of native copper. However, it was believed that if twelve samples were selected from nine separate streams that cut across the strike of the flows, and five samples from the Kettle River, most of the sample points would not overlie or be very close to a copper zone. One sample (No. 7) was collected 200 ft downstream from an exposure of native copper in the Kettle River.

The results of chromograph tests of size fractions are given in Table III.

Table III. Copper Content, Ppm, in Size Fractions of Active Stream Sediments, St. Croix Park Area, Minnesota

Mesh	Average of 12 Stream Samples	Average of 4 River Samples	Sample No. 7 River Sample	
9	8	5	300	
-9 + 32	3	Ö	50	
-32 + 80	3.5	Õ	0	
-80 + 150	14	6	10	
-150 + 200	109	56	20	
200	370	240	150	

Sample No. 7 and the samples from Fillson Creek (Fig. 5) are similar both in copper distribution and nearness to a mineralized source. The other St. Croix Park samples display a different distribution in that the coarser fractions are very low in copper. This is interpreted as an expression of an additional factor in the geologic history of the material, the effect of transport to a greater distance from the metal source.

#### Conclusion

Heavy metal distribution data for soil fractions of till and for active stream sediments show that the soil size fraction containing the highest proportion of heavy metals may differ in materials of different geologic history. A channel-flow hypothesis can explain the distribution curve of heavy metals in till. It is suggested that the distribution curve of heavy metals is a result of the geologic history of the sampled material, and it follows that a distribution curve indicates something of the geologic history of the soil.

Understanding of the heavy metal distribution trends is a useful guide in selection of sample material in geochemical reconnaissance work. A great

deal more data will be needed before it is possible to make reliable predictions of the type of distribution a certain soil sample might have. It is hoped that this article will stimulate further investigation in materials of various origins.

Acknowledgment

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# Graphical Representation of Theoretical Soluble Losses by CCD

by R. J. Woody

DESIGN of the most economic continuous countercurrent decantation (CCD) circuit is based on selection of the number of stages and the wash

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volume that will give the minimum summation of the following items:

- 1) Capital and operating costs of the CCD circuit.
- 2) Capital and operating costs of the precipitation circuit.
  - 3) Value of the dissolved product lost.

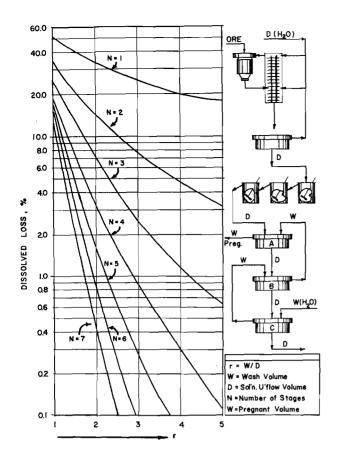


Fig. 1-Straight CCD after water grind.

Items 1 and 2 are fairly straightforward problems of estimating from ore testing data.

Item 3 involves what is commonly referred to as the theoretical soluble loss, and its value is essential in comparing like installations. Once the type of flowsheet is established and the practical operating level of the thickener underflow dilution is determined from the test data, the theoretical loss can be calculated. However, the number of stages and the wash volume must be fixed for each computation, and determination of the optimum layout for CCD and precipitation by this method becomes extremely laborious.

The charts (Figs. 1 and 2) presented here were prepared at the Winchester Laboratory to expedite the study of uranium ores with respect to the possible application of CCD. The flowsheets for which soluble losses are plotted in Figs. 1 and 2 are the two most common for straight CCD washing. A broad practical range of conditions with respect to number of stages and wash ratios is covered in the curves accompanying the flowsheets.

The soluble loss is expressed as a percentage of the desired product that is in solution in the feed to the CCD circuit.

The symbols D and W of Fig. 1 are liquid volumes in thickener underflow and overflow respectively and are assumed to remain constant at all stages. These quantities are commonly expressed as volume tons (32 cu ft) per ton of ore treated. D is determined by laboratory or pilot plant testing and represents the volume of solution per unit of dry solids in the pulp at or near its terminal density. In the determination of washing efficiency, the ratio of

# **Derivation of Soluble Loss Formulas**

## Water Grind Flowsheet (Fig. 1)

Let x = valuable product that was dissolved in the agitator circuit and lost in the last CCD thickener underflow in pounds per ton of ore.

And, let W/D = r C underflow,  $C_u = x$  C overflow,  $C_0 = rx$ From product balance at thickener C:  $B_u = C_u + C_0 - \text{zero} = x(r+1)$ , and  $B_0 = r B_u = x(r^2 + r)$ .

 $B_0 = r B_u = x(r^2 + r)$ . From product balance at thickener B:  $A_u = B_u + B_0 - C_0 = x(r^2 + r + 1)$ , and  $A_0 = r A_u = x(r^2 + r^2 + r)$ .

From the overall product balance: Total dissolved in CCD feed =  $C_u + A_0$ Percentage loss for three stages is,  $100 \ C_u$   $100 \ x$ 

 $\frac{A_0 + C_u}{A_0 + C_u} = \frac{1}{x(r^3 + r^2 + r + 1)}$ The general formula for N stages is, therefore:

Soluble loss, pct =  $\frac{1}{r^{N} + r^{N-1} + r^{N-2} + \dots + r^{N-N}}$ 

W to D is the controlling factor, rather than the size of either quantity, and values of W/D (r) constitute the horizontal axes of the charts.

The following example illustrates a method of using the chart in Fig. 1:

**Problem:** Find the combinations of number of stages (N) and pregnant solution volumes (W=rD) that will yield a theoretical soluble loss of 0.2 pct if the thickener spigot dilution is 0.8 volume tons per ton of ore. The essential numbers may be quickly found and tabulated (Table I).

Table I. Combinations for 0.2 Pct Soluble Loss (D - 0.8)

Stages $r$ Preg $(rD)$	7	6	5	4
	2.3	2.6	3.2	4.4
	1.8	2.1	2.6	3.5

It is readily apparent that information of this type is useful in estimating the combined costs of CCD and precipitation. If cost plus soluble losses is compared at enough loss levels the optimum layout with respect to number of stages and size of precipitation circuit can be established. The optimum theoretical soluble loss can also be determined.

The curves in Fig. 2 differ from those in Fig. 1 because the flowsheets are different. In the flowsheet represented by Fig. 1 water enters the feed end of the mill in volume equivalent to D, and wash volume (W) is applied at the last stage of thickening. In the flowsheet for Fig. 2 wash volume W, applied to the last thickener, is the only water added, and the water required in the grinding circuit is taken from the second stage of CCD. This solution re-enters the CCD circuit at stage 1 via the leached pulp. This type of flowsheet is very common in cyanidation. Fig. 2 also applies to acid leaching and CCD following a dry grind.

Although r in Fig. 2 is also W/D, the volume of pregnant solution per ton of ore is W minus D. Total water required in Fig. 2 is W, whereas in Fig. 1 it is W plus D. Evaporation losses are of course neglected in the estimation of theoretical soluble losses.

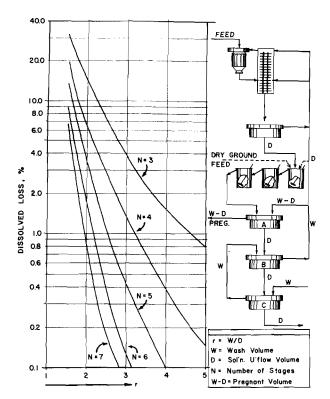


Fig. 2-Straight CCD after grinding dry or in solution.

The curves in each of these charts are the result of substitution in formulas developed for the particular flowsheets. The derivation of these formulas is presented here.

Figs. 1 and 2, and perhaps other charts like them, could be extremely useful to the design engineer for determining the most efficient system to recover products dissolved from ores and similar raw materials. Such charts are also useful for com-

# **Derivation of Soluble Loss Formulas**

Solution on Dry Grind Flowsheet (Fig. 2)

According to the same nomenclature used in the derivation for Fig. 1:

$$C_{\mathbf{u}} = x$$
, and

$$C_0 = r x$$
.

From product balance at thickener C:

$$B_u = C_u + C_0 - \text{zero} = x(r+1), \text{ and } B_0 = r B_u = x(r^2 + r).$$

From product balance at thickener B:

$$A_{u} = B_{u} + B_{0} - C_{0} = x(r^{2} + r + 1), \text{ and } A_{0} = rac{W - D}{D} A_{u} = (r - 1) A_{u}$$

 $=x(r^3-1)$ . From the overall balance:

Total dissolved = 
$$C_u + A_0$$
  
=  $x + (xr^3 - x)$   
=  $x r^3$ 

Percentage loss for three stages: 100x

Soluble loss, pct,= 
$$\frac{100x}{xr^3}$$

For N stages:

Soluble loss, pct = 
$$\frac{100}{r^{N}} = 100 \left(\frac{D}{W}\right)^{N}$$

parison of actual and theoretical washing efficiency of existing plants.

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# Distribution Curves for Sink-and-Float Separation of Iron Ores

by Rudolph G. Wuerker

W ITH the growing complexity of ore dressing processes and the diversity of equipment, efficiency control has become increasingly important in beneficiation. In the case of iron ore dressing, there have been sporadic attempts<sup>1-3</sup> to establish the optimum separation for various ores so that grade and recovery would be readily predictable. But no rigorous statistical analysis and graphical presenta-

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tion of such tests could be found in the literature of this country.

# Tests Made with Iron Ores

Expanding upon existing methods of plant supervision and efficiency control, an investigation was started in the ore dressing laboratory at the University of Illinois on the applicability of distribution analysis to iron ores. A sample of crude ore was obtained from the Ohio mine of Cleveland-Cliffs Iron Co. at Ishpeming, Mich., consisting mostly of alternating bands of hematite and siliceous gangue, both about ¼ in. wide. The ore was heavily coated with limonite, which often filled the cracks.

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