

Chapter 30

CARBON SAMPLING IN GOLD CIRCUITS

by

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ABSTRACT

This paper discusses the accuracy of determining the quantities of gold and silver on activated carbon in various stages of process for typical precious metals flowsheets. Accurate plant performance evaluation depends upon reliable estimates of carbon and precious metals inventories. The sources of sampling error are identified and methods of reducing them discussed. Several case studies illustrating the sensitivity of flowsheet performance to sampling error are presented.

INTRODUCTION

Metallurgical performance of gold and silver mineral processing flowsheets is typically evaluated using assay balance and production balance techniques. With assay balance the millfeed, tailings, and some intermediate streams are sampled and assayed. Plant performance can then be

evaluated using mass balance techniques. Unsteady plant conditions and difficulties in sampling and measuring moving streams are some problems with this method. Production balance measures two rather tangible quantities, tons milled and ounces poured, combines this with the tailings assay to calculate head grade and recovery. Changes to in-process inventory must be monitored as the production balance is highly sensitive to this factor.

The primary inventory location for flowsheets utilizing activated carbon is gold (and silver) on the carbon. Thus a production balance must include a sampling program to determine the amount of carbon in the various stages of process and the gold adsorbed on that carbon. To get an accurate estimate of the inventory the sampling program must satisfy 5 conditions:

- 1) The concentration of carbon in the sample must be representative of the concentration of carbon in the vessel sampled.

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- 2) The gold grade of the sample must be representative of the gold grade of the carbon in the vessel.
- 3) The sample preparation procedure must not introduce a bias of the assay sample from the original sample.
- 4) The assay methodology must reflect the true grade of the assay sample.
- 5) The samples must be taken at a time that coincides with the termination of the production period.

Accurate estimation of gold inventory will assist in scheduling and control of the carbon and strip circuits, improve production forecasting, and provide increased security controls.

ESTIMATION OF CARBON INVENTORIES

The first task is to measure the quantity of carbon in the various process stages. In carbon columns (CC) or strip vessels where only carbon is present, a direct volumetric measurement is possible. In carbon-in-pulp (CIP) or carbon-in-leach (CIL) systems it is necessary to obtain a sample from the agitated mix of carbon and pulp. Wetted carbon will settle (sp gr 1.35) in water. Thus a complex situation involving pulp rheology (sp gr, viscosity, and % solids), carbon particle parameters (size, density, and shape), and agitation dynamics determines the suspension of the mix.

The accuracy of the sample (in terms of carbon concentration) depends upon three conditions being met:

- 1) The agitation and pulp characteristics provide a uniform concentration of carbon throughout the tank. If this is not the case then a method of correction must be devised. This usually involves sampling at various vessel locations.
- 2) The sample methodology must not disturb the agitation conditions beyond an acceptable limit. Holding a sample cup into the pulp for a period of minutes will result in a cupful of carbon, the interior of the cup being a quiescent zone allowing the carbon to settle. A methodology which favors carbon particles of a certain size range or shape would create a bias in gold grade, as discussed in the next section.
- 3) The sample is of sufficient size to be representative of the vessel. A one litre sample is only about one millionth the volume of a typical CIP/CIL vessel.

Popular sample techniques are a) the surface dip sample, b) a sampler made of a long pipe with a foot valve at the bottom and a ball valve on top, c) sampling spigots along the side of the vessel, and d) an air lift mechanism to lift a sample stream to the surface. If vibrating deck screens are installed as interstage screens it is possible to directly measure the amount of carbon being transferred from stage to stage.

From a gold inventory perspective, greater effort should go toward sampling the first and second stages as most of the gold inventory resides at these locations. This may involve larger samples, sample duplication, or an additional sampling technique. If agitation and rheology conditions deteriorate, carbon may settle out of suspension to become dead inventory. Dead inventory carbon can adsorb substantial gold over time, with significant effects upon the production balance. Favorite deposition sites are along the bottom edge of flat bottomed tanks and directly under the impeller shaft.

CARBON GRADE DISTRIBUTIONS

The ability of activated carbon to adsorb gold and silver is a complex matter of many variables, but for a given pulp (or pregnant solution) and agitation conditions, the gold grade of the carbon is a function of 1) the activity of the carbon, 2) the carbon surface area available for adsorption of gold cyanide complexes, and 3) the contact time.

$$\text{Grade} = f(\text{Activity, Surface area, Contact time})$$

Two important relationships are applied to this equation, that the process flowsheet can determine the relative contact times of carbon particles in the system, and that size and shape factors can influence the surface area to mass ratio of the particles. Both relationships effect the gold grade of individual carbon particles.

Contact times

Carbon columns involve a fixed amount of carbon being contacted with pregnant solution in an ebullated bed, with the contact time of the carbon particles being equal. Assuming adequate mixing, the grade distribution of the particles is dependent upon the first two variables above. This should result in a 'normal' or 'gaussian' grade distribution, as shown by the solid line in Figure 1.

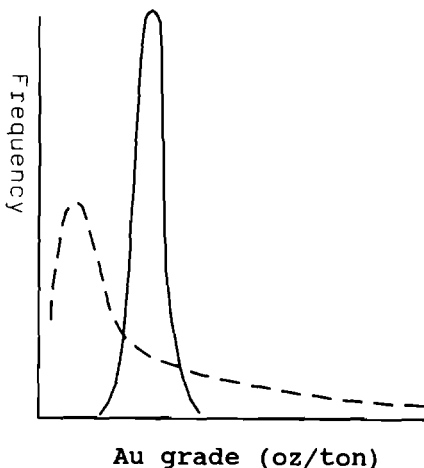


Figure 1. Frequency distribution of carbon particle gold grades.

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A countercurrent system such as CIL or CIP with interstage carbon transfer will result in a far different distribution. For example, if a tank with an initial concentration of carbon has a given quantity of pulp pumped across a screen, removing the carbon (the pulp returns to the tank), the concentration of carbon will display an exponential decay over time. Likewise, if gold grade is dependent upon contact time, the carbon particle gold grades will be a highly skewed exponential distribution, with most particles having a low grade but a few having very long contact times resulting in very high grades.

The CIL/CIP circuit situation is more complex because 1) carbon is being transferred in as well as out, 2) the carbon being transferred in has an initial grade distribution, and 3) activity decreases with contact time. Thus the grade distribution of carbon particles from a countercurrent system is approximated as lognormal, shown as the dashed line in Figure 1. Note that both distributions have the same mean grade.

Thus the number of carbon particles required to make a robust estimate of the mean grade will be much greater for the lognormal distribution (CIP/CIL) due to the wide scatter in individual grades. This can affect the sample size requirements and the sample preparation procedures, as discussed in that section.

Size and shape factors

Gold adsorption onto carbon

particles is limited by film diffusion as described by Davidson (1974). This means that the gold grade of a carbon particle will be a function of its surface area to mass ratio. Figure 2 illustrates this relationship. Thus smaller, flakier, and irregular shaped particles will have higher grades than their larger, regular shaped cousins. The behavior of such particles in the agitation tanks will be different, possibly resulting in a sample bias. Size and shape factors may cause segregation in sample preparation.

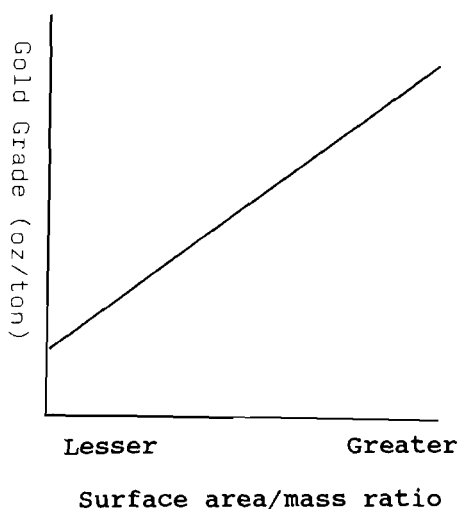


Figure 2. Relationship of surface area / mass ratio to carbon particle gold grades.

SAMPLE PREPARATION AND ASSAY

Having obtained a sample of carbon during our carbon concentration exercise, a subsample can be taken from this for sample preparation and assay.

The size of this subsample should be large enough to contain sufficient carbon particles to provide a robust estimation of the gold grade. As noted in the previous section this will involve a larger sample for the CIL/CIP situation due to its skewed lognormal grade distribution. Segregation will cause the higher grade, smaller particles to separate from the lower grade, larger particles creating a potential sample bias.

Sample weight reduction should be preceded by reduction in sample particle size as outlined by Gy (1979). This is critical for the CIL/CIP case as one high grade particle could bias the results considerably. Thus it is preferable to pulverize the entire sample (dry) prior to splitting to assay charge size. The drawbacks are time, labor, and increased potential for contamination of other samples (loaded carbon may be +200 oz/ton).

Results of 11 round robin carbon assay trials conducted by the Society of Mineral Analysts, Wright (1990), indicates the accuracy of carbon assay repeats to be 7% (standard deviation as a percent of the mean). Thus 32% of the time (one standard deviation) we can expect an error of greater than +/- 7% in the assay.

CASE STUDY

To illustrate the results of 'typical' accuracies from the estimation of carbon

inventories a hypothetical gold mine case study is presented. Results of an industry survey, Bruington (1990), show that mill metallurgists estimate the accuracy of estimating carbon concentration to be about +/- 10% to 15%. No correlation of the level of this estimate with sample method, carbon concentration levels, or plant size was detected.

Assume a CIL operation milled 100,000 tons over a one month period with a true head grade of 0.050 oz/ton and a recovery of 86%, resulting from a tailings assay of 0.007 oz/ton. Assume the first stage CIL tank contains 10 tons of carbon at a true grade of 150 oz/ton, and that the true inventory level is unchanged over the month. An error of 10% occurs in estimating carbon concentration, an error of 3% occurs in sample preparation, and an error of 7% occurs in assaying the carbon. If all three sources of error are in the same direction and occur only in the first tank, what are the resulting calculated recoveries and head grades?

VARIABLE	CASE		
	LOW	TRUE	HIGH
FEED (oz)	5000	5000	5000
TAILS (oz)	4300	4300	4300
POURED (oz)	700	700	700
NET TO INVENTORY (calc oz's)	+282	0	-282
RECOVERY (calc)	92%	86%	80%
HEAD GRADE (calc oz/ton)	0.053	0.050	0.047

Table 1. Changes in head grade, net inventory, and recovery by production balance with sampling uncertainty effects.

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Table 1 illustrates the impact upon calculated inventory change, head grade, and recovery.

Obviously the errors will not always fall in the same direction, there will be some cancellation of errors. The important point is that the magnitude of the errors can be large and that they are cumulative. Also some of the errors may contain a bias.

CONCLUSIONS

Despite the uniform appearance of activated carbon, significant uncertainties exist for the sampling, sample preparation, and assaying steps of determining carbon (and gold on carbon) inventories. The distribution of carbon particle grades and the surface area to mass ratio of the carbon particles are factors contributing to this uncertainty. Sampling of countercurrent CIL/CIP systems is a complex situation involving pulp rheology, carbon particle shapes, and agitation dynamics. The effect of carbon inventory uncertainties upon a monthly production balance can be substantial.

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