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Recausticizing material balance equations relating to digester requirements

Scope

One of the objectives of the Process Engineering Committee is to provide information and instructions for the various pulp and paper making systems and equipment to assist management and the pulp and paper mill engineer in specification, evaluation and design of pulp and paper mill facilities. Particularly, such information will show the interrelationships within and between systems.

This paper shows the material interrelationships within the recausticizing system as well as between it and the digester system. Specifically, it lists all the major material balance equations for the recausticizing system, starting with the smelt stream from the recovery furnace and continuing through the white liquor stream to the digester. All equations relate to only a few independent variables from the digester and recausticizing operations.

For each major press stream - recovery smelt, green liquor, raw white liquor, white liquor (clarified), lime mud and weak wash - equations are given for each of the following:

Overall material flow rates

Chemical component breakdown in Na_2O equivalents

Chemical component breakdown in actual chemical form

Overall water flow rate

Water content on each stream

In addition, for the raw white liquor and lime mud streams, the following equations are given:

Available lime and total lime flow rates

Total and net "grits" flow rate

Water consumed in slaking reaction

Total lime mud solids flow rate

The significance of this paper is not that the equations are particularly new and different, but that they are presented in one concise set; and that they are in simple form and can be conveniently used by anyone be they engineer, designer, mill operator or whoever. Further, it is significant that the equations are based on only six digester variables and three recausticizing variables. Also, they are written such they can be conveniently used as a base for further mathematical manipulations.

Certain basic definitions, assumptions and derivatives are presented in the appendix. For the most part, derivatives for all equations are not given in order to keep the paper as simple and direct as possible. The derivations are basically simple and the interested party can readily do their own.

Definitions

Basis for the equations

The requirements of the recausticizing system are dependent on the digester requirements and thus the following six independent digester variables form most of the basis for the material balance equations:

Digester air-dry pulp production, kg (lb)
Digester yield
Active alkali charge to the digester (%)
White liquor active alkali strength
White liquor sulfidity
Total titratable alkali strength in white liquor

The other independent variables are from the recausticizing and lime burning systems. They are:

Excess lime
Average availability of reburned and make-up lime
Solids in the unwashed lime mud slurry (%)

For the sake of practical convenience, there are simplifications and assumptions contained in the equations. When such simplifications occur, they represent only very small inaccuracies. For those who are interested in the highest order of accuracy, they can easily revise the equations to suit their particular needs.

Safety precautions

No safety precautions.

Keywords

Recausticize, Chemical recovery, Green liquor, White liquor, Lime mud, Digester balance equation

Additional information

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Users of this TIP should contact the TAPPI Standards Director if there is evidence that a review of this document is needed, or if any errors are discovered.

Content

MATERIAL BALANCE EQUATIONS

White Liquor to Digester

- Q_{AD} = wt. air dried pulp from digester, lb (kg)
 Y = % digester yield
 CH_{AA} = % active alkali (AA) charge to digester
 V_{WL}^D = volume white liquor to digester, ft³ (m³)
 WL_{STR} = white liquor strength, lb AA/ft³ (kg AA/m³)
 S_{WL} = % sulfidity of white liquor
 TTA_{WL} = total titratable alkali strength in W.L., lb Na₂O/ft³ (kg Na₂O/m³)
 A_O^D = Na₂S as Na₂O in W.L. to digester, lb (kg)
 A_1^D = Na₂S as Na₂S in W.L. to digester, lb (kg)
 B_O^D = NaOH as Na₂O in W.L. to digester, lb (kg)
 B_1^D = NaOH as NaOH in W.L. to digester, lb (kg)
 C_O^D = Na₂CO₃ as Na₂O in W.L. to digester, lb (kg)
 C_1^D = Na₂CO₃ as Na₂CO₃ in W.L. to digester, lb (kg)
 D_O^D = Na₂SO₄ as Na₂O in W.L. to digester, lb (kg)
 D_1^D = Na₂SO₄ as Na₂SO₄ in W.L. to digester, lb (kg)
 CA_{WL}^D = Causticizing efficiency
 W_{WL}^D = white liquor to digester, lb (kg)
 H_O^D = water in white liquor to digester, lb (kg)
 WL_{DS}^D = dissolved solids in W.L. to digester, lb (kg)

WHITE LIQUOR VOLUME TO DIGESTER

$$V_{WL}^D = \frac{.90 Q_{AD}}{Y} \times \frac{CH_{AA}}{WL_{STR}}$$

White Liquor Quantities

- Na₂S AS Na₂O⁺⁺
 $A_O^D = \frac{S_{WL} \times TTA_{WL}}{100} \times V_{WL}^D$
 OR
 $A_O^D = \frac{S_{WL} \times TTA_{WL}}{100} \times \frac{.90 Q_{AD}}{Y} \times \frac{CH_{AA}}{WL_{STR}}$
- Na₂S AS Na₂S⁺⁺
 $A_1^D = \frac{78}{62} \times A_O^D = 1.26 \times A_O^D$

- NaOH AS Na₂O⁺⁺

$$B_O^D = WL_{STR} \times V_{WL}^D - A_O^D$$

OR

$$B_O^D = \frac{.90 Q_{AD} \times CH_{AA}}{Y} - A_O^D$$

- NaOH AS NaOH⁺⁺

$$B_1^D = \frac{80}{62} \times B_O^D = 1.29 \times B_O^D$$

- Na₂CO₃ AS Na₂O⁺⁺

$$C_O^D = V_{WL}^D (TTA_{WL} - WL_{STR})$$

OR

$$C_O^D = \frac{.90 Q_{AD}}{Y} \times \frac{CH_{AA}}{WL_{STR}} \times (TTA_{WL} - WL_{STR})$$

- Na₂CO₃ AS Na₂CO₃⁺⁺

$$C_1^D = \frac{106}{62} \times C_O^D = 1.71 \times C_O^D$$

- Na₂SO₄ AS Na₂SO₄⁺⁺

$$D_1^D = .10 \times A_1^D \text{ (ASSUMED)}$$

- Na₂SO₄ AS Na₂O⁺⁺

$$D_O^D = \frac{62}{142} \times D_1^D = .436 \times D_1^D$$

Causticizing Efficiency

$$CA_{WL}^D = \frac{B_O^D}{B_O^D + C_O^D} \times 100$$

OR

$$CA_{WL}^D = \frac{100 WL_{STR} - S_{WL} \times TTA_{WL}}{TTA_{WL} (100 - S_{WL})} \times 100$$

TOTAL WEIGHT WHITE LIQUOR

SPECIFIC GRAVITY WHITE LIQUOR = 1.16 (ASSUMED)

$$W_{WL}^D = 1.16 \times 62.4 \times V_{WL}^D = 72.4 \times V_{WL}^D$$

TOTAL POUNDS (KILOGRAMS) DISSOLVED SOLIDS IN WHITE LIQUOR

$$WL_{DS}^D = A_1^D + B_1^D + C_1^D + D_1^D$$

WATER IN WHITE LIQUOR

$$H_O^D = W_{WL}^D - WL_{DS}^D$$



**WHITE LIQUOR
FROM RECAUSTICIZING**

Assume 1% loss of all white liquor quantities. Therefore, all quantities in recausticizing system are:

$$1.01 \times (\text{white liquor quantities to digester})$$

SMELT FROM RECOVERY FURNACE

- N_{SM} = total Na_2O in smelt, lb (kg)
 A_{O}^{SM} = Na_2S as Na_2O in smelt, lb (kg)
 A_1^{SM} = Na_2S as Na_2S in smelt, lb (kg)
 B_{O}^{SM} = NaOH as Na_2O in smelt, lb (kg)
 B_1^{SM} = NaOH as NaOH in smelt, lb (kg)
 C_{O}^{SM} = Na_2CO_3 as Na_2O in smelt, lb (kg)
 C_1^{SM} = Na_2CO_3 as Na_2CO_3 in smelt, lb (kg)
 D_{O}^{SM} = Na_2SO_4 as Na_2O in smelt, lb (kg)
 D_1^{SM} = Na_2SO_4 as Na_2SO_4 in smelt, lb (kg)
 SM = total weight smelt, lb (kg)
 R_{SM} = % reduction.

The following smelt quantities are required to make the white liquor in the "White Liquor from Recausticizing" section.

TOTAL Na_2O IN SMELT

$$N_{SM} = 1.01 (A_{O}^{D} + B_{O}^{D} + C_{O}^{D} + D_{O}^{D})$$

SMELT QUANTITIES

- $\text{Na}_2\text{S AS Na}_2\text{O} -$
 $A_{O}^{SM} = 1.01 \times A_{O}^{D}$
- $\text{Na}_2\text{S AS Na}_2\text{S} -$
 $A_1^{SM} = 1.01 \times A_1^{D}$
- $\text{NaOH AS Na}_2\text{O} -$
 $\text{NaOH AS NaOH} -$
 $B_{O}^{SM} = 0$
 $B_1^{SM} = 0$
- $\text{Na}_2\text{SO}_4 \text{ AS Na}_2\text{O} -$
 $D_{O}^{SM} = 1.01 \times D_{O}^{D}$

- $\text{Na}_2\text{SO}_4 \text{ AS Na}_2\text{SO}_4 -$
 $D_1^{SM} = 1.01 \times D_1^{D}$

- $\text{Na}_2\text{CO}_3 \text{ AS Na}_2\text{CO}_3 -$

$$C_1^{SM} = 1.01 C_1^{D} + (1.01 \times B_1^{D} \times \frac{1}{40} \times \frac{1}{2} \times 106 =$$

$$1.01 \times C_1^{D} + 1.34 B_1^{D}$$

- $\text{Na}_2\text{CO}_3 \text{ AS Na}_2\text{O} -$

$$C_0^{SM} = \frac{62}{106} \times C_1^{SM} = .585 \times C_1^{SM}$$

TOTAL POUNDS (KILOGRAMS) SMELT

$$SM = A_1^{SM} + B_1^{SM} + C_1^{SM} + D_1^{SM}$$

% REDUCTION

$$R_{SM} = \frac{A_0^{SM}}{A_0^{SM} + D_0^{SM}} \times 100$$

LIQUOR QUANTITIES IN UNWASHED LIME MUD

- LM_{SM} = available lime from reburned and make-up, lb (kg)
 E_{LM} = % excess lime
 LM_T = total lime from reburned and make-up, lb (kg)
 AV_{LM} = % availability of reburned and make-up lime
 GR_T = total grits from unavailable lime, lb (kg)
 GR_{RM} = grits remaining in system, lb (kg)
 GR_L = grits leaving system, lb (kg)
 HY = excess $\text{Ca}(\text{OH})_2$ formed in causticizing, lb (kg)
 F = total CaCO_3 formed in causticizing, lb (kg)
 W_R = total water reacting to slake CaO , lb (kg)
 LM = total lime mud solids (dry), lb (kg)
 ULM_{SL} = unwashed lime mud slurry, lb (kg)
 P = % solids in unwashed lime mud slurry
 WL_{ULM} = white liquor in unwashed lime mud slurry
 A_0^{WW} = Na_2S as Na_2O in weak wash, lb (kg)
 A_1^{WW} = Na_2S as Na_2S in weak wash, lb (kg)
 B_0^{WW} = NaOH as Na_2O in weak wash, lb (kg)
 B_1^{WW} = NaOH as Na_2OH in weak wash, lb (kg)