Continuous Countercurrent Decantation Calculations

by T. B. Counselman

Continuous countercurrent decantation calculations have always been a headache to the cyanide man (and the chemical engineer) because of the simultaneous equations involved. These are tedious to solve, and there is considerable opportunity for mathematical error. This paper presents a shortcut method for making these calculations, which has been in successful use for twenty years by the author, and which is particularly valuable in selecting the best of several possible flowsheets, or evaluating the effect of various assumptions.

EVERYONE who has to calculate cyanide circuits, using either thickeners, filters or both, realizes the headaches involved in solving a set of simultaneous equations. When you calculate a large number of these, based on experimental data, trying to arrive at the best flowsheet, you can spend days at the task.

T. B. COUNSELMAN, Member AIME, is Manager, FluoSolids Division, The Dorr Co., Stamford, Conn.

AIME New York Meeting, Feb. 1950.
TP 2783 B. Discussion (2 copies) may be sent to Transactions *AIME before March 31, 1950. Manuscript received Aug. 23, 1949.*

Herewith is presented a short method, equally accurate with the standard simultaneous equation method, and much quicker.

Here for instance is the standard simultaneous equation method, for 100 tons per day of $10 ore, with the conditions assumed as below (fig. 1).

Conditions Assumed

a. 100 tons of ore per day crushed in cyanide solution.

b. Discharge from all thickeners with 50 pct moisture.

c. $10 value dissolved per ton of ore.

d. 50 pct in mill and 50 pct in agitators.

e. 400 tons of solution from thickener V precipitated to $0.02.

f. Agitation with a dilution of 2 of solution to 1 of solids.

g. Let V, W, X, Y and Z represent value in dollars per ton of solution discharged from the respective thickeners.

Equating Out of and Into Each Thickener

1. $100V$ plus $400V = 500W$ plus $(0.50 \times \$10 \times 100)$
2. $100W$ plus $600W = 500X$ plus $100W$ plus $(0.50 \times \$10 \times 100)$ plus $100V$
3. $100X$ plus $500X = 100W$ plus $500Y$
4. $100Y$ plus $500Y = 100Z$ plus $100X$ plus (400×0.02)
5. $100Z$ plus $100Z = 100Y$ plus 100 tons of water (value $0.00)

Simplifying:

1. $V = W$ plus 1.00
2. $W = X$ plus 1.20
3. $X = Y$ plus 0.24
4. $Y = 0.2Z$ plus 0.064
5. $2Z = Y$

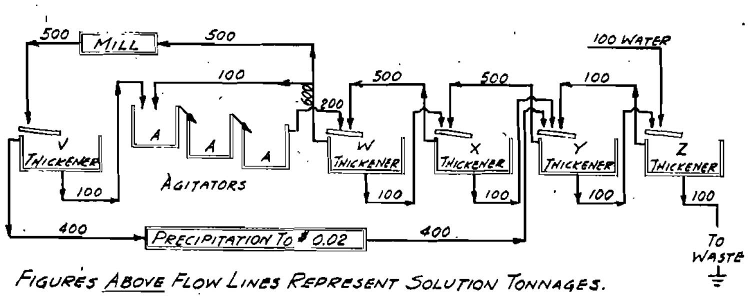


Fig. 1—Simultaneous equation method.

Solving:

$V = \$2.51111$
$W = \$1.51111$
$X = \$0.31111$
$Y = \$0.07111$
$Z = \$0.03556$ —*Loss* per ton

To Check the Calculations Above:

The amount precipitated from 400 tons at \$2.5111—0.02	= \$996.44
The amount lost in tailings, 100 tons at \$0.03556	= 3.556
	\$999.996

The amount dissolved, 100 tons at \$10.00 = \$1,000.

From the Foregoing, the Following Results are Deduced:

Assay value of pregnant solution, i.e., Value of V	= \$2.51111
Assay value of discharged solution, i.e., Value of Z	= 0.03556
Loss of dissolved value per ton of ore	= 0.03556
Dissolved value saved, 99.64 pct	

Shortcut Method

Now for the shortcut method, using exactly the same assumptions. First sketch the flowsheet exactly as before (fig. 1), and put the solution tonnages above the line exactly as before (fig. 2).

The conditions assumed are the same as before.

Now assume that the total dissolved value loss per day is (x) dollars. In other words, the dissolved value in the tailing discharged as underflow from thickener Z, is (x). Put (x) under the line of the tailing from this thickener. Since the concentration of dissolved value must be exactly the same in the overflow and underflow of any thickener, and since the solution tonnage of overflow and underflow is the same in this case, it follows that the dissolved value in the overflow of thickener Z is also (x). Therefore, put (x) under the line of the overflow of this thickener.

The total discharge from thickener Z, overflow plus underflow, contains dissolved value in the amount of $(2x)$. The wash water added to Z is barren. Therefore, this total of dissolved values of $(2x)$ must come with the underflow of thickener Y. Therefore, put $(2x)$ under the line of the underflow from Y.

Since the concentration in the overflow must be the same as in the solution with the underflow, but since the tonnage of overflow is in this case, 500, as against 100 tons of solution in the underflow, it follows that the dissolved value in the overflow of thickener Y is $(10x)$, and this figure is put under the line of the overflow.

Leaving thickener Y therefore, we have $(10x)$ with the overflow and $(2x)$ with the underflow or a total of $(12x)$. Coming into this same thickener is the overflow of thickener Z, plus the solution after precipitation which carries a total value of \$8, (400 tons of solution, precipitated to two cents). The only other source of values coming to thickener Y is the underflow of thickener X. The value of its underflow is $(10x)$ plus $(2x)$ — (x) — \$8 = $11x$ — 8, which we write under the underflow line of thickener X.

By the same method of proportioning, we find that the overflow of thickener X contains values amounting to $(55x - 40)$ and that the underflow of W must contain $(56x - 48)$. By the same method we find that the solution going to the mill carries $(280x - 240)$, and the 100 tons of overflow from W which goes to the agitators carries values of $(56x - 48)$. Also the discharge from the agitators to thickener W must carry $(337x - 296)$.

Knowing what comes out of the agitators, $(337x - 296)$, and the portion of W overflow carrying $(56x - 48)$ added to the agitators, the value of the solution with the underflow of thickener V, *after all gold values are dissolved*, must be $(281x - 248)$. However, we have assumed 50 pct of the gold dissolved in the mill, and 50 pct, or \$500, dissolved in the agitators. Therefore, we must subtract another 500 from the value in the solution with the underflow from V because as yet the gold is undissolved. This makes the solution value of the underflow of V $(281x - 748)$.

By proportion, the value in the overflow, going to precipitation is $(1124x - 2992)$.

Now then, the total dissolved values in the overflow plus underflow of thickener V, with half the gold as yet undissolved, less the dissolved value of the solution going to the ball mill must equal the \$500 assumed to be dissolved in the mill. Or:

$$(1124x - 2992) \text{ plus } (281x - 748) - (280x - 240) = \$500$$
$$1125x - 3500 \qquad 500$$
$$(x) = 3.556 \text{ dissolved loss per day}$$

The dissolved loss per ton is of course \$0.03556, which checks exactly with the simultaneous equation answer, but only one unknown and only one equation had to be solved.

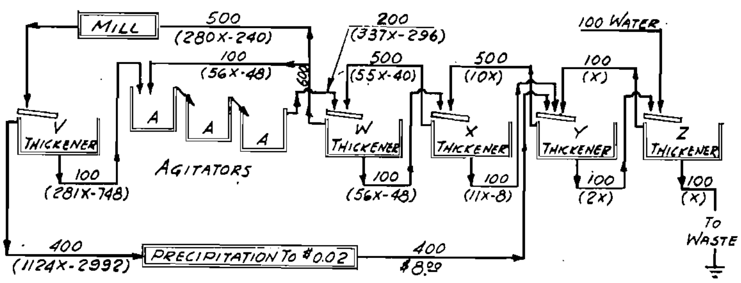
Checking this:

Total value dissolved in plant, 100 tons at \$10 (50 pct in mill) (50 pct in agitators) =	\$1000.00
400 tons precipitated:	
$(1124x - 2992) - 400$ times \$0.02 $= 1004.94 - 8.00$	996.944
Loss or residue (x)	3.556
Total	\$1,000.500

back to thickener Z, (displacing an equal amount of wash water previously added to that thickener), and the stronger filtrate back to thickener Y, the tonnages would divide as follows (fig. 3):

The (x) values balance out, by the method described above, as shown for the last part of the flowsheet.

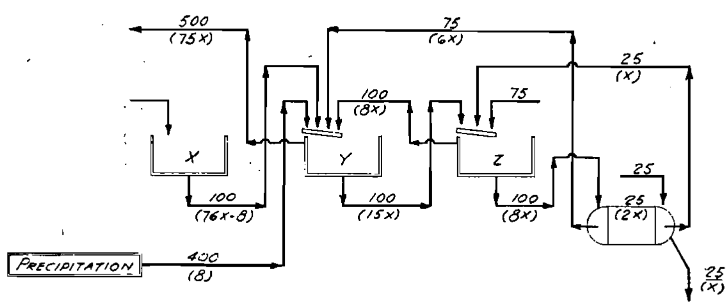
It can, of course, be assumed that there will be a volumetric displacement of, say, 75 pct of the solution in the filter cake, followed by dilution of the remaining solution with water. The same principle of computation would apply to whatever assumption was selected.



FIGURES ABOVE FLOW LINES REPRESENT SOLUTION TONNAGES

FIGURES ( ) BELOW FLOW LINES ARE TOTAL VALUES PER 24 HRS.

Fig. 2—Shortcut method.



FIGURES ABOVE FLOW LINES REPRESENT SOLUTION TONNAGES

Fig. 3—Shortcut method with filter.

The above flowsheet can be made and the loss calculated in a few minutes, as against 20 or 30 min for simultaneous equations, and gives satisfactorily accurate results.

The same simplified method can be used to include filtration, at any desired point in the flowsheet (fig. 3). For instance in the example given above, if the final thickener underflow were filtered to a final cake moisture of, say, 25 pct, you would assume that the filtration took place in two steps. First the straight filtration to final moisture, and second the addition of an amount of wash water equal to the moisture left in the cake, with a second filtration to final cake moisture. Conventionalized for calculations, and taking the wash filtrate

This same method of calculation may be used for calculating countercurrent decantation circuits in the chemical industry, for example causticizing flowsheets, the manufacture of alum from bauxite, or the washing, by countercurrent methods, of any solid, free from solutions.

Acknowledgment

Thanks are due to Mr. Dycus, of Golden Cycle Corp., and Nathaniel Herz, of Homestake Mining Co., for helping to work out the application of this method of calculation to cyaniding.