Ways of making Alumina Refinery Energy Efficient

by

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Benefits of conducting process Audit

- Energy Reduction is possible in any operating plant
- Energy reduction can be achieved by reducing Raw Material consumption by conducting Process Audit

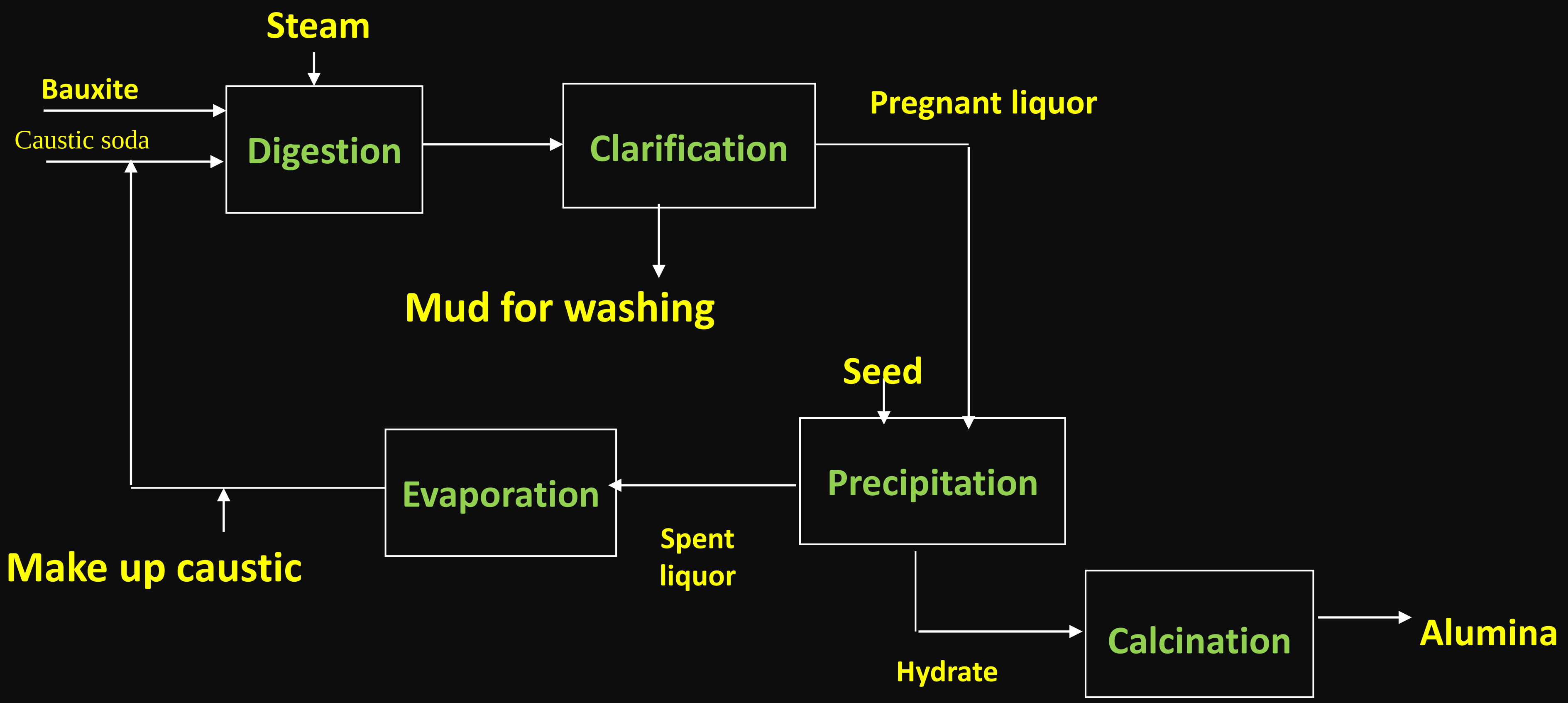
Process Audit

- Process Audit is primarily the management tool to **identify deficiencies** and recommending **implementable remedial** measures for improvement.
- The Process Audit Report will provide all **assessment data** and information to management to ensure their implementation in the plant.
- During the Process Audit of the plant, **thorough evaluation** of operation, process control, **efficiency parameters**, safety and quality control including **analytical aspects** of Alumina refinery will be done to arrive at recommendations for improvement in respective areas thereby improvement in profitability of the plant.
- Process Audit of the plant will **uncover the shortcomings** / limitations in operation, process control, equipment, training, quality control, documentation and other related technical aspects of the plant.

Objective of Process Audit

- To identify problems and specific solution to those problems for implementation with more focus to :
- reduce production cost by reduction in consumption of Caustic soda,
- improvement in extraction efficiency,
- improvement in liquor productivity,
- reduction in evaporation load,
- improvement in steam economy and reduction in utilities and services.

Flow chart of Bayer process



Specific Raw Material Consumption in Bayer Process

- The raw material consumption can be divided into :
- Bauxite
- Caustic soda
- Water
- Lime
- Flocculant, Defoamer,Dewatering agents,CGM, additives, chemicals, filter cloths etc

Specific Bauxite Consumption(SBC)

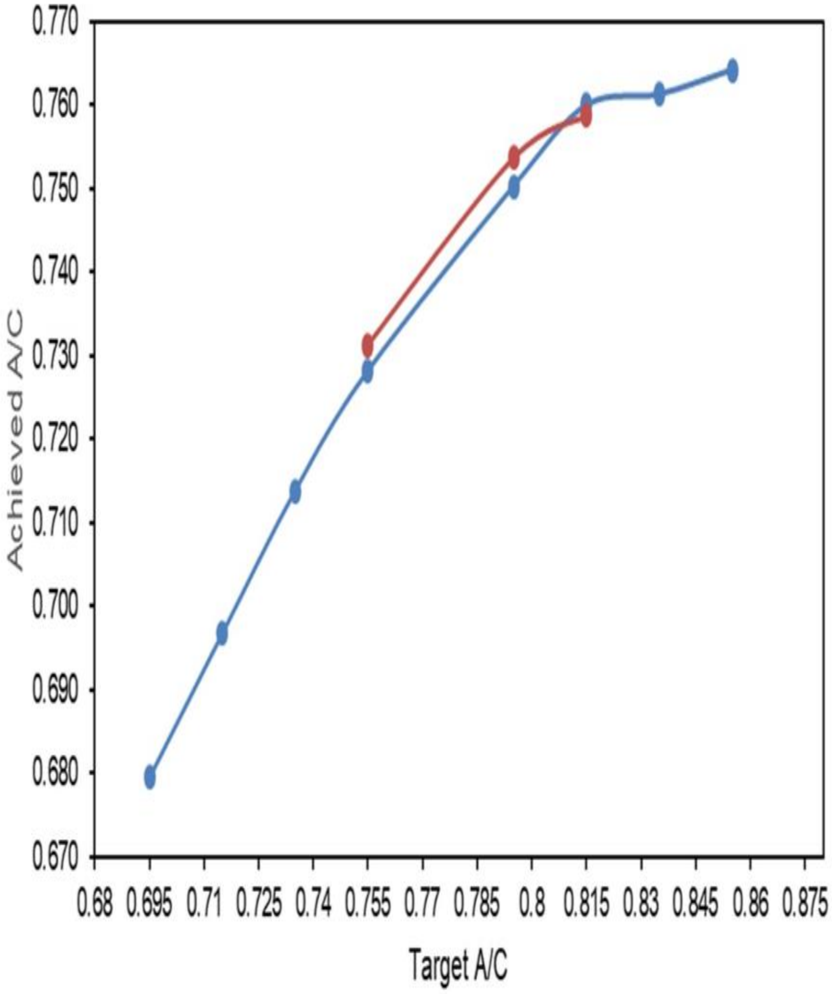
- SBC depends on extractability of alumina and supersaturation (RP)
- Extractability depends on Temperature, Caustic Conc. & Residence time
- SBC = 1010/(M.E.A)x % Ext.)
- M.E.A = Maximum Extraction Alumina (THA/(THA +MHA))
- % Ext. = Extraction after considering all losses such as unextracted alumina, auto-precipitation etc.

Determination of Break-Point of Digestion

In an Alumina Refinery or technological testing of bauxite it is sometimes required to know what should be the maximum target RP which can be achieved without much loss of digestion efficiency.

- **To determine it one has to conduct digestion test at different target RP and Temperature to determine achieved RP along with digestion efficiency. A point is achieved when there is a drop of achieved RP which shows the breakpoint as shown in the figure.**

Target A/C vs Achieved A/C



Target A/C	Al_2O_3, gpl	Na_2O_c, gpl	SiO_2, gpl	Ach. A/C	Digestion Efficiency (TA Basis)	Remarks
0.695	183.00	157.50	1.21	0.680	83.21	
0.715	188.00	157.80	1.30	0.697	82.85	
0.735	192.27	157.52	1.42	0.714	82.71	
0.755	196.86	158.10	1.49	0.728	82.43	
0.795	201.96	157.42	1.51	0.750	81.05	Break Point
0.815	204.51	157.38	1.48	0.760	76.56	
0.835	205.02	157.50	1.30	0.761	74.76	
0.855	206.98	158.40	1.20	0.764	70.46	

Analysing Distribution of Alumina Losses

Distribution of Alumina Losses	Kg Al_2O_3 /ton	Recoveries	Kg Al_2O_3 /ton
Unextracted and bound with sodalite in the digestion Stage		Alumina through Return Water	
Salt + Adhesive Moisture at Evaporation (Vanadium Removal)			
Auto-precipitation in settlers & Washers			
Soluble alumina losses with Mud			
Alumina loss during TCA manufacture			
Unaccountable Alumina losses			
Net Alumina Losses = Losses - Recovery			

Analysing Distribution of Caustic Soda Losses

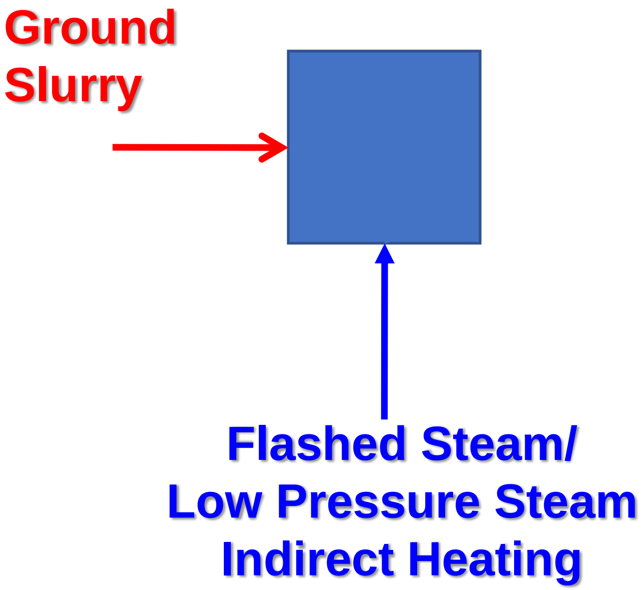
Distribution of Caustic Soda Losses	Kg Al_2O_3 /ton	Recoveries	Kg Al_2O_3 /ton
Bound with sodalite in the digestion Stage		Through Mud Causticization	
Salt + Adhesive Moisture at Evaporation (Vanadium Removal)		Soda through Return Water	
Bound with Product Hydrate			
Soluble Soda losses with Mud			
Unaccountable Caustic Soda Losses			
Net Caustic Losses = Losses - Recovery			

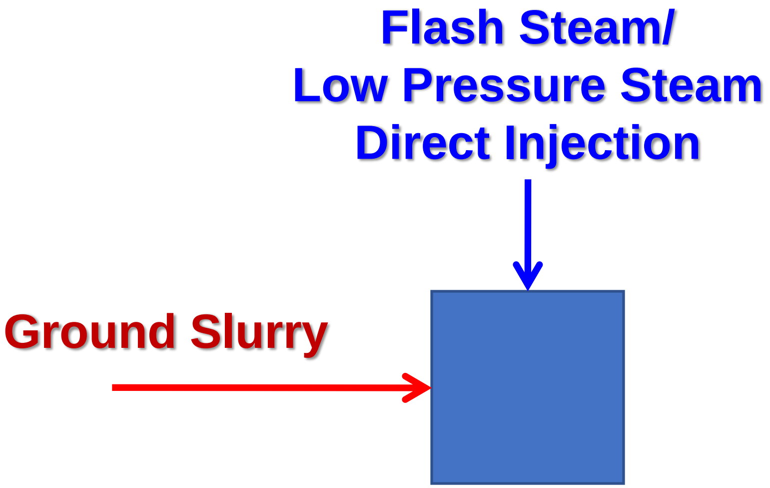
Conducting Caustic Soda Consumption Audit

Particulars of Caustic Soda Losses				Reason
Bound Soda with Sodalite complex, Kg NaOH/ton	66.82	69.20	76.10	Lower THA, High Reactive silica, Higher SBC
Tri Hydrate Alumina, % Reactive Silica, % Specific Bauxite Consumption, t/t	39.04 2.68 2.76	38.16 2.70 2.80	37.27 2.99 2.88	
Soluble Soda with Red Mud , Kg NaOH/ton	16.73	17.19	18.75	Higher Red Mud generation, Reduction in Wash water m^3/ton red mud
Red Mud Generation, t/t Wash water in m^3/ton Al_2O_3 Wash water in m^3/ton red mud generated Na_2O concentration in gpl	1.306 3.466 2.654 12.69	1.356 3.643 2.686 12.17	1.456 3.634 2.496 12.63	
Product Hydrate Bound + Soluble Kg NaOH /ton	5.19	5.12	5.09	
Pond water ,m^3/ton Return water Na_2O conc. (gpl) % Caustic Soda Recovered/Soluble soda losses	1.467 2.29 25.90	1.756 2.28 29.03	1.756 2.76 33.34	
Total Caustic Soda Consumption, Kg NaOH/ton	88.22	92.52	100.55	
Net Caustic Soda Consumption, Kg NaOH/ton	83.89	87.36	94.30	

PRE-DESILICATION

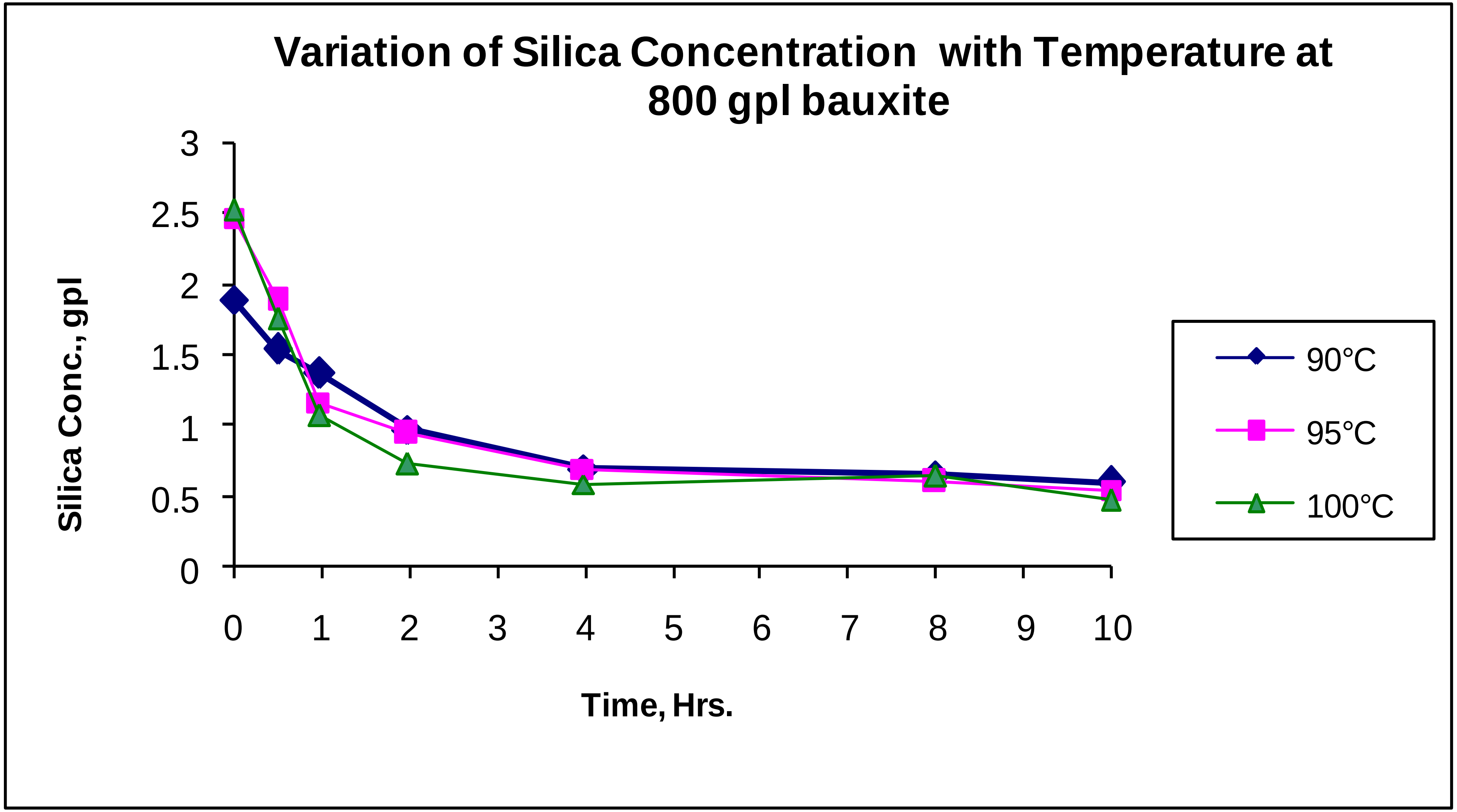
- $Na_2O + SiO_2 = Na_2SiO_3$ ------ (1)
- $Na_2O + Al_2O_3 = 2NaAlO_2$ ------ (2)
- $Na_2SiO_3 + NaAlO_2 = x\,Na_2O.\ y\,Al_2O_3\ z\,SiO_2\ n\,H_2O$ -- (3)
- $A \ (k_1) \rightarrow \ B \ (k_2) \rightarrow C$ Where $k_1 >> k_2$



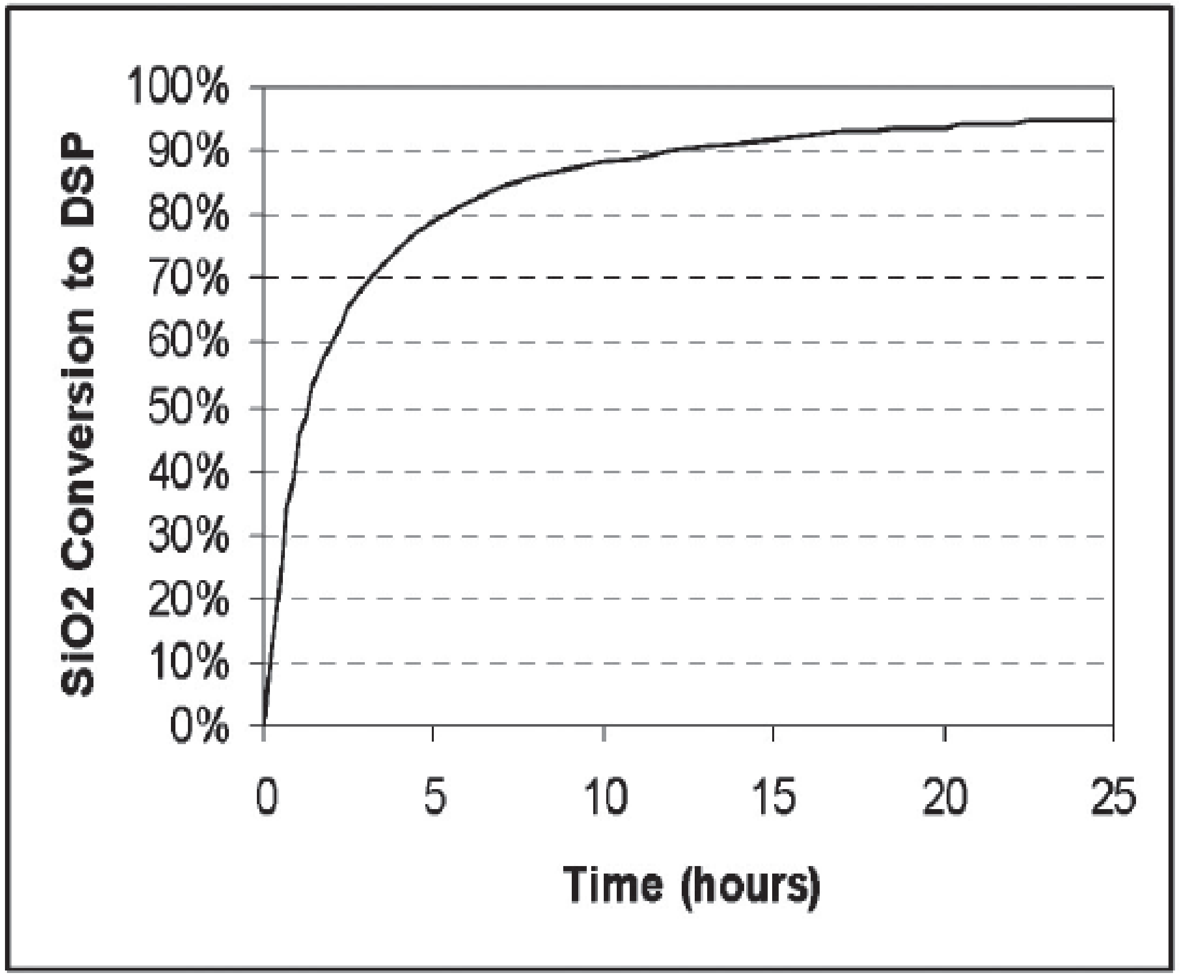


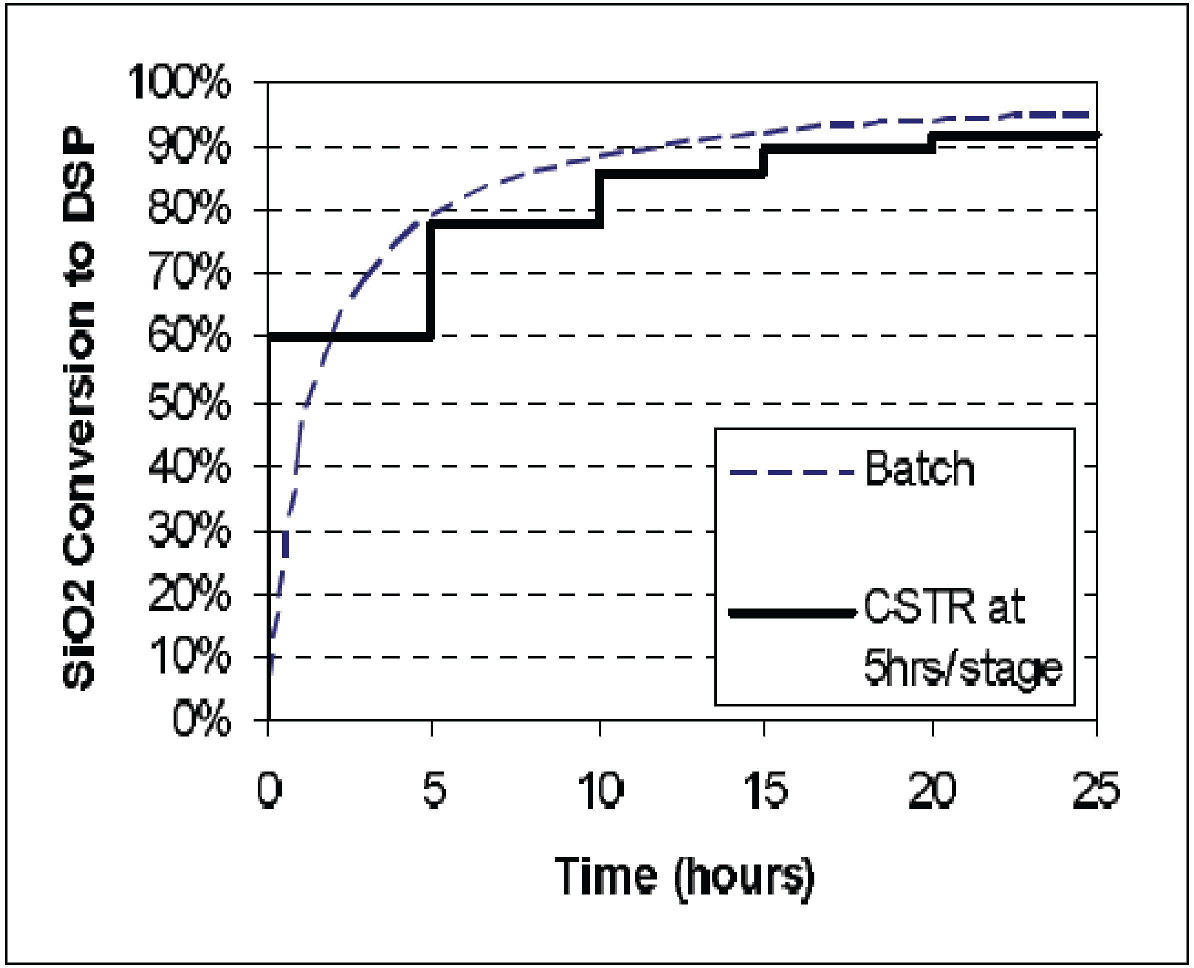
ENERGY REDUCTION OPPORTUNITIES IN PRE-DESILICATION

- **Study Kinetics of Pre-desilication**



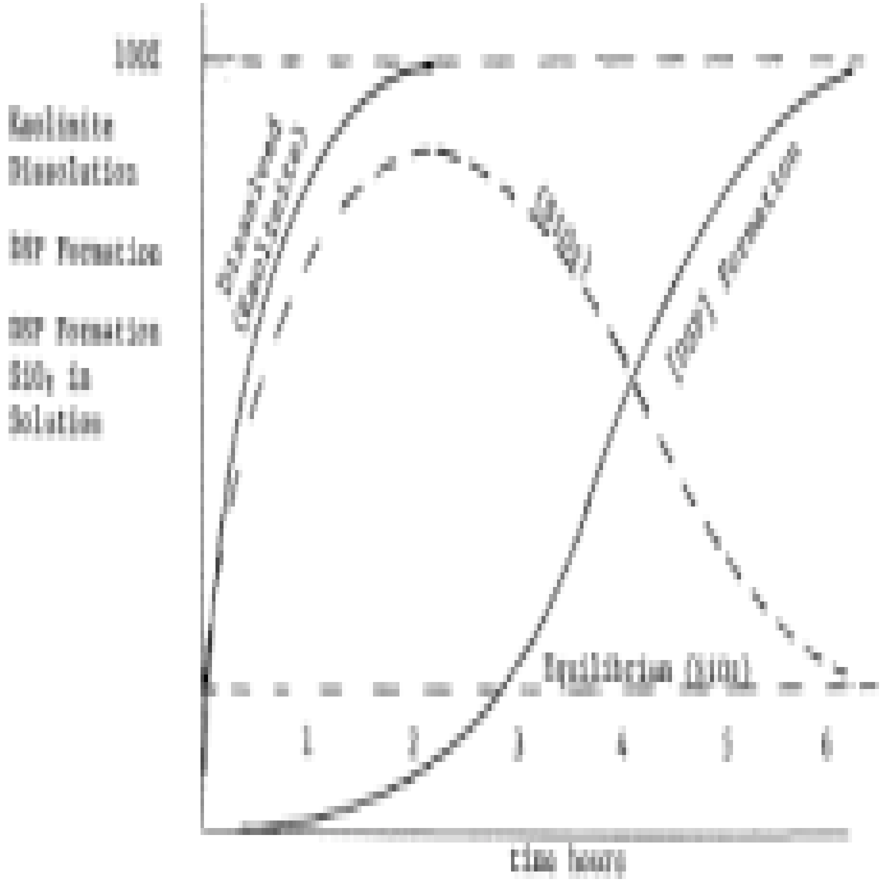
SiO_2 Conversion Batch vs Continuous





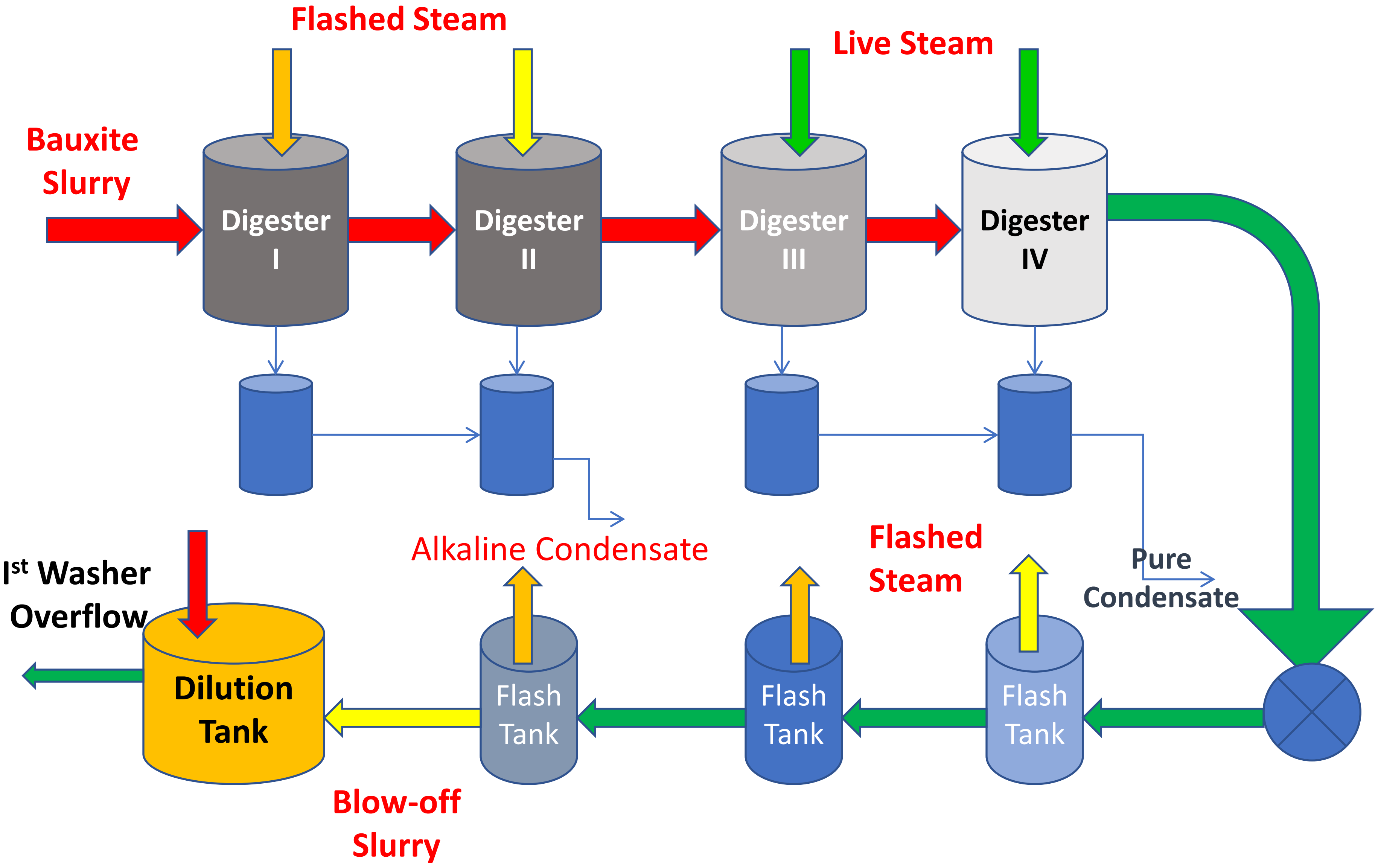
Kinetics of Pre-desilication

$- d[SiO_2]/dt = k\ [(SiO_2)_t - (SiO_2)_{equ}\ ]^n$



- $-dC/dt = K\ (C_t\text{-}C^*)^n$ where n is the order of reaction
- If n = 1 Then $\ln\ [C_o\text{-}C^*] / [C_t - C^*] = kt$ ------ (1)
- If n= 2 Then $1/\ [C_o\ \text{-}C^*] - 1/\ [C_t\text{-}\ C^*] = kt$ ------ (2)
- Plot the value of (1) & (2) vs time at different temperature, if it is linear than determine $k = A\ \exp(E_a/RT)$ to determine activation energy in KJ/mol
- $-dC/dt\ = A\ \exp(Ea/RT)\ x\ [C_t - C^*]^n$

Digestion- Flashing System



Terminology of Flash Type Heat Exchanger

W1 = Mass Flow rate in ton/hr x Specific heat of Slurry in Mcal/ton/^{o}C

W1 represents slurry flow to digester circuit for heating in flash heaters

W2 = represents flow of digested slurry from last digester entering the flash tank **PE1**

ME1 = flashed steam leaving first flash tank in tons/hr

hE1$^{!!}$ = Represents Enthalpy of flashed steam in Mcal/ton

hE1$^{!}$ = Enthalpy of condensate in Mcal/ton

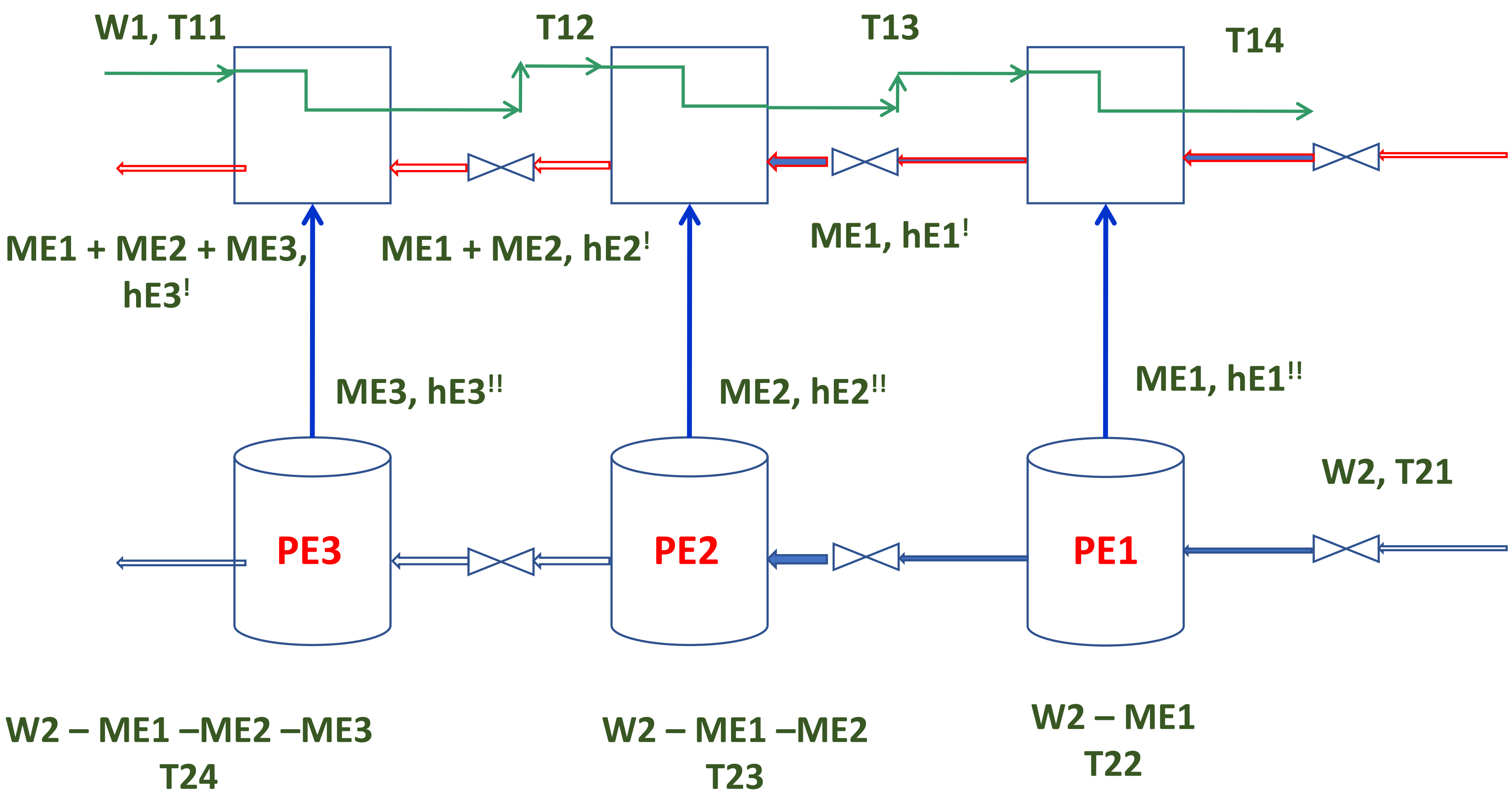
Heat Balance for first flash tank

W2 x (T21 –T22) = ME1 x (hE1$^{!!}$ – hE1$^{!}$) + Heat Loss

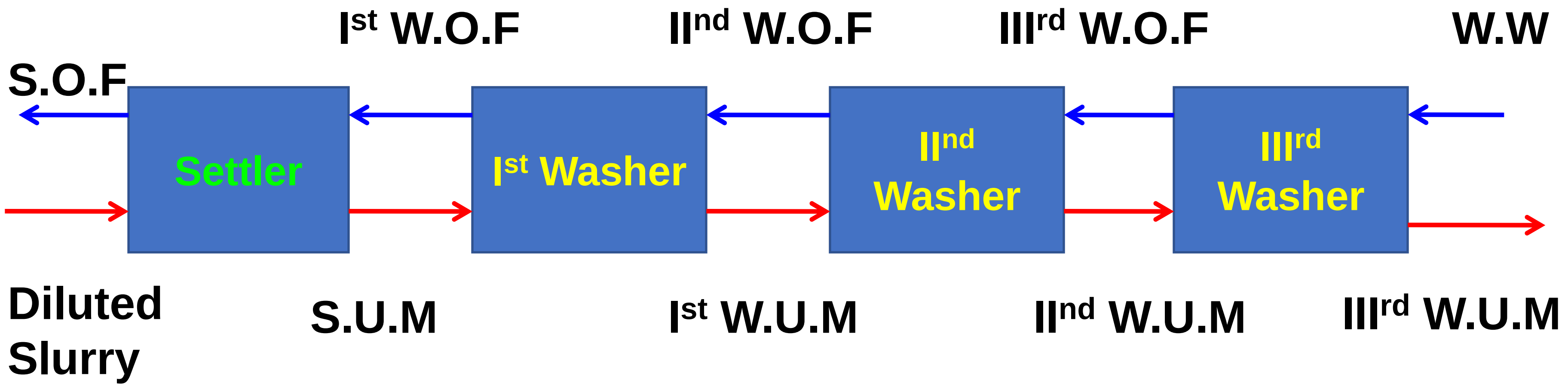
Overall Heat Balance

W1 x (T14-T13) = W2 x T21 – (W2- ME1-ME2-ME3) x T24 – (ME1 x hE1$^{!}$ + ME2 x hE2$^{!}$ + ME3 x hE3$^{!}$) + Heat loss

Flash Type Heat Exchangers & Flashing Tanks



Counter-current Decantation (WASHING)



Counter Current Decantation of Red mud Washing

Efficiency of Red mud Washing any stage (E_n) :

$$E_n = \frac{(CNa_2O)\ \text{underflow}\ (n-1) - (CNa_2O)\text{underflow}}{(CNa_2O)\ \text{underflow}\ (n-1) - (CNa_2O)\ \text{overflow}} \times 100$$

For E.g. Settler underflow Na_2O conc. = 150 gpl
1st Washer overflow Na_2O conc. = 72 gpl
1st Washer underflow Na_2O conc. = 75 gpl

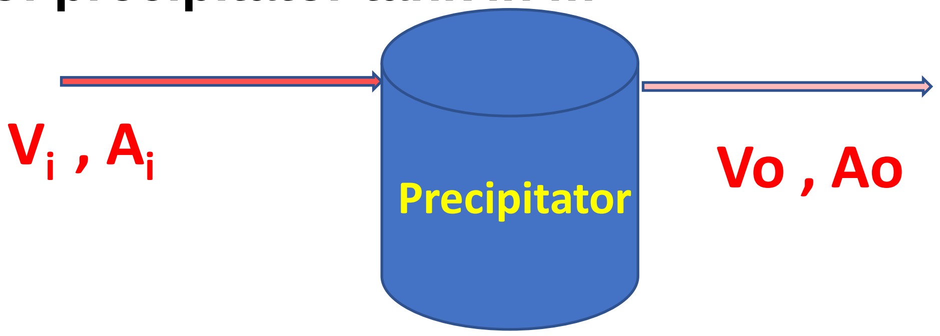
Then 1st Washer Washing Efficiency = $$\frac{150 - 75}{150 - 72} \times 100$$

= 96.15 %

- **To Increase Washing Efficiency : Maintain Higher Temperature in washer circuit**
- **This will also reduce auto-precipitation in settlers and washing line**

Precipitation Modeling

- $dA/dt = K \times S \times e^{-(\Delta E/RT)} \times (A-A_e)^2 / (FC)^2$
- Where K = rate constant
- S = Surface area of seed available in tank in m^2/lit
- ΔE = Activation energy in Kcal/mole
- FC = Free caustic concentration in gpl
- A_e = Equilibrium alumina concentration in gpl
- T = Temperature in Kelvin
- $V_i \times A_i - V_o \times A_o = V_t \times (dA/dt)$ Taking Alumina Balance
- $V_i \times A_i - V_o \times A_o = V_t \times K \times S \times e^{-(\Delta E/RT)} \times (A-A_e)^2 / (FC)^2$
- Where V_i & V_o is volume of liquor entering & leaving Precipitator tank in m^3/hr
- Where V_t = Volume of precipitator tank in m^3



- $\mathbf{dA/dt = K \times S \times e^{-(\Delta E/RT)} \times (A-A_e)^2 / (FC)^2}$
- Conduct Batch Precipitation test at 2 to 3 precipitation temperature and determine dA/dt. Calculate Value of K and ΔE for the plant liquor. Substitute the value in equation and you can even calculate the percentage or extent of bypassing of aluminate liquor.

Conclusion

- There is a considerable scope in reducing material as well as energy consumption in alumina manufacture to reach goal of 10.5 GJ/ton and further down.
- The Alumina Refinery should appoint Consultant for Process Audit to identify plant implementable measures to bring down the material & energy consumption in a phased manner.
- All alumina refineries should go for break-point digestion studies for increasing alumina extraction & supersaturation.
- Precipitation Modeling studies should be conducted to evaluate optimum liquor productivity
- In-house plant measures such as maximizing hot condensate recovery from digester-flashing system and reducing unauthorised water into the system which will help in reducing evaporation load thus reducing energy consumption.