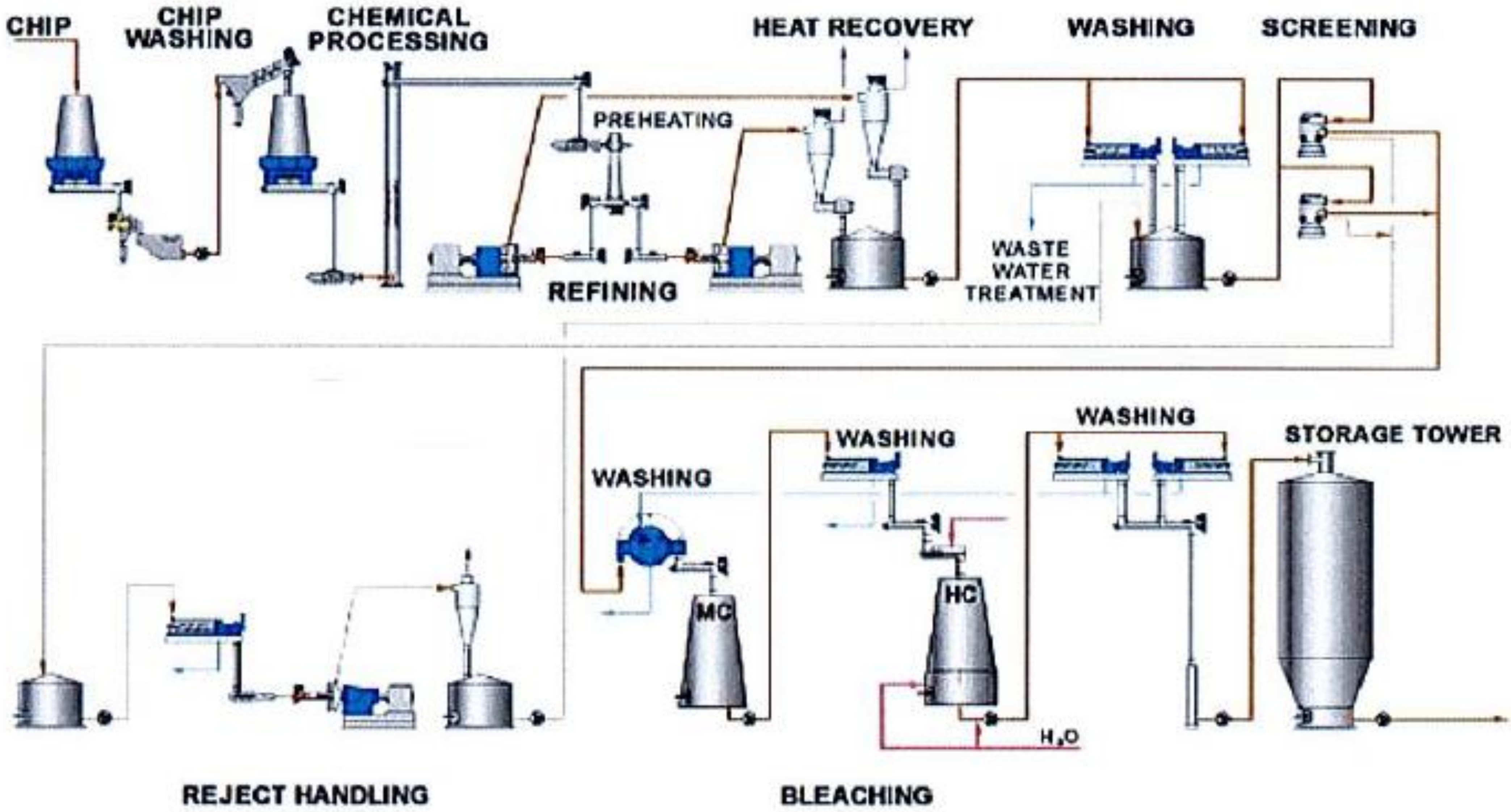
Passive Variables
- Plate geometry
- Bar Material
- Disc Rotational Speed

Secondary Variables
- Motor Load
- Production Rate
- Specific Energy
- Outlet Consistency
- Residence Time
- Refining Intensity
- Specific Refining Power

Output Variables
- Pulp Freeness
- Long Fibre Content
- Shive Content

Hand Sheet Properties
- Textile index
- Tear Index
- Burst Index
- Scattering coefficient

BCTMP Process
(Ref: Valmet)



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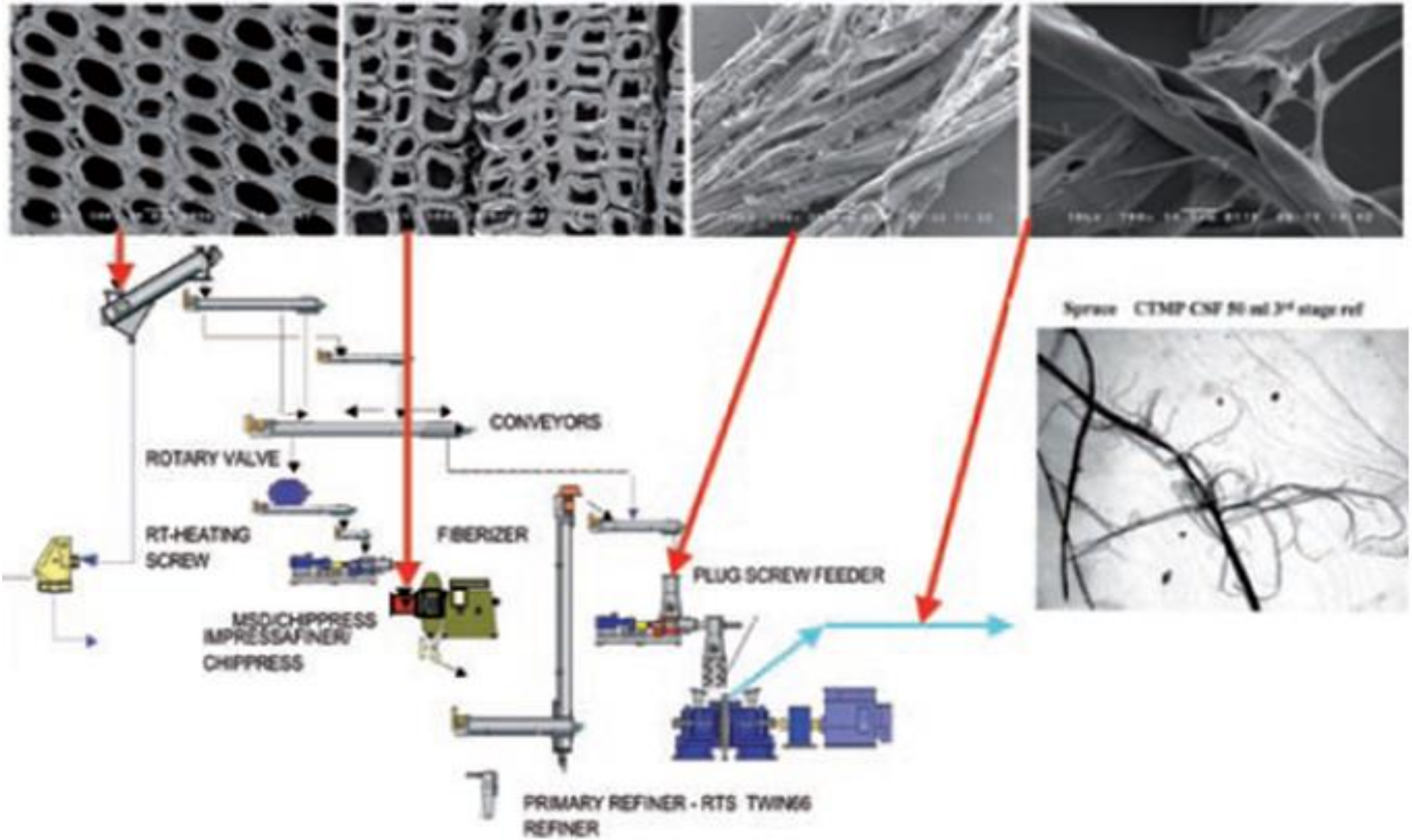
APMP Process – *Fiber Development*

(Ref: Andritz)



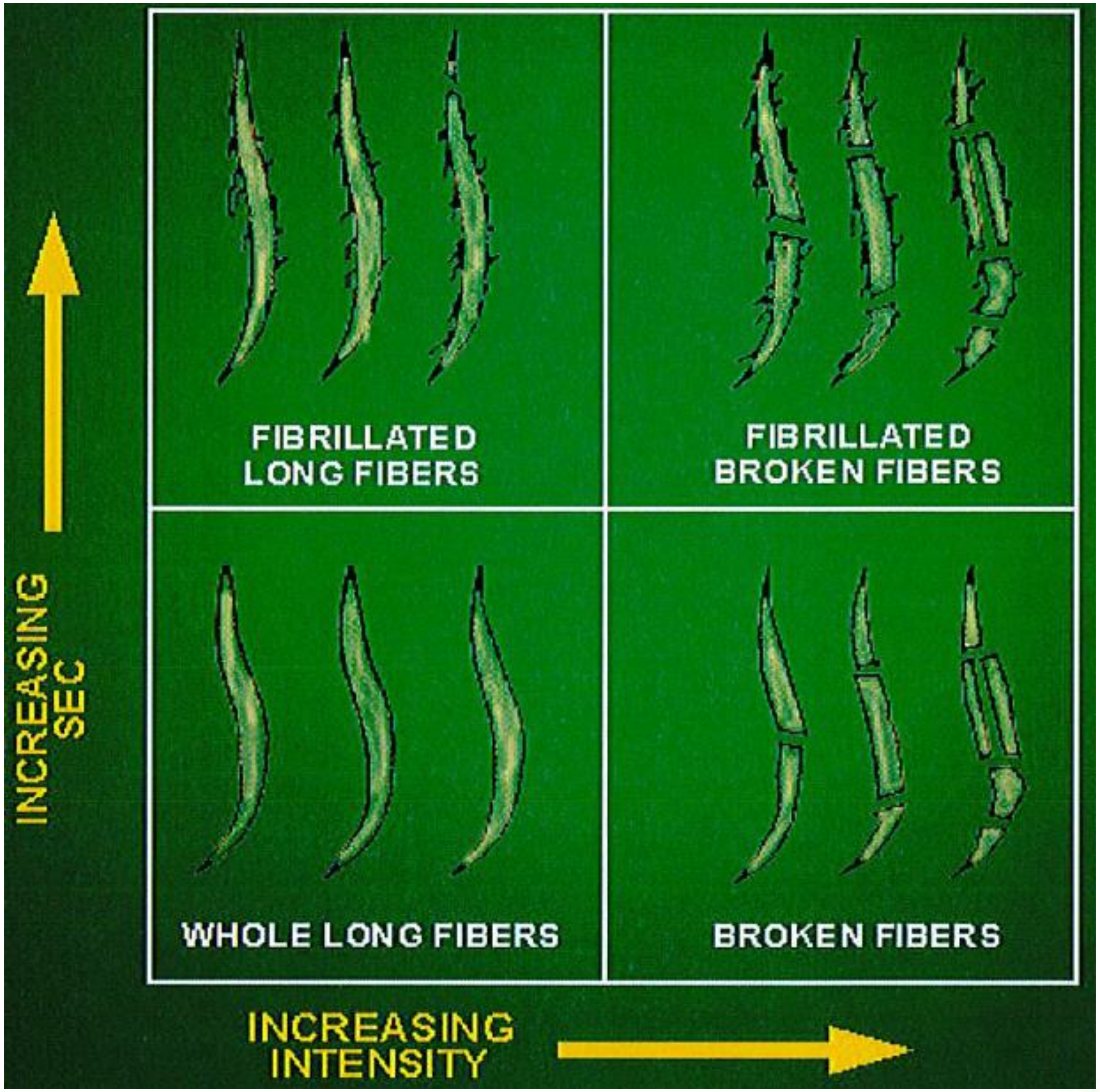
Development of Chips to Fiber

In mechanical pulping

(Ref: From web. Source unknown)

Various Stages of Fiber Development

Fiber Development in a Refiner



(Ref: From web. Source unknown)

Properties of BCTMP VS Kraft Pulps

Properties	SBKP	HBKP	HYP
Moisture content (%)	7.7	7.9	9.4
Caliper (mm)	101	103	145
Bulk (cm^3/g)	1.71	1.75	2.42
Burst index ($kP \times m^2/g$)	4.56	2.12	0.67
Tear index ($mN \times m^2/g$)	13.69	8.15	2.28
Tensile index ($N \times m/g$)	64.6	42.0	20.3
Breaking length (km)	6.58	4.28	2.07
Stretch (%)	3.27	1.98	0.80
TEA (mJ/g)	1447	587	91
Elastic modulus (km)	609	561	355
Zero-span tensile strength (km)	15.3	14.8	11.6
MIT double folds	257	9	too weak
Scott bond (J/m^2)	209	152	53
Light scattering coefficient (m^2/kg)	29.1	38.0	43.6
Brightness (%)	87.3	88.2	83.4
Opacity (ISO, %)	69.5	75.3	79.0

(Ref: From web. Source unknown)

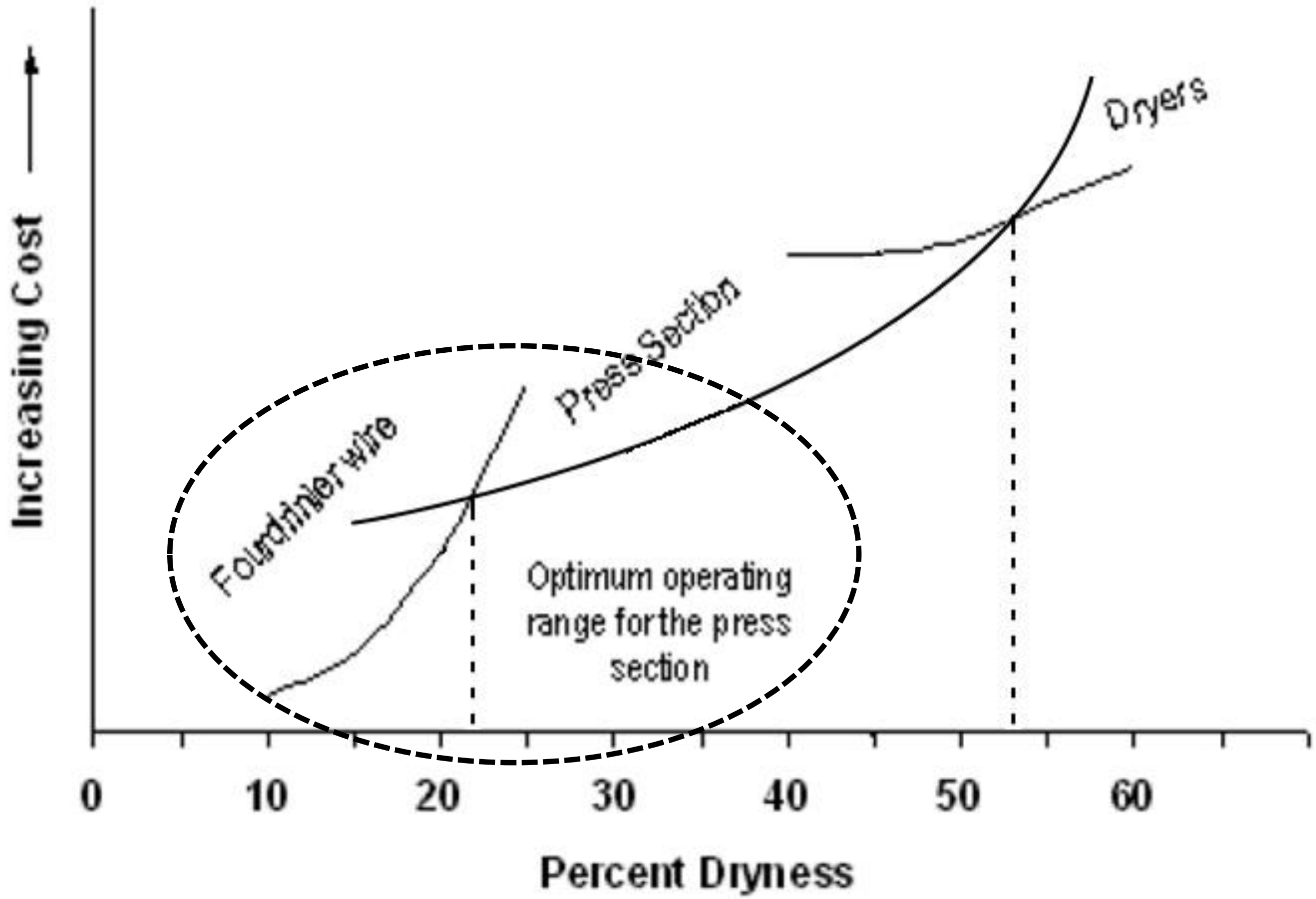
Improving Output at Pulp Dryer

(Ref: From web. Source unknown)

Areas of Focus during Drainage

Area	Description
Forming zone	Gravity drainage on Fourdrinier wire and the initial forming section of twin wire machines
Vacuum zone	Augmented drainage in the suction boxes, top wire and couch
Press section	Mechanical removal in the wet presses
Dryer section	Evaporation in the dryer section

Cost Relation for Drying Process



A 1% increase in sheet dryness leaving wire part or press section will ***increase production by 4-5%*** or a ***comparable decrease in energy*** consumption during drying.

Forming Section	**10% Cost**
Press Section	**12-15% Cost**
Dryer Section	**75-80% Cost**

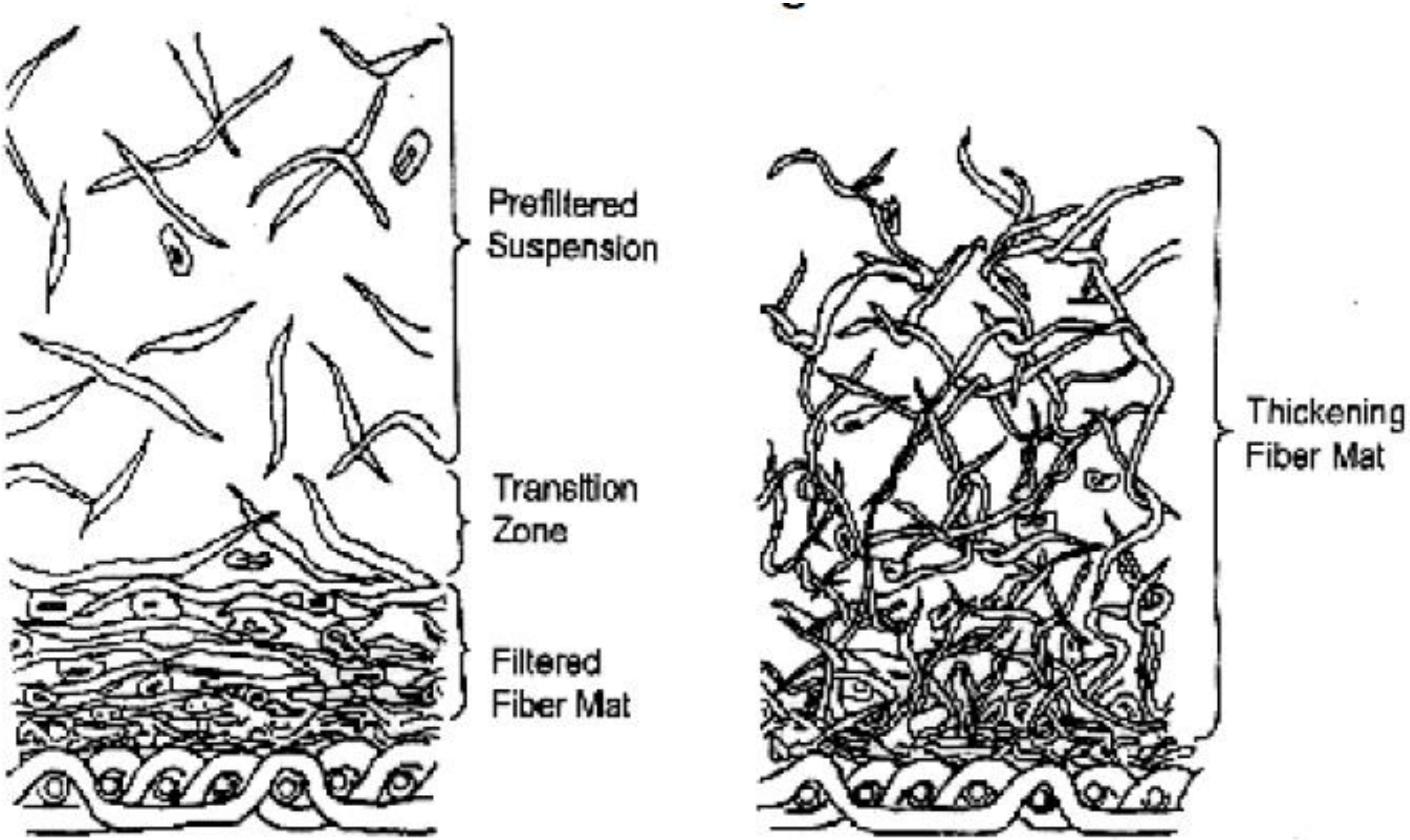
(Ref: From web. Source unknown)

Drainage Mechanism…… # 1

- **Mechanism of Dewatering of the fiber**
  - **Filtration**
    - When fibers move independent of each other
    - Free drainage just before the thickened stock hits vacuum boxes
  - **Thickening**
    - When the fibers in the suspensions are immobilized (floc together in coherent networks)
    - Sheet structure more flocky and felted (randomly oriented)
    - The fibers are like compressible structure.

The drainage is not only determined by the amount but also the rate of water removal.

Drainage Mechanism.....# 2



(Ref: From web. Source unknown)

Pulp Machine Operations

Factors Affecting Drainage

- Type of fiber – HW/SW
- Fiber length
- Fiber width
- Surface area of fines and fibers
- Sheet structure
- Hydration
- Consistency
- Entrained air

- Temperature
- Permeability of the forming web
- Wet compressibility of pulp
- Machine configuration
- Wire design
- Effective suction head
- Sheet weight
- **Drainage aid**

Factors Affecting Pulp Mills

Operational, Environmental and COST

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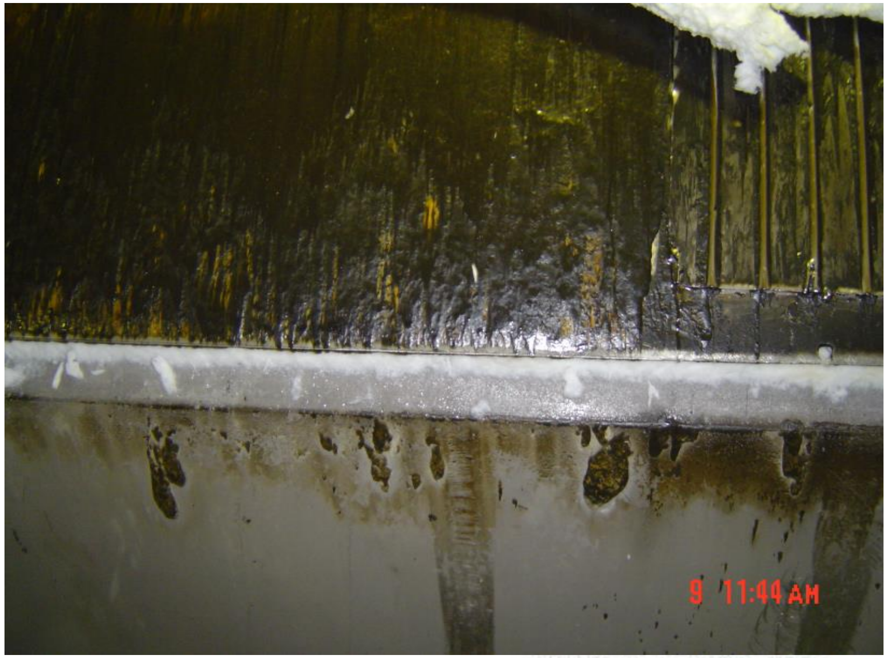
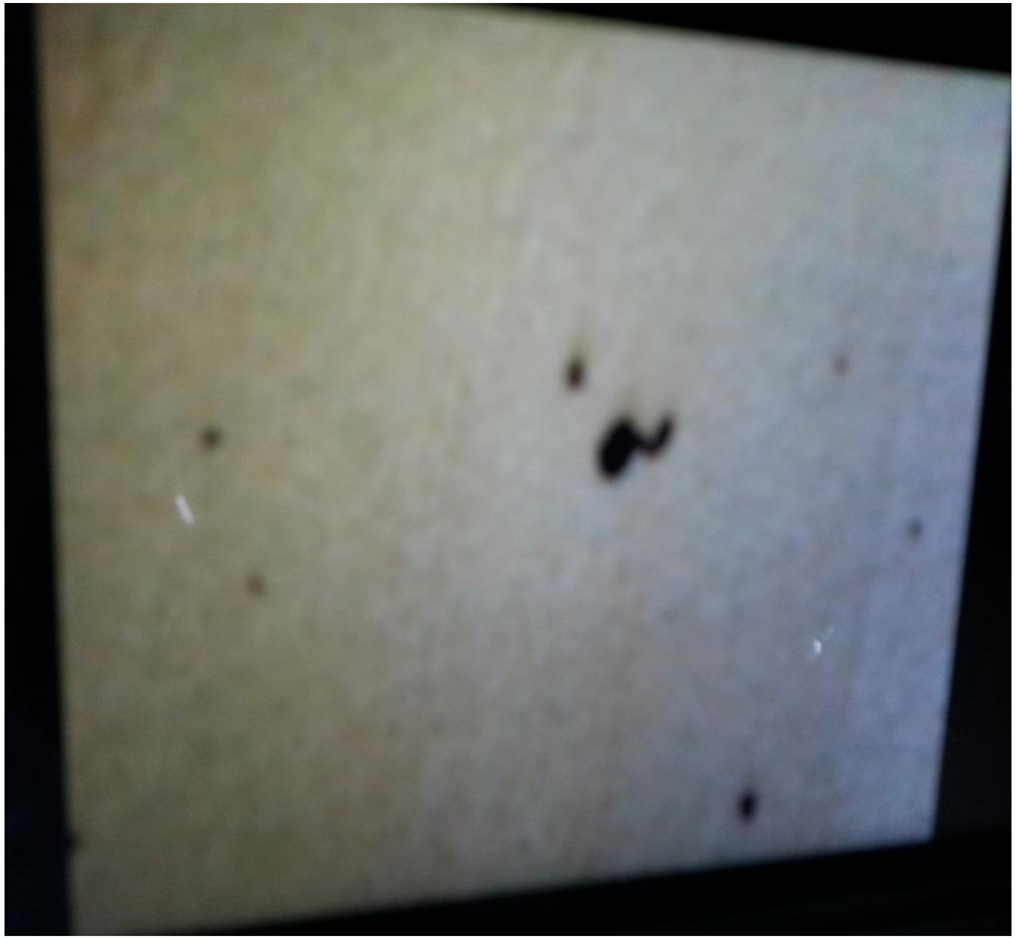
Pitch Related

- Hydrophobic
- Colloidal Particles
  - *0.2-2.0 Microns*
- Dilute Oil-in-Water Emulsion
- Negatively Charged
- Unstable Dispersed State
- Dark, Tacky, Layered Deposits
- Causes specks in the paper
- Runnability issues in pulp mill and on paper machines



Pitch Deposit on Felt



Sources of Scale Components

- **Calcium**
  - *Wood (especially bark)*
  - *White liquor*
  - *Mill water*
- **Carbonate**
  - *Cellulose/lignin breakdown during pulping and bleaching*
  - *White liquor*
  - *Water*
  - *Atmosphere*
- **Silicate**
  - *Sand / dirt*
  - *Wood*
  - *Water*

Sources of Scale Components…#2

- **Oxalate**
  - *Bark*
  - *Oxidation of lignin & other components by pulping, bleaching chemicals*

- **Barium**
  - *Wood if tree grows where there is barium in soil*

- **Magnesium**
  - *Not common*
  - *Similar characteristics and sources as Calcium*

Typical Areas of Scale Formation

Scale Type	Location
$CaCO_3$	Digesters Liquor heaters Evaporators Bleach plants
$BaSO_4$	Bleach plants *(first acid stage)*
CaC_2O_4	Bleach Plants
$CaSO_4$	Evaporators
Silica	Wash/Bleach Plants Evaporators

Bleach Plant Scale

Bleach Plant Scale – D1 Filter

Post Oxygen Scale


Screen Holes are Plugged

Bleach Plant Scale - APMP

Evaporator Scale

Evaporator Scale

Evaporator Scale

Pirssonite Scale in Gren Liquor Line

Problems from Scale Deposition

- Operational/Productivity/Quality
- Interference with plant instrumentation
- Initiates fiber and pitch deposition
- Initiates corrosion
- Interferes with heat transfer
- Pulp quality problems

Factors Affecting Pulp Mill Operations

Cost, Operational, Environmental & Quality

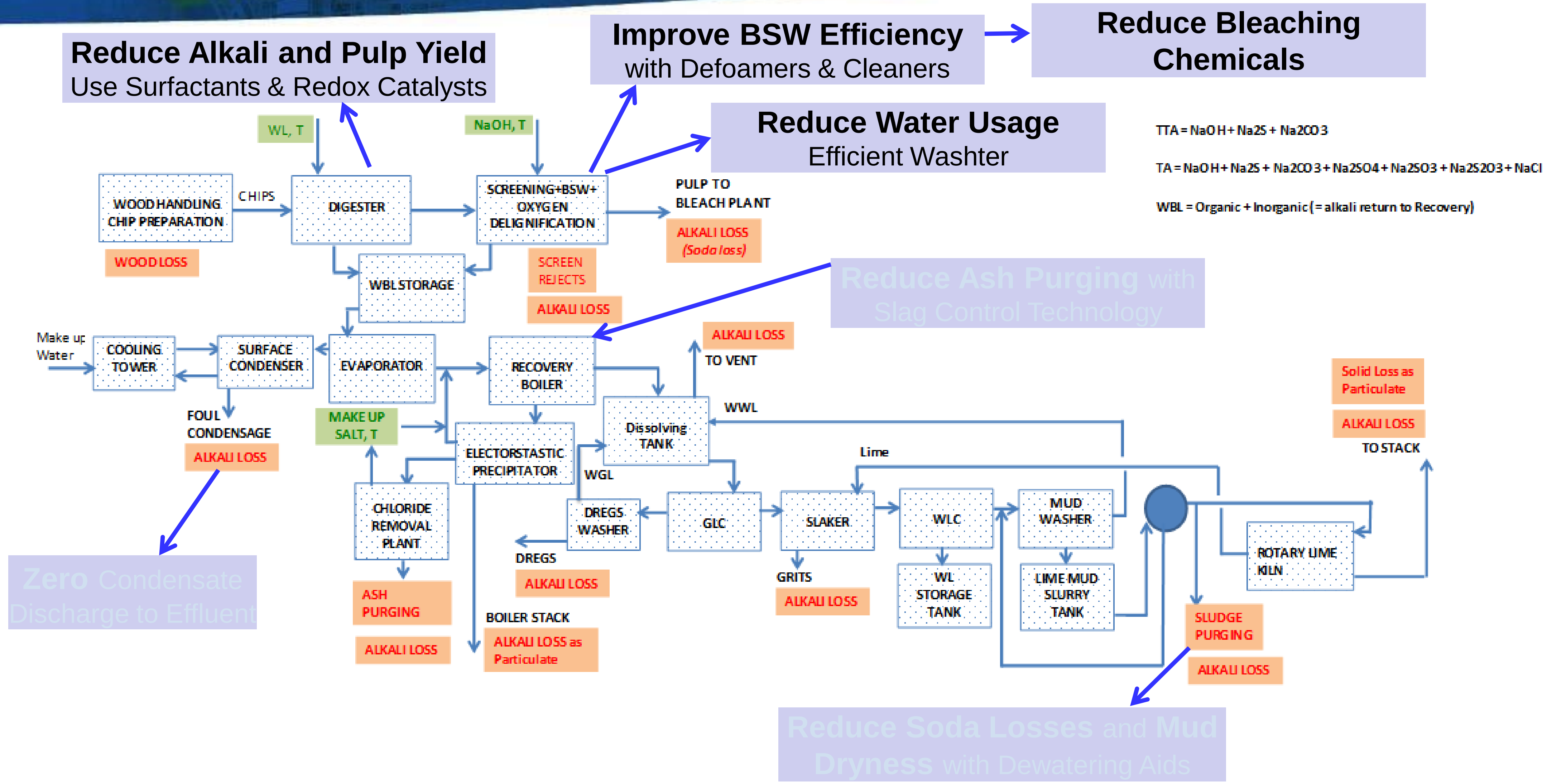
- **Cost**, *$/T*
  - *Chips, T/T*
  - *Production, TPD*
  - *Rejects, %*
  - *Maintenance, $/T*
  - *Weak Black Liquor, m^3/T*
  - *Chemicals usage, kg/T*
    - *Alkali*
    - O_2
    - ClO_2
    - H_2O_2
    - *Defoamer*
- **Operational**
  - *Foaming*
    - *Production*
    - *Alkali carryover*
  - *Scale Deposit*
    - *Production*
    - *Washing*
  - Pitch Deposit
    - *Pulp Quality*
    - *Pulp production*
  - *Pulp/Paper Quality*
- **Quality (=Cost)**
  - *Brightness, % ISO*
  - *Viscosity, CPS*
- **Environmental**
  - *Water usage*
  - *Steam usage*

Solution for Improved Mill Operations

Continuous Improvement, Chemical & Mechanical

- **Mechanical**
  - *Efficient Equipment*
  - ***CAPEX, $$***
- **Operational**
  - ***Process Audit/Optimization***
    - ***Continuous improvement ($)***
  - *Increase Yield ($) – **Digester Additive***
  - *Reduce Alkali ($) – **Digester Additive***
    - *Push for more production*
  - *Reduce K# - **Digester Additive***
    - *Reduce bleaching chemicals*
      - *Increase production ($)*
  - ***Improve ODL efficiency***
    - *Improve selectivity for maximum reduction in K# with minimum losses in pulp viscosity*
  - *Optimize Brown Stock Washing*
    - *Optimize Dilution Factor*
    - *Use efficient Defoamers/Drainage Aids*
      - *Improves throughput ($$)*
    - *Reduced alkali /COD carryover*
      - *Reduced environmental load*
      - *$ Savings*
      - *Lower bleaching chemical usage*
  - *Scale Deposit – **Scale Control***
    - *Enhanced Heat Transfer Efficiency*
    - *Increased throughput ($)*
  - Pitch Deposit – **Pitch Control**
    - *Improved pulp quality ($)*
    - *Enhanced pulp production*
- **Quality (=Cost)**
  - *Brightness, % ISO – **Bleaching Enhancers***
  - *Viscosity, CPS – **Digester Additive***
- **Environmental Sustainability**
  - *Minimize water usage ($)*
    - *Reduced effluent*
    - *Lower black liquor volume*
  - *Minimize steam usage ($)*

Improve Efficiency Across Pulp Mill



Delivering Value Through People Chemistry

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Conclusion

- Focus on Process Audits and Data Analysis
- Save Energy/Water
- Production Cost ($)
- Focus on CONTINUOUS IMPROVEMENT in output and quality

Further Reading

1. ACHIEVEMENT AND SIGNIFICANCE OF OPTIMAL CHIP QUALITY *by Nils Hartler (TAPPI Journal)*
2. CHEMISTRY OF PULPING AND BLEACHING *by Tapani Vuorinen*
3. IMPACT OF COOKING CONDITIONS ON PULP YIELD AND OTHER PARAMETERS *by Nam Hee Shin and Bertil Stromberg*
4. INFLUENCE OF COOKING CONDITIONS ON THE PROPERTIES OF FIRST-THINNING SCOTS PINE (*Pinus sylvestris*) KRAFT PULP *by Riika Rautiainen and Raimo Alen*
5. THE TOP TEN FACTORS IN KRAFT PULP YIELD *by Martin MacLeod*
6. THE PULPING OF WOOD *by R.G. MacDonald and J.N. Franklin, McGraw Hill Book Company, N.Y*.
7. ALKALINE PULPING *by T.M. Grace et.al., TAPPI Press (1989)*
8. **HANDBOOK OF PULP AND PAPERMAKING** *by Christopher J. Biermann, Academic Press (1996) or 2nd Edition by CBS Publishers & Distributors (2005)*
9. **HANDBOOK FOR PULP & PAPER TECHNOLOGISTS** *by G. A. Smook, Angus Wilde Publication*
10. KRAFT PULPING: A COMPILATION OF NOTES *by Agneta Mimms et.al, TAPPI PRESS (1989)*
11. CHEMICAL PULPING *by Johan Gullichsen et. Al. Fapet Oy (1999)*
12. PULPING CHEMISTRY AND TECHNOLOGY *by Monica Ek et. al., Walter de Gruyter (2009)*
13. PULP BLEACHING: PRINCIPLES AND PRACTICE *by Carlton W. Dence et. al. (1996)*
14. PULP BLEACHING TODAY *by Hans Ulrich Suess, Walter de Gruyter (2010)*

Any Questions

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