A Quick Method of Estimating Batch Digester Charge

SINGH S.P.* & RAO N. J.*

SUMMARY

A graphical method for quick estimation of various materials required at the time of charging a batch of digester has been discussed. Necessary material balance equations have been given to enable the individual mills to prepare their own charts corresponding to their operating conditions. These charts are easy to use by the pulp mill personnel. This will ensure unifrom pulp quality from batch to batch.

Normal digester operation includes charging a known quantity of chips of a given moisture content into a digester of known volume. A fixed percentage of active alkali on the dry raw material is charged. The volume of the white liquor (W/L) to be added is determined based on the required amount of active alkali and the concentration of active alkali in the white liquor. In very few cases corrections for sulphidity are made. Finally black liquor is added to obtain the desired liquor to raw material ratio (Bath ratio) in the digester so that the transport and distribution of chemicals and heat in the digester will be facilitated in the best way.

The variations in moisture content, active alkali concentration and sulphidity of white liquor result in fluctuating quality of pulp from batch to batch. Further, operations like periodic make-up sulphur addition, washing and cleaning of evaporators by caustic lye or excess loss of sodium or sulphur due to any reason result in varying sulphidity and active alkali in white liquor.

The present paper deals with a simplified graphical procedure to estimate the correct quantities of active alkali, sulphur (either as elemental sulphur or as sodium sulphide) and black liquor to be charged to the digester based on available laboratory data and desired operating levels.

For the use of this procedure the process parameters and laboratory analysis as shown in tables 1 and 2 are required.

TABLE–1 PROCESS OPERATING PARAMETERS.

S.No.	Parameter	Normal range
1.	Digester volume (m^3)	40—80
2.	Oven dry raw material charged per unit volume of digester, (t/m^3).	0 23—0 35.
3.	Voidage of chips, percent	50—60
4.	Apperent density of raw material. kg/m^3	500—800
5.	O D. chips loaded per digester charge	can be calculated as the product of voidagè, apperent density and the digester volume or an average value obtained from the material balance of raw material over a number of cooks.
6.	Percent active alkali on o.d. raw material	14–17.
7.	Bath ratio (m^3 liquor/t, raw material)	2.5 - 3.5

*Institute of Paper Technology, Saharanpur.

TABLE 2– DATA FROM LABORATORY

S No.	Variable	Normal range
1.	Moisture content in the raw material, percent	10–25
2.	Active alkali concentration of the white liquor, (as Na_2O), gpl,	65–100
3.	Sulphidity of white liquor, percent	18–30

The attached graphs are prepared based on material balance calculations which are shown in Appendix. The graph A indicates mass of raw material loaded for a known moisture content. From this, the quantity of active alkai to be charged is estimated in graph B knowing percentage of active alkali requied. If the white liquor analysis gives a lower sulphidity than the desired level the necessary amounts of either Na_2S or sulphur addition may be assessed from graph C–1 or graph C–2 respectively. Similarly, if the white liquor sulphidity is higher than the desired value, the volume of 100 gpl caustic ley to be added can also be assessed from graph C–1.

The volume of white paper to be chrged is estimated from graph D knowing the active alkali concentration of white liquor (gpl). If sulphidity adjustments are made by adding Na_2S or NaOH the active alkali charged through white liquor is reduced by that amount. On the other hand if elemental sulphur is added the quantity of white liquor is increased to charge the desired active alkali. The corresponding corrections are shown on graphs C–1 and C–2

The graph E indicates the total quantity of the liquor to be charged for a given bath ratio. This is used to calculate the black liquor to be charged as under—

$$V_{BL} = V_T - V_{WL} - (M_W - M)$$

A typical sequential procedure is shown on the graphs

For 18 tonnes o. d. raw material, M, containing 15% moisture, the amount of raw material loaded, M_w, is given by graph A to be 21 2 tonnes (M_w). The active alkali required at 15% alkali charge is 2 7 tonnes (as Na_2O) from graph B. If the sulphidity of the white liquor is 18% and the desired value is 22%, then the amount of Na_2S to be added is estimated from graph C-1 to be 175 Kg. A correction, f, to be subtracted from the active alkali at the time of calculating white liquor volume is also seen from graph C–1 as 0.14 tonnes. The volume of white liquor to be charged is then obtained corresponding to 2.7–0 14 i.e., 2.56 t active alkali. The volume is obtained from graph D as 39.5 m^3.

The volume of total liquor for a bath ratio of 3 is obtained as 54 m^3 from grap E. The volume of black liquor to be added is calculated as under.

$$V_{BL} = 54 - 39.5 - (21.2 - 18)$$
$$= 11.3 \text{ m}^3$$

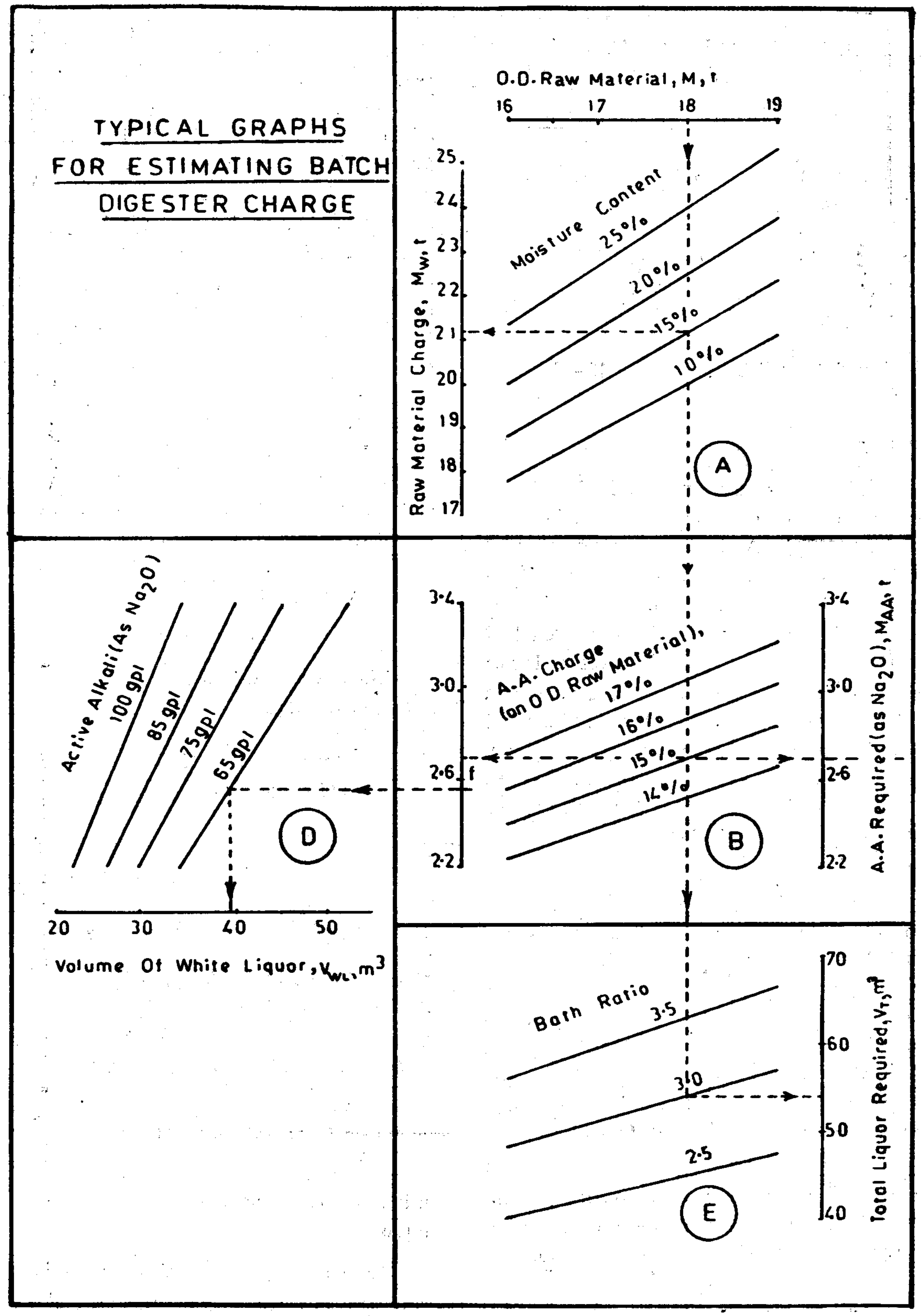
Thus we see that the procedure quickly yields the values of the variables as shown in table–3.

TABLE–3 THE VARIABLES OBTAINED BY THE GRAPHS :

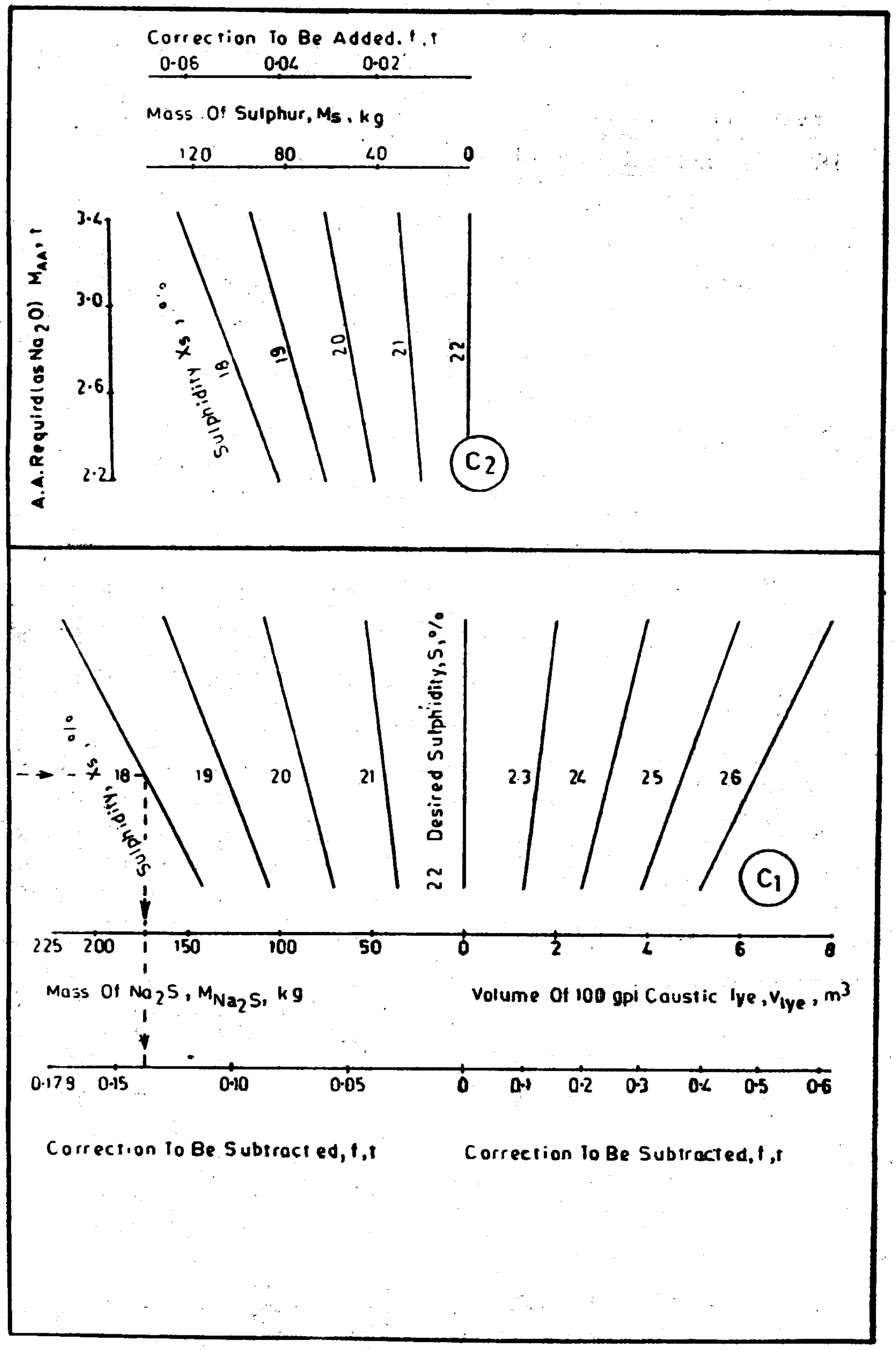
S.No.	Variable
1.	Weight of raw material, M_W
2.	Total active alkalio to be charged, M_{AA}
3.	Volume of white liquor required, V_{WL}
4.	Amount of sulphur, Na_2S, or NaOH to be added for sulphidity corrections.
5.	Black liquor make up, V_{BL}

The graphs drawn here are valid under the assumption of negligible amodnt of alkali in the black liquor

Similar graphs can be developed for non sulphur soda process using agricultural residues by omitting graphs C–1 & C–2. Individual mills can develop these graphs specific to their mill conditions for routine control of digester charge. Such graphs will be clear and simple with only one or two lines in each figure.



TYPICAL GRAPHS
FOR ESTIMATING BATCH
DIGESTER CHARGE
O.D. Raw Material, M, t
16
17
18
19
Raw Material Charge, M_W, t
25
24
23
22
21
20
19
18
17
Moisture Content
25%
20%
15%
10%
A
3·4
3·0
2·6
2·2
A.A. Charge
(on O.D. Raw Material),
17%
16%
15%
14%
B
A.A. Required (as Na_2O), M_{AA}, t
Active Alkali (As Na_2O)
100 gpl
85 gpl
75 gpl
65 gpl
D
20
30
40
50
Volume Of White Liquor, V_{WL}, m^3
Bath Ratio
3·5
3·0
2·5
E
70
60
50
40
Total Liquor Required, V_T, m^3


Correction To Be Added, f, t
0·06 0·04 0·02
Mass Of Sulphur, Ms, kg
120 80 40 0
A.A. Requird (as Na2O) MAA, t
3·4
3·0
2·6
2·2
Sulphidity Xs, %
18 19 20 21 22
C2
Desired Sulphidity, S, %
Sulphidity, Xs, %
18 19 20 21 22 23 24 25 26
C1
225 200 150 100 50 0 2 4 6 8
Mass Of Na2S, MNa2S, kg
Volume Of 100 gpl Caustic lye, Vlye, m3
0·179 0·15 0·10 0·05 0 0·1 0·2 0·3 0·4 0·5 0·6
Correction To Be Subtracted, f, t
Correction To Be Subtracted, f, t

APPENDIX

A-1 MASS OF THE RAW MATERIAL :

Let M be the mass of Oven Dry raw material load to the digester per charge, then the mass of the raw material alongwith the moisture content, M_w will be

$M_w = M/(100-x)$ .... (1)

Where x = percent moisture in chips.

A-2 ACTIVE ALKALI REQUIRED :

Amount of active alkali required M_{AA} will be given by

$M_{AA} = (x_{aa}/100) . M$ .... (2)

(expressed as Na_2O)

Where x_{aa} = percent active alkali on raw material (as Na_2O)

Let S be the level of sulphidity of W/L, in percentage, desired to be controllcd, and x_s be the percentage snlphidity of the white liquor obtained from laboratory analysis then a suitable chemical is added to correct the deviation. If the sulphidity is lower than the control sulphidity, either sodium sulphide (Na_2S or elemental sulphur is added to the system. If the sulphidity value is higher (in rare cases), the caustic lye should be added so as to ensure sufficient effective alkali for a given amount of active alkali charged.

A-3 ADDITION OF Na_2S :

Mass of Na_2S to be added is given by

$$M_{Na_2S} = \frac{(S-x_s)}{100-S} . M_{AA} \quad \text{.................} \quad (3a)$$

(as Na_2O)

Where x_s = Sulphidity of the white liquor

or $$M_{Na_2S} = 1.258 \frac{(S-x_s)}{(100-S)} . M_{AA} \quad \text{...........} \quad (3b)$$

(as Na_2S)

A-4 ADDITION OF ELEMENTAL SULPHUR :

For the calculation of the amount of elemental sulphur for the correction in sulphidity deviations the following commonly accepted stoichiometric relation can be used (1)

$$6NaOH + 4S = 2Na_2S + Na_2S_2O_3 + 3H_2O \quad \text{........} \quad (4a)$$

Mass of sulphur to be added can be found out

$$M_s = 2.0645 \frac{(S-x_s)}{(S+200)} M_{AA} \quad \text{.......... ....} \quad (4b)$$

(as sulphur)

A-5 ADDITION OF CAUSTIC LYE :

If the sulphidity x_s is higher than S then the amount of caustic soda to be added to control sulphidity is given by

$$M_{NaOH} = 1.29 \frac{(x_s-S)}{S} . M_{AA} \quad \text{.......................} \quad (5a)$$

(as NaOH)

Volume of 100 gpl caustic lye will be

$$V_{lye} = 12\,9 \frac{(x_s-S)}{S} . M_{AA}\ (m^3) \quad \text{.............} \quad (5b)$$

When M_{AA} is used in tonnes

A-6 VOLUME OF THE WHITE LIQUOR :

The amount of white liquor to be added can be calculated from

$$V_{wL} = \frac{1000.}{C_{wL}} (M_{AA} - f)\ (m^3) \quad \text{........ ... ...} \quad (8)$$

Where C_{wL} is the active alkali concentration of white liquor in g/l and M_{AA} is expressed in tonnes.

A-7 CORRECTION FACTOR :

To be able to charge exact amount of active alkali required, the volume of white liquor should be calculated after subtracting the amount of alkali added as Na_2S or NaOH for sulphidity corrections. In case of the use of elemental sulphur for these corrections, additional quantity of white liquor is added to take into account the NaOH consumed in reaction (4a). The correction factor f is given by

$f = 0.7948\ M_{Na_2S}$ .... (9)

$f = 0.775\ M_{NaOH}$ .... (10)

$f = -0\,4843\ M_{S}$. .... (11)

NOTATION

C_{wL}	=	Active alkali concentration of white liquor, gpl
f	=	Correction to the substracted from M_{AA} while estimating volume of white liquor, tonnes.
M	=	Mass of o.d. raw material, tonnes.
M_{AA}	=	Mass of active alkali required (as Na_2O), tonnes.
M_{Na_2S}	=	Mass of sodium sulphide to be added for sulphidity control, kg
M_{NaOH}	=	Mass of caustic soda to be added for sulphidity control, kg.

$_sM$ = Mass of sulphur to be added for sulphidity control, kg.

M_w = Mass of raw material alongwith its moisture content, tonnes.

S = Control sulphidity, percent.

V_T ≃ Total volume of liquor, m^3

V_{lye} = Volume of 100 gpl caustic lye equivalent to M_{NaOH}, m^3

V_{BL} = Volume of black liquor, m^3

V_{WL} = Volume of white liquor, m^3

x = moisture content in the raw material, percent.

x_{aa} = active alkali charged on o.d. raw material, basis, percent.

x_s = Sulphidity of white liquor, percent.

REFERENCES

1. Casey, J.P., "Pulp and Paper-Chemistry and Chemical Technology, vol. I, IIIrd edition, John Wiley & sons (1981)

2. Rajan, T.N.S., IPPTA 25(2), 1-22(1988)