

Towards more effective simulation of CIP and CIL processes. 1. The modelling of adsorption and leaching

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SYNOPSIS

To date developments in the simulation of carbon-in-pulp (CIP) adsorption circuits have focused primarily on the modelling of adsorption. This series of three papers describes a development in a direction that has received less attention, i.e. the need for a detailed description of the movement of carbon and slurry in continuous CIP and carbon-in-leach (CIL) plants. A new simulator has been developed based on the population-balance approach for modelling the movement of carbon and slurry. Existing adsorption and leaching models are evaluated in this paper in order to establish which are appropriate for use in the new simulator. The details of the simulator are given in Part 2 of this series.

SAMEVATTING

Tot op hede was ontwikkelings in die simulering van koolstof-in-pulpadsorpsiekring (KIP) hoofsaaklik op die modellering van adsorpsie toegespits. Hierdie reeks van drie referate beskryf 'n ontwikkeling in 'n rigting wat minder aandag geniet het, d.w.s. die behoefte aan 'n uitvoerige beskrywing van die beweging van koolstof en flodder in KIP- en koolstof-in-loogaanlegte (KIL). Daar is 'n nuwe simuleerder ontwikkel wat gebaseer is op die nuwe populasie-balansbenadering vir die modellering van die beweging van koolstof en flodder. Die bestaande adsorpsie- en loogmodelle word in hierdie referaat geëvalueer ten einde te bepaal watter modelle geskik is vir gebruik in die nuwe simuleerder. Die besonderhede van die simuleerder word in Deel 2 van hierdie reeks verstrekk.

Introduction

This is the first of a series of three papers that describe the development and testing of a new tool for the simulation of carbon-in-pulp (CIP) and carbon-in-leach (CIL) adsorption circuits. Bailey¹, using a fairly simple simulator, has shown how useful such tools can be when exploring the influence of design and operational variables and cost factors on performance. In CIP and CIL plants, the number of these variables and the complexity of their inter-relations are such that simulation techniques are the most cost-effective means available for conducting any extensive and in-depth examination of design or operational alternatives.

The two fundamental aspects of a CIP operation that any simulation approach must model are the chemistry and the configuration of the process, the latter being the way in which leach slurry is contacted with carbon. The former requires the development of appropriate rate models for adsorption and leaching, and the latter involves mass-balance equations that describe the countercurrent flow of slurry and carbon. This series of papers explores the way in which the accuracy of simulation predictions might be improved if more attention were paid to the modelling of process configuration. The point of departure in a new simulator that has been developed is the use of the population-balance approach to describe how slurry and carbon are contacted. This approach allows a more detailed description of carbon and slurry movement than is possible with the methodologies used

in the simulators previously reported. The simulator uses existing models for adsorption and leaching.

In this paper, Part 1 of the series, the work is put in perspective by a discussion of the capabilities and limitations of existing methodologies. The available adsorption and leaching models are evaluated to establish which should be used in the new simulator. The simulator itself is described in Part 2 of the series. In Part 3, data from operating plants are used in the validation of the simulator, and its capabilities are examined in a number of case studies.

Modelling of the Process Configuration

For a detailed description of the process configuration in a CIP or CIL adsorption circuit, the following factors need to be considered.

Slurry Flow and Carbon Transfer

Mass-balance equations are needed to describe the countercurrent movement of carbon and slurry. With one exception, previous simulation approaches adopted one of two extreme positions in modelling the carbon movement. The *kn* model of Fleming, Nicol, and Nicol² assumed continuous countercurrent movement. Other approaches like that of Johns³ recognized the periodicity of the carbon transfer but assumed that the transfer is instantaneous. In general, both approaches are restrictive since in many cases a complete carbon-transfer cycle may occupy from 10 to 70 per cent of the available operating time. To model the carbon movement realistically, consideration must be given both to the rate and duration of transfer and to the sequence in which carbon is moved from one tank to another. The only simulator previous-

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ly reported that takes this into account is that of Carrier *et al.*⁴.

Backmixing of Slurry

The favoured method for the transfer of carbon is to pump the slurry-carbon mixture upstream, which results in significant back-mixing of the slurry. Back-mixing influences the extent of both adsorption and leaching. To a limited extent, this aspect of CIP and CIL operation is accounted for in models that assume instantaneous carbon transfer since these usually also assume instantaneous transfer of the associated slurry.

Co-current Movement of Carbon

Some carbon may leak through the interstage screens—either as a result of breakage or because of holes in the screens—and move co-current with the slurry. Previous methodologies were not able to simulate this effect. Whyte *et al.*⁵, using the simulator reported in this series of papers, found that a carbon concentration of only 0,06 g/l in the interstage streams increased the gold tenor of the average barren solutions by 21 per cent and the gold lock-up by 24 per cent.

Bypassing of Slurry

All the modelling techniques reported in the literature assume that the contacting vessels in a CIP or CIL train are well-mixed. The implication of this is that the gold tenor of the slurry within and leaving a tank are the same, and that no slurry bypasses or short-circuits to the outlet in a time less than the mean residence time of the slurry in the tank. This may not always be true. When it is not, the effect of slurry bypassing can be described quite simply as shown by Williams and Glasser⁶.

Distribution of Gold Loading

Any scheme for carbon transfer that does not involve an instantaneous transfer of the whole carbon inventory will result in a distribution of the gold loading on the carbon in each tank⁷. Any co-current movement of carbon will accentuate such distribution. Differences in the sizes of the carbon particles will also affect the loading distribution. The influence of the distribution of carbon loadings and the effects of carbon size on CIP or CIL performance have not previously been considered in simulation studies.

Process Dynamics

A number of dynamic effects could potentially have a significant influence on the performance of a CIP operation. These include fluctuations in the flowrate, density, and solution tenor of the feed, as well as transient effects set up by the carbon-transfer scheme. Carrier *et al.*⁴ found in one case that half the soluble losses of gold could be attributed to the fluctuations in solution tenor that are set up by the carbon-transfer process.

Modelling Approach

The complexities of the carbon-transfer scheme and the influence of back-mixing, co-current movement of carbon, and distributed carbon loadings require a modelling approach that allows a detailed accounting of carbon and slurry movement. Of necessity, the approach must

be dynamic in order to account for time-dependent effects. The population-balance approach used in the modelling of complex particulate processes provides a convenient vehicle for the detailed dynamic accounting that is required. The use of this approach allows a more comprehensive simulation of the process configuration in CIP and CIL circuits, and is the important point of departure for the new simulator. The approach is discussed in detail in Part 2 of this series of papers.

Modelling of the Process Chemistry

With regard to the modelling of the process chemistry, adequate models for concurrent leaching and adsorption must be linked to the detailed simulation of carbon and slurry movement. In the new simulator, no new developments in adsorption models were considered. However, some rationalization of the available models was necessary and will be described.

With regard to the modelling of leaching, very little has been reported on the use of available leaching models to simulate CIP or CIL operations. Only one simple functional form for a leaching model has been reported⁸. In the remainder of the present paper, therefore, the modelling of adsorption and leaching will be discussed with the object of establishing which models should be included in the new simulator. In the discussion that follows, the focus will be the extraction of gold.

Modelling of Adsorption

The *kn* Model

During the early development of the CIP process, Fleming, Nicol, and Nicol² proposed a simple empirical model for adsorption. Although the model was of a preliminary nature, it has been used widely and is referred to as the *kn* model. It assumes that the rate of adsorption is independent of the gold loading on the carbon, and that the solution tenor in each stage of CIP circuits remains at a steady-state value C_{ss} , equation (1):

$$kn \text{ model: } y - y_0 = k C_{ss} t^n, \dots\dots\dots (1)$$

where y_0 and y are the concentrations of gold on the carbon initially and after an adsorption period, t , and k and n are model parameters.

Simple Film-diffusion Models

The classical expression for film-diffusion mass transfer can be used to model the kinetics of adsorption in CIP systems (equation (2) and Fig. 1):

Classical model for film-diffusion mass transfer:

$$R = A_c k_f (C - C^*), \dots\dots\dots (2)$$

where R is the rate of adsorption per unit mass of carbon, C and y are respectively the concentrations of adsorbing species in solution and in the carbon at time t , A_c is the film area per unit mass of carbon, k_f is the film mass-transfer coefficient, and C^* is the species concentration in solution that is in equilibrium with carbon loading y .

This term must be determined from the appropriate isotherm relationship. Three such relationships have commonly been used in describing the adsorption equilibrium in CIP systems. These are the linear isotherm (equation (3)) and the Freundlich and Langmuir isotherm expressions (equations (4) and (5) respectively).

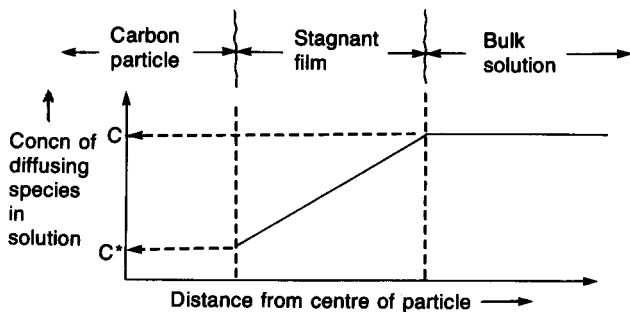


Fig. 1—The simple film-diffusion model

Isotherm models:

Linear $y_e = K c_e$, (3)

Freundlich $y_e = y_f (c_e)^{n_f}$, (4)

Langmuir $\frac{1}{y_e} = \frac{1}{y^+} + \frac{K_L}{y^+ c_e}$, (5)

where K , n_f , K_L , y_f , and y^+ are parameters, y^+ and y_f relate to the loading capacity of the carbon, and y_e and c_e are the carbon loading and solution tenor at equilibrium.

If a linear isotherm is used for the determination of C^* in equation (2), then the expression takes the form of the model proposed by Nicol and Fleming,⁹ equation (6). Johns³ used the Freundlich expression to arrive at equation (7):

Nicol-Fleming: $R = A_c k_f (C - y/K)$ (6)

Johns: $R = A_c k_f (C - (y/y_f)^{1/n_f})$ (7)

If a Langmuir isotherm is used for the evaluation of C^* , then the film-diffusion model would take the form given in equation (8). This expression has not been reported previously.

$$R = A_c k_f \left(C - \frac{K_L y}{y^+ - y} \right) \text{ (8)}$$

Dixon Model

The adsorption-rate model proposed by Dixon *et al.*¹⁰ and used by many others^{4,6,11} is shown in equation (9):

Dixon: $R = k_1 (C (y^+ - y) - K_L y)$, (9)

where k_1 is a rate constant. Frequently in adsorption situations as they occur in CIP circuits and in batch kinetic experiments, y is small or changes little compared with y^+ ; so the term $y^+ - y$ is effectively constant. In such situations, the Dixon model is indistinguishable from the film-diffusion model based on the Langmuir isotherm (equation (8)), and the two expressions can be related through equation (10):

$$k_1 = \frac{A_c k_f}{y^+ - y} \text{ (10)}$$

Simple First-order Rate Model

Equation (11) is a simple rate model that has been used by many workers to describe initial adsorption rates in kinetic experiments^{3,12}.

Simple first-order rate model: $R = k_2 C$, (11)

where k_2 is a rate parameter.

Comparison of Models

There is a degree of relatedness between the adsorption models described so far, the Dixon model being similar to equation (8) as already noted. At low carbon loadings, the Dixon and the different forms of the film-diffusion model reduce to the simple first-order model, equation (11). If this expression is integrated at constant solution tenor, it yields the kn model with a value of unity for n .

More Complex Adsorption Models

A number of adsorption models have been developed that consider other rate-controlling mechanisms in addition to film diffusion. Dixon, Cho, and Pitt¹⁰ considered a pore-diffusion model, while Brinkmann and King¹³ considered film diffusion, pore diffusion, and reaction kinetics as rate-controlling mechanisms. Van Deventer¹⁴ proposed that four processes may influence the adsorption rate: film diffusion, equilibrium at the solid-liquid interface, surface diffusion in the macropore network within the carbon particles, and diffusion from macropores into micropores. Johns¹⁵ attempted to account for intra-particle diffusion in an empirical manner. He suggested that the kinetic term in his film-diffusion model could be modified by use of a factor α to represent the degree of control exerted by intra-particle diffusion.

Evaluation of the Adsorption Models

In the following evaluation of the adsorption models described above, data will be presented to give some indication of the reliability of the predictions. This will provide a rational basis for the selection of the models to be included in the new simulator.

The kn Model

The limitations of the kn model have been well-known for some time. In the first place, the process does not operate at a true steady state; instead, the solution tenors in each stage fluctuate in sympathy with the carbon-transfer scheme (Fig. 2). Further, gold loading on carbon has a significant effect on adsorption rates, a factor that the model does not consider directly. The value of k in general is not constant for a given operation but may vary from tank to tank. This is illustrated in Table I, which shows data obtained from full-scale operation at the Grootvlei Gold Plant.

The empirical nature of the kn adsorption expression offers no basis for the modelling of the observed change in the value of k down the CIP train. What is more, it will be appreciated that, for the situation shown in Table I, a simulation of the adsorption circuit based on the mean value of k for the first two stages—where 93 per cent of the gold is extracted—will predict barren values significantly lower than those achieved.

The Simple Film-diffusion and Dixon Models

The early work in CIP modelling indicated that the rate of adsorption in many situations would be controlled by film diffusion¹². A rough estimation of the likely minimum value of the film-transfer coefficient for transfer of the auricyanide ion confirms this observation. The minimum Sherwood number for film diffusion is 2; so the minimum film-transfer coefficient, $k_{f,min}$, for auri-

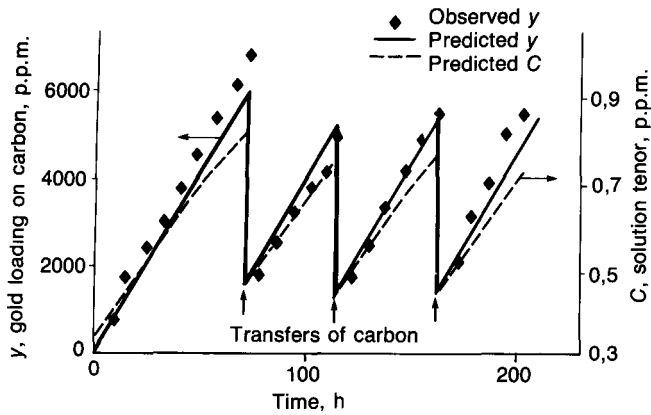


Fig. 2—Cyclic behaviour of a CIP pilot plant (after Nicol *et al.*⁸)

TABLE I
MEAN k VALUES DETERMINED FROM SPOT SAMPLING AT
GROOTVLEI (30.9.87–3.10.87)

Stage no.	1	2	3	4	5	6
Carbon loading*, g/t	3000	1200	600	(90)	100	55
Solution tenor*, mg/l	0,68	0,18	0,05	(0,011)	0,005	0,002
No. of deter- minations	17	13	14	1	10	10
k ($l\ kg^{-1}\cdot h^{-1}$)†	115 ± 28	95 ± 20	87 ± 35	(38)	61 ± 42	35 ± 32
Extraction*, %	75	73	72	(78)	(54)	60
Cum. extraction*, %	75	93,5	98,2	(99,6)	99,8	99,9

The tenor of the feed solution was about 2,75 p.p.m.

* The values given are average values

† $n = 1$ for Grootvlei pulps (Nicol *et al.*⁹)

cyanide would be

$$k_{f,\min} = \frac{2D_{Au(CN)_2}}{dp}, \dots\dots\dots (12)$$

where dp is the diameter of the carbon particle and $D_{Au(CN)_2}$ the diffusivity of the auricyanide ion. The diffusivity¹⁶ of CN^- is $1,8 \times 10^{-9} m^2/s$, which will be greater than that for the larger auricyanide ion. Therefore, if dp is 2 mm, the minimum likely value for the film-diffusion coefficient will be about $1,8 \times 10^{-6} m/s$. Van Deventer¹⁷ measured mass-transfer coefficients in the range 1×10^{-5} to $2 \times 10^{-4} m/s$, an order of magnitude larger than the minimum likely film-transfer coefficient. This suggests that it is totally feasible that film transfer can be rate-controlling, and that the film-diffusion models described may give appropriate descriptions of adsorption in CIP circuits.

The simple film-diffusion model requires an expression for the description of the equilibrium term C^* . Some indication is needed as to which isotherm expression is the more appropriate to use. Johns³ and Van Deventer¹⁴ suggest that, of the non-linear expressions commonly used for gold CIP systems, the Freundlich expression (equation (4)) is generally preferred to the Langmuir (equation (5)). The following data, however, suggest that the Langmuir expression may be more applicable in dump-treatment situations.

Isotherms for three typical Witwatersrand leach slurries are shown in Fig. 3. Notice that none of the isotherms is at all linear, even for situations where the feed tenor is low. Notice, too, that the isotherm for Fig. 3a (for a leach solution containing 7 p.p.m. of gold) is best fitted by the Freundlich expression, while Langmuir fits the isotherm better in Fig. 3c (for a solution tenor of 0,5 p.p.m.). For the isotherm in Fig. 3b (at an intermediate solution tenor of 2,5 p.p.m.), there is less to choose between the two, although the Freundlich expression gives the better fit. Clearly, more work is necessary to model the equilibrium more generally.

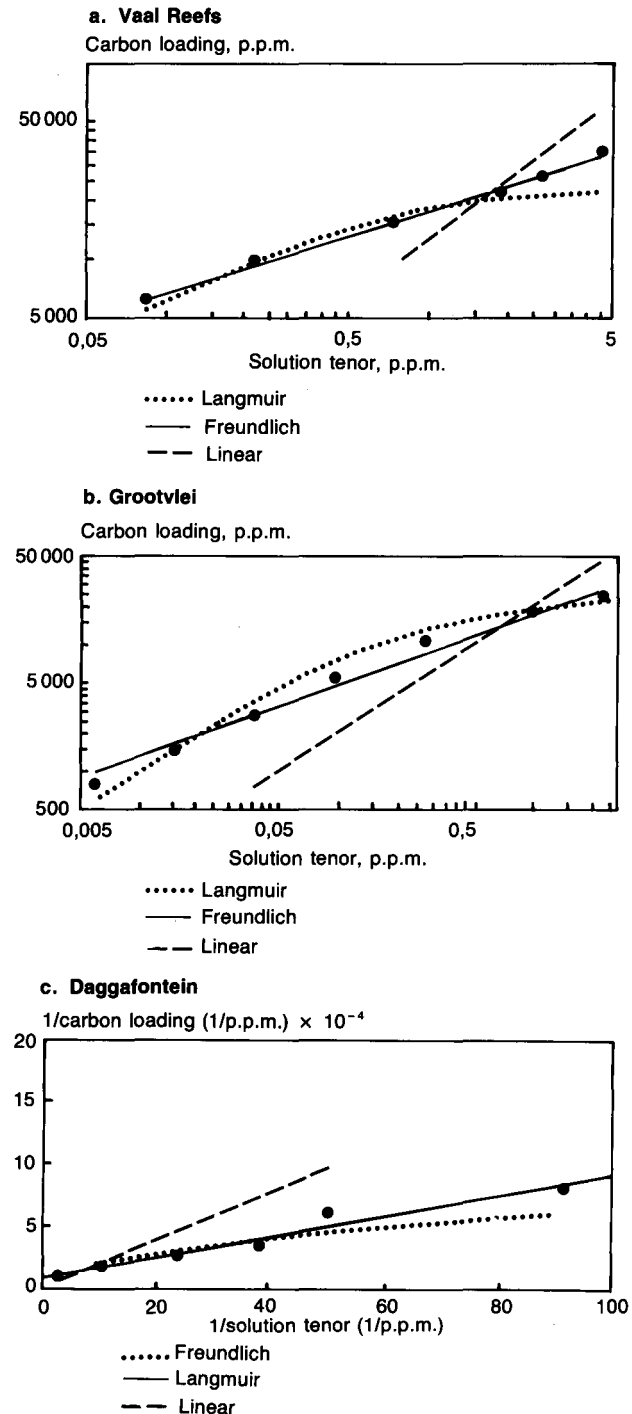


Fig. 3—Isotherms for three typical Witwatersrand ores

The implications for the current work are as follows:

- the use of a linear isotherm in the adsorption model is not likely to provide good predictions over a wide range of conditions;
- in the absence of a general isotherm expression that applies over a wide range of conditions, the film-diffusion adsorption model should accommodate both the Langmuir and the Freundlich expressions,
- equations (7) and (8) are the more appropriate forms of the film-diffusion model.

Two tests will be applied to evaluate the film-diffusion adsorption model. The form of the model that is tested will depend on the isotherm expression that is appropriate.

The first test focuses on the mathematical form of the model and considers how well this form can fit experimental data. Fig. 4a shows data from a batch kinetic experiment on Grootvlei slurry and carbon. In this experiment, a mass of carbon was contacted with a fixed volume of slurry in a stirred vessel, and the tenor of the solution in the vessel was determined as a function of time. The equilibrium parameters were obtained from independent equilibrium tests.

A linear scale is commonly used for the solution tenor in the presentation of batch kinetic data. If this is done here (Figure 4a), an apparently satisfactory fit of the

model to the data is obtained. In Figure 4b, the same data are plotted on a logarithmic scale to accentuate the differences at low solution tenors, and the fit is seen to be less than satisfactory. The lack of fit is attributed to intraparticle diffusion, which increasingly exerts control over the adsorption rate as the system approaches equilibrium. The film mass-transfer coefficient determined from the initial part of the batch curve suggests that, if film diffusion were the only rate-controlling process, the solution tenor should drop essentially to its equilibrium value, as indicated by the isotherm, within a very short period of time—less than 4 hours in this case.

The diagrams illustrate the well-known fact that the film-diffusion model is capable of fitting only the initial part of the batch kinetic curve, and that no confidence can be placed in this type of model for systems approaching equilibrium. It should also be noted in passing that the initial part of the batch curve in Fig. 4b is also well-fitted by the simple first-order rate model, equation (11).

A second test can be applied to examine the ability of the simple models to predict adsorption kinetics when interparticle diffusion is not apparently influencing the adsorption rate. In this case, the focus is on the ability of the model to predict adsorption rates under conditions different from those under which the model parameters are measured. Fig. 5 presents three sets of data, each set involving a series of batch kinetic experiments conducted under the same conditions but at different concentrations of carbon in the slurry. For each set of data, a single value for the kinetic parameter, $A_c k_r$, and for each equilibrium parameter is used to predict the kinetic curve at the different carbon concentrations. The value of the kinetic parameter used is either the mean for the set (Figs. 5a and b) or use is made of the value for one of the curves (the value for the 2,36 g/l curve in Fig. 5c). The kinetic parameters were estimated from the initial part of the relevant kinetic curves, and the equilibrium parameters from independent equilibrium tests. The Freundlich isotherm was used in Figs. 5b and c, and the Langmuir for Fig. 5a. In these diagrams, the predicted kinetic curves are presented along with the associated experimental data.

Fig. 5a (for a slurry from a plant with a feed of low tenor) shows that the predicted and actual kinetic curves are in very good agreement. Agreement is still good in Fig. 5b for a slurry with an intermediate feed tenor. Intraparticle diffusion effects are more noticeable here, and the prediction of the kinetic curve at the highest carbon concentration is a little off. In Fig. 5c (for a slurry from a plant feed of higher tenor), intraparticle diffusion effects are more marked, and the predictions for the initial part of the kinetic curves are not quite as reliable.

The following conclusions can be drawn.

- The kn model (equation (1)), the film-diffusion model based on a linear isotherm (equation (6)), and the simple first-order rate model (equation (11)) are useful only as empirical descriptions of the adsorption process. The various parameters in these expressions are not truly independent of the carbon loading and solution tenor.
- Expressions (7) and (8) can be treated as different forms of the same film-diffusion model. The Dixon model (equation (9)) is in many situations similar to expression (8). Provided the adsorption system is well

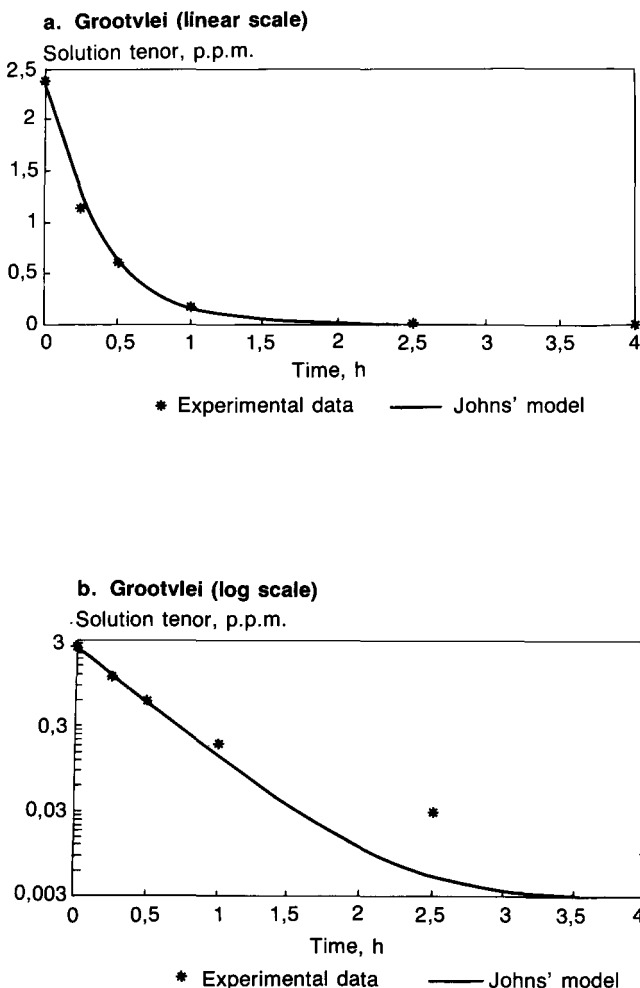


Fig. 4—Typical kinetics for batch adsorption

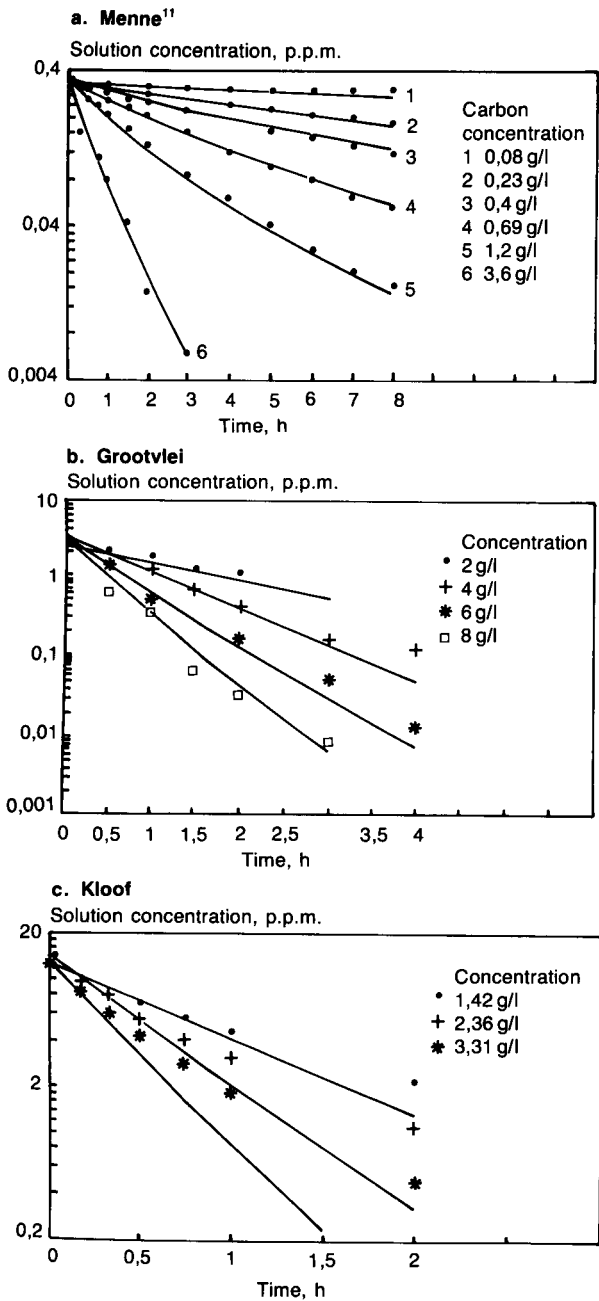


Fig. 5—Prediction of the effect of carbon concentration on kinetics

away from equilibrium, these models can predict adsorption behaviour reasonably well. This ability has been demonstrated here by the use of a very limited set of data.

- While there is some justification for the use of the simple film-diffusion model to describe adsorption in CIP systems, it is also clear that this type of model is not entirely satisfactory. As a consequence, more serious attention should be given to the more complex adsorption models that have been alluded to briefly. This is not done in the current study because of the difficult numerical and practical problems that they introduce. These will be addressed in a subsequent study.

Modelling of Leaching

The leaching of metallic species from ground ore has been the subject of investigation over many years, and much of this work has been reported in the literature. For the modelling of the leaching that occurs concurrently with adsorption in a CIP or CIL circuit, four leaching models were considered. These have been used fairly successfully in describing the leaching kinetics of gold or uranium from Witwatersrand ores.

The Mintek Expression

This is an empirical expression used by Mintek⁸ in leaching and CIL studies and has the form

$$R_1 = k_p(S - S_m)^2, \dots\dots\dots (13)$$

where R_1 is the rate at which gold is leached from the ore into the solution, S is the concentration of gold in the ore, S_m is the concentration after an infinite leaching time, and k_p is an empirical rate constant. When equation (13) is integrated for a batch configuration and S_0 is taken as the head grade of the ore,

$$S(t) = \frac{k_p S_m (S_0 - S_m)t + S_0}{1 + k_p (S_0 - S_m)t} \dots\dots\dots (14)$$

The AARL Expression

This is also an empirical expression and has the following form¹⁸ for a batch configuration:

$$R_1 = \frac{a S_0}{(a + bt)^2} \dots\dots\dots (15)$$

Here a and b are found experimentally. When equation (15) is integrated for the batch situation,

$$S(t) = S_0 \left(1 - \frac{t}{(a + bt)} \right) \dots\dots\dots (16)$$

Brittan's Rate Expression

Brittan¹⁹ derived an expression for the leaching rate by lumping the rate-limiting effect as an Arrhenius-type activation-energy barrier. As the reaction proceeds, the reactive material is leached out first, leaving behind material that is more refractory. This effect is modelled by an increase in activation energy as the leaching proceeds, i.e. the rate 'constant' decreases as leaching proceeds. The expression obtained has the form

$$R_1 = (S_0 - S_m) \exp[b_1(S_0 - S_m) - b_2] \dots\dots\dots (17)$$

Here S_m and S_0 have the same significance as before, and b_1 and b_2 are determined experimentally. This expression has no analytic integral for the batch configuration.

Rate Expression of Loveday *et al.*²⁰

Loveday *et al.* developed a model to quantify the kinetics of leaching of a low-grade uranium oxide ore. This model is based on the assumption that the rate of dissolution of individual sites is zero-order, and that there is a distribution of these zero-order constants. The Schumann distribution is used to describe the distribution of the initial zero-order constants. Loveday *et al.* obtained good fits to experimental data over a range of temperatures and particle-size distributions, establishing

that particle-size distribution has a significant effect on the estimated parameters. This effect makes this expression very suitable for modelling the effect of size distribution on leaching.

The batch expression is

$$S(t) = (S_o - S_m) \left(1 + \frac{n}{n+1} k_{\max} t \right) + S_m \quad t \leq 1/k_{\max}$$

$$S(t) = \left(\frac{S_o - S_m}{n+1} \right) \left(\frac{1}{k_{\max} t} \right)^n + S_m \quad t > \frac{1}{k_{\max}} \quad \dots (18)$$

Here, k_{\max} is the maximum zero-order rate constant, and n is the shape parameter (both obtained as parameters from the Schumann distribution).

Evaluation of the Leaching Models

Each model was evaluated by the use of 25 sets of data obtained from Anglo American, Mintek, and the Department of Chemical Engineering, University of the Witwatersrand. In these sets of data, the head grades of the ore ranged from 2,6 to 15,2 g/t with leaching times varying from 24 to 72 hours. The leaching data had been obtained from batch kinetic tests in which the ground ore was leached in either rolling bottles or stirred vessels, and the tenor of the leach solution was determined as a function of time. Typical plots of the data and the fitted points are shown in Fig. 6.

The AARL model was found to be indistinguishable from the Mintek expression, and therefore is not discussed further. In a comparison of the models, the relative error between the predicted and the actual value at each data point in each data set was considered. The average and standard deviations of the sum of the squares of these relative errors were as follows:

Loveday	0,0074 ± 0,0083
Mintek	0,043 ± 0,084
Brittan	0,10 ± 0,15.

The error for the Brittan model is seen to be twice as large as for the Mintek expression, even through the Brittan expression has three parameters while the Mintek expression has two. The sum of squared errors for the Loveday expression is almost an order of magnitude less than for the other models. What is more, the progress of leaching after protracted leaching times is better described by the Loveday model than by either of the others. It is this portion of the leaching curve that is most relevant in a CIP operation. Thus, Loveday's model is considered to be the most suitable expression of those evaluated for the modelling of gold leaching in CIP and CIL circuits.

Conclusions

Of the various models that can be used to describe the adsorption and leaching processes in CIP and CIL systems, the Loveday model appears to offer a better quantitative description of the leaching of Witwatersrand ores. However, it is felt that the Mintek expression should also be included in the simulator because it is easier to use than the Loveday expression, and provides satisfactory fits to leaching data. With regard to the adsorption model, the use of a simple film-diffusion model to describe the operation of many CIP operations appears

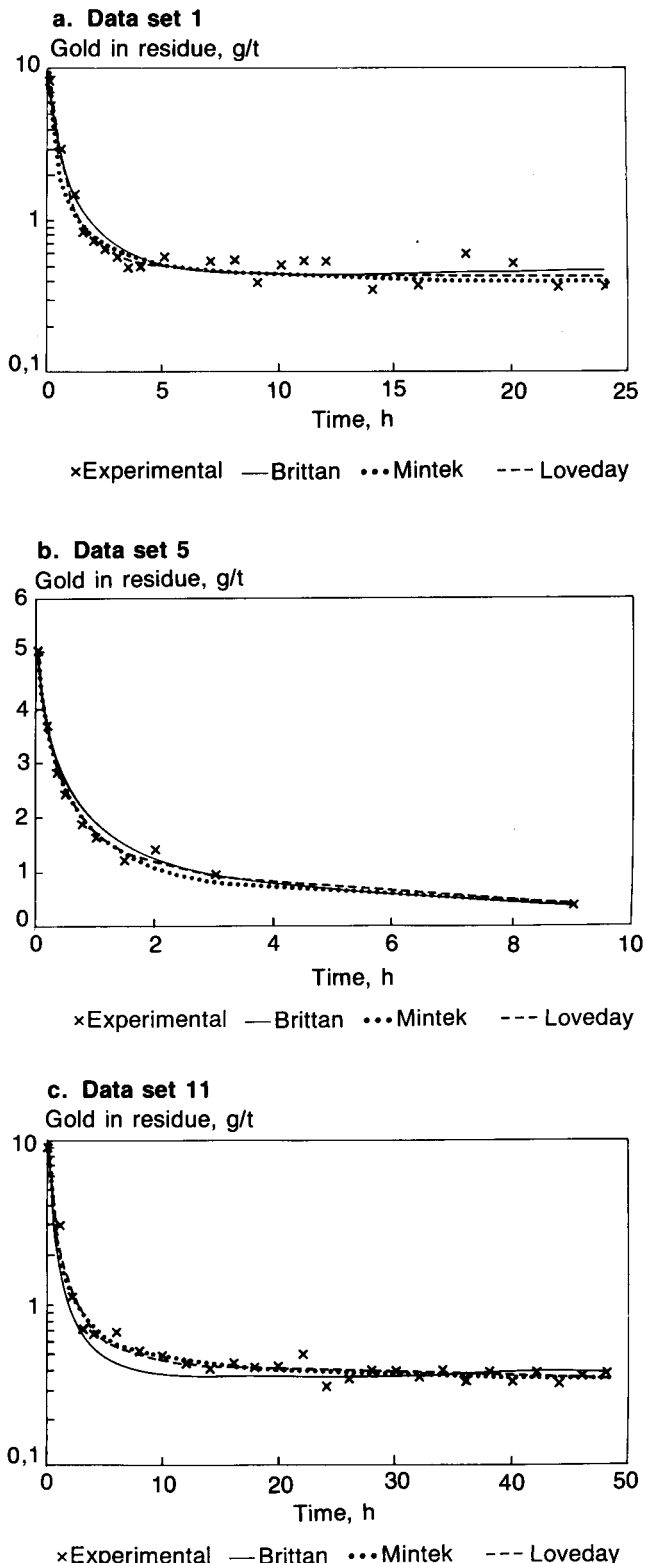


Fig. 6—Leaching models fitted to experimental results

justified. Different forms of the film-diffusion model should be provided to allow for the isotherm expression that is relevant to the adsorption system being modelled.

The manner in which these models can be incorporated in a realistic description of the complex movement of slurry and carbon in a CIP or CIL operation will be presented in Part 2 of this series of papers.

Acknowledgements

The authors gratefully acknowledge the following: Anglo American Corporation, Genmin, Mintek, and the Department of Chemical Engineering, University of the Witwatersrand for permission to use the data presented in this paper; Gold Fields of South Africa for the data provided by Kloof Gold Mine and Mintek personnel; and C. Draper, D. Loch, and J. Eklund for conducting the testwork that generated the Grootvlei data.

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Cyanide in gold processing

A Symposium on Cyanide in Gold Processing: The Next 100 Years, organized by The South African Chemical Institute, is to be held at the Holiday Inn, Sandton, on 5th and 6th November, 1990.

As 1990 is the centenary year of the use of cyanide in gold processing on the Witwatersrand, this Symposium will provide the opportunity to examine some of the milestones of the past as well as to explore innovations and new technologies with an eye to the future. The objective of the Symposium is to provide an overview of present processing methods, to bring delegates up to date with new technology, and to look to the next decade.

The programme will be structured so as to be of interest to mine managers, metallurgical-plant staff, researchers in the field, analytical chemists, process-control engineers, plant-design engineers, business analysts, economists, analytical and other engineering students, as well as to suppliers of chemicals and equipment.

Sessions on the following major topics have been arranged:

- Historical, environmental, and regulatory aspects
- Analysis of cyanides
- Leaching
- Engineering aspects
- Removal of cyanide
- Destruction of cyanide
- Carbon-in-pulp
- Ion-exchange recovery of gold.

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