The Pump-Cell Adsorption Circuit For In Pulp Application

E.J. Rogans and W.N. Cartner
Kemix (Pty) Ltd
60 Kyalami Boulevard
Kyalami Business Park
Midrand, South Africa
(+27 11) 466-2490 phone
(+27 11) 466-2190 fax

INTRODUCTION

Carbon technology has largely superseded filtration plants as the more acceptable gold recovery technology. This has, over the last two decades, provided a tremendous driving force for the development of new equipment. One of the main focus areas of this technological development is the development of efficient interstage screening systems. Several variations of external and internal screens are available, with the more recent shift away from air cleaned units to mechanically swept units. This paper discusses the development of one such mechanically swept interstage screen and how the development led to the successful implementation of a carousel type of CIP operation.

The first generation Pump-cell emerged as a consequence of the success achieved with the mechanically swept NKM screen. The idea was to modify the screen to incorporate the functions of pumping, screening and agitation in a single drive unit, the screen generating sufficient lift for interstage slurry flow so that all contactors would be at the same level. This system was further incorporated as a high intensity modular CIP contactor, i.e. low slurry residence times combined with high carbon concentrations. A discussion on the kinetic gold adsorption theory and its manipulation in the design of the pump-cell concept is discussed in a paper published in a previous Randol Conference(1).

Testwork carried out at Vaal Reefs proved the concept of the Pump-cell on a pilot plant scale(2), which resulted in the building in 1990 of the first large Pump-cell plant at West Witwatersrand Gold Mine designed to treat 340m^3 of pulp per hour and , even though the plant operated successfully with respect to gold recovery performance, a few problems were experienced with the basic engineering design(3).

The second generation Pump-cell unit successfully overcame the original design problems, and a full scale plant was installed at Vaal Reefs in late 1991. This plant was designed to treat 460m^3/hour of filtration plant residue, subsequent to the start up at Vaal Reefs another plant was built at Hartebeestfontein, which also scavenged gold from filtration plant residue. The Vaal Reefs pump-cell plant is currently being utilised to recover gold from repulped slimes dam material.

PRINCIPLES OF OPERATION

The Pump-cell combines the functions of pumping, screening and agitation in a single drive unit operating within a modular high capacity cell. This is achieved by the mechanism shown in Figure 1 with its placement in an adsorption cell shown in Figure 2. The mechanism consists of a single gear drive that combines up-pumping (impeller), screen cleaning (rotary cage sweeps screen on the outside) and agitation (hydrofoil assembly).

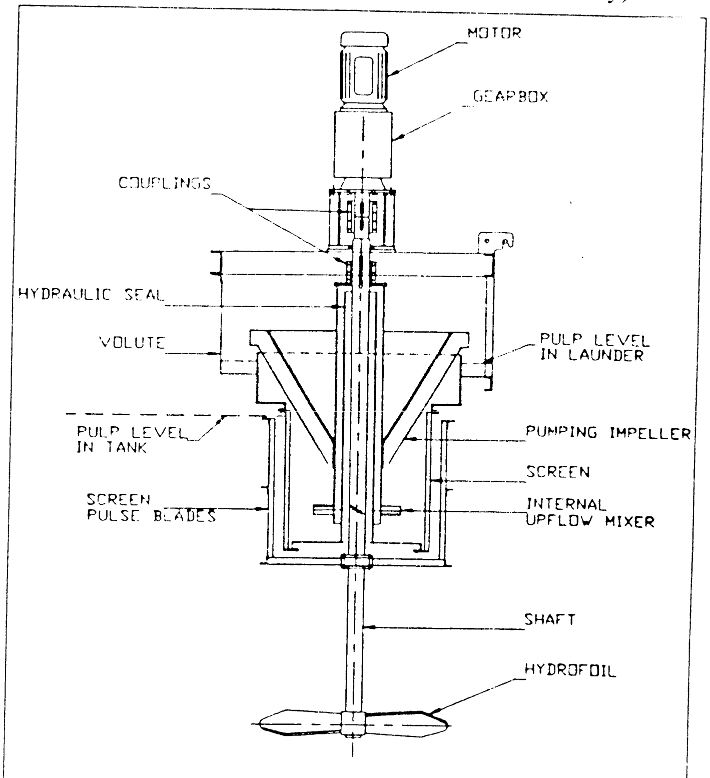

FIGURE 1.
SECTION THROUGH PUMP - CELL MECHANISM

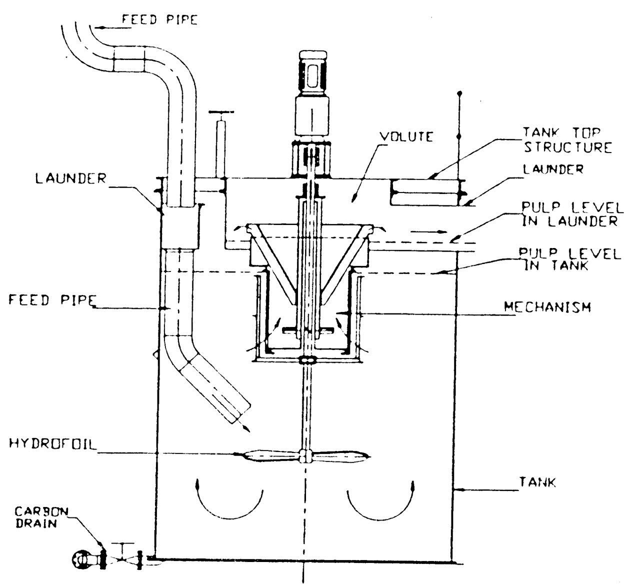

FIGURE 2.
SECTION OF SINGLE PUMP - CELL

The heart of the mechanism is a low speed rotating impeller. The impeller lifts pulp from inside the cylinder screen and deposits it in the launder above the level of the pulp in the contor outside the screen. This is achieved by the spiral vein inside the impeller that causes an upward movement of pulp through centrifugal forces. This creates a pressure drop across the screen causing flow of pulp from exterior to interior of the screen basket. The pulp in the launder is at a high enough level above the pulp in the contactor to flow into any neighbouring contactor with similar pulp levels to that in the contractor. This allows the contactors to be placed at the same elevation which facilitates the carousel mode of operation. In the carousel mode of operation, the pulp feed and tailings discharge positions are rotated in such a manner that a counter current movement of carbon is achieved without the need to physically move carbon from one contactor to another.

THE CAROUSEL MODE OF OPERATION

The recovery of gold Carbon-in-Pulp and Carbon-in-Leach plants is achieved in the adsorption circuit, which is typically a cascade circuit in which the counter-current movement of the activated carbon is achieved by pumping the pulp with carbon upstream for a period of time (usually 15 to 20 % of duration of pulp flow). Few problems that occur with this system are:-

1. Carbon Mixing

The carbon cannot be transferred as a batch, nor can all the carbon be removed from the contactor, thus back mixing of the carbon occurs continuously (short-circuiting). The carbon may reside in the adsorption circuit for extended periods of time. This results in:-

- variable carbon loadings;
- variable carbon activities, the carbon that has been in circuit for an extended period will have no activity due to extensive fouling.

This makes the adsorption circuit difficult to mange in terms of gold-on-carbon and gold-in-solution profiles and makes the performance of the plant difficult to predict. These problems are usually compensated by adding more carbon than is necessary.

2. Recirculating Pulp load

The carbon is transferred upstream the adsorption circuit by pumping the carbon with pulp. To achieve proper transfer of carbon, up to 20% of the total pulp flow is recirculated. This leads to:-

- 20% larger interstage screens;
- a loss of pulp residence time through adsorption circuit.

The pumping of the carbon results in an increase in degradation of the carbon. Also, fairly large pumps are required to carry out the carbon transfer with pulp.

3. Capital Costs

Inducing height requires extensive civil construction in cascade adsorption circuits. A carousel adsorption circuit does not require this capital expenditure to induce height.

A recent development in adsorption circuit design, is the carousel system, in which the feed and discharge points of each contactor are changed. As the carbon is not transferred, a batch of carbon spends an entire adsorption cycle in one tank. The advantages of the carousel adsorption systems over the cascade adsorption circuit counter current system are as follows:-

1. Discrete Batches Carbon

The carbon is not transferred from contactor to contactor, the advantages are:

- There is no backmixing of carbon, each contactor has its own discrete batch of carbon which spends a definite period of time in the circuit before the entire batch is removed for elution.
- Gold loadings on carbon are uniform thus exact carbon requirements are utilised;
- The activity of the carbon does not vary within each contactor;
- The gold-on-carbon and gold-in-solution profiles are easy to manage and predict
- Gold accounting is accurate.

2. No Pulp Recirculation

Since the activated carbon is not transferred from contactor to contactor, there is no pulp recirculation load. The advantages of this are:-

- No transfer pumps;
- Interstage screens are sized to suit the flow;

- Carbon in not pumped from tank to tank thus .there is no consumption of activated carbon caused by pumping.

3. Capital Costs

Adsorption contactors that are level and on the ground require minimal civils as there is no need to induce height.

4. Maintenance

A carousel adsorption circuit has level contactors thus the opening platform is level which makes maintenance easier. Maintenance and cleaning of screens is facilitated by the fact that each cell is off line an a routine basis when the tank is emptied to remove loaded carbon.

The nature of the launder arrangement of a carousel adsorption circuit determine the ease of operation of the carousel circuit. A plan view of the launder and pump-cells arrangement for a 6 stage Pump-cell plant is shown in figure 3. All the cells are level, and are fed from above via the feed launder. The valves as shown direct the flow of pulp into the desired contactor (B1 open and BB1 closed, which directs pulp into cell No1).

The mechanism lifts the pulp from the cell and deposits in the launder above the level of pulp, at a speed of 0.5 meters per second, thus the pulp flows through open gate valves I1, C1, into feed pipe A2 of the next cell. This is repeated until the pulp exits cell No 6, the last contactor, from which the pulp is directed to the tails manifold via plug valve D6 (valves AA6 and C6 are closed).

Once the carbon is loaded, cell No1 is bypassed by simply redirecting the pulp feed to the next cell by opening and closing the required valves. The cell is isolated, the entire contents removed via the carbon discharge manifold which is below the level of the bottom of the cell. The carbon discharge manifold serves all six cells, thus any cell can provide the function of load, normal and tails contactor.

COMPARATIVE SIZING

Table 1 gives an idea of the size of the Pump-cell units required for specified throughputs as shown. A solids density of 50% and a slurry residence time per contactor of 12 minutes are assumed. The table demonstrates how much smaller the volume of the pump-cell is compared to a CIP plant (with volume throughput per hour = hourly residue time).

THE PUMP-CELL PLANT INSTALLED AT HARTEBEESTFONTEIN GOLD MINE

A four stage Pump-cell plant was commissioned at the Hartebeestfontein Gold Mine in December 1993 for a total capital cost of R 5.6 million. Repulped filtration plant residue is first screened over $20m^2$ Delkor Linear screen before gravitating to the four stage pump-cell plant. Final tailings are screened over a 4 x 1,5m vibrating screen before being pumped to residue. The more important operating parameters are shown in the table below.

The carbon spends approximately 16 days in the circuit after which it is acid washed, eluted and regenerated at the low grade gold plant on a toll treatment basis. Comparatively few mechanical problems have been experienced with the pump-cell plant since commissioning, however there has been severe calcium fouling of the activated carbon due to the nature of the material being treated.

TABLE 1 - PUMP-CELL COMPARATIVE SIZES

Effective size (m^3)	Volume Throughput per hour(m^3)	Tonnage (mt/month)	Diameter of Contactor (m)	kW Motor Size
15	75	40 000	2.5	11
30	150	80 000	3.5	15
60	300	160 000	4.0	22
70	350	185 000	4.5	30
80	400	212 000	4.5	30
100	500	265 000	5.0	37
125	675	330 000	5.0	37
150	750	400 000	5.5	45

TABLE 2 - HARTEBEESTFONTEIN GOLD PLANT OPERATING PARAMETERS

Throughput	250 000 t/month
% Solids	53%
Solution grade feeding CIP	0.035 g/t
Solution grade existing CIP	<0.01 g/t
Carbon concentration	45 g/l
Carbon usage (Total)	35 to 40*g/t
Effective volume per cell	$100m^3$
Interstage Screen	Mesh covering wedge wire

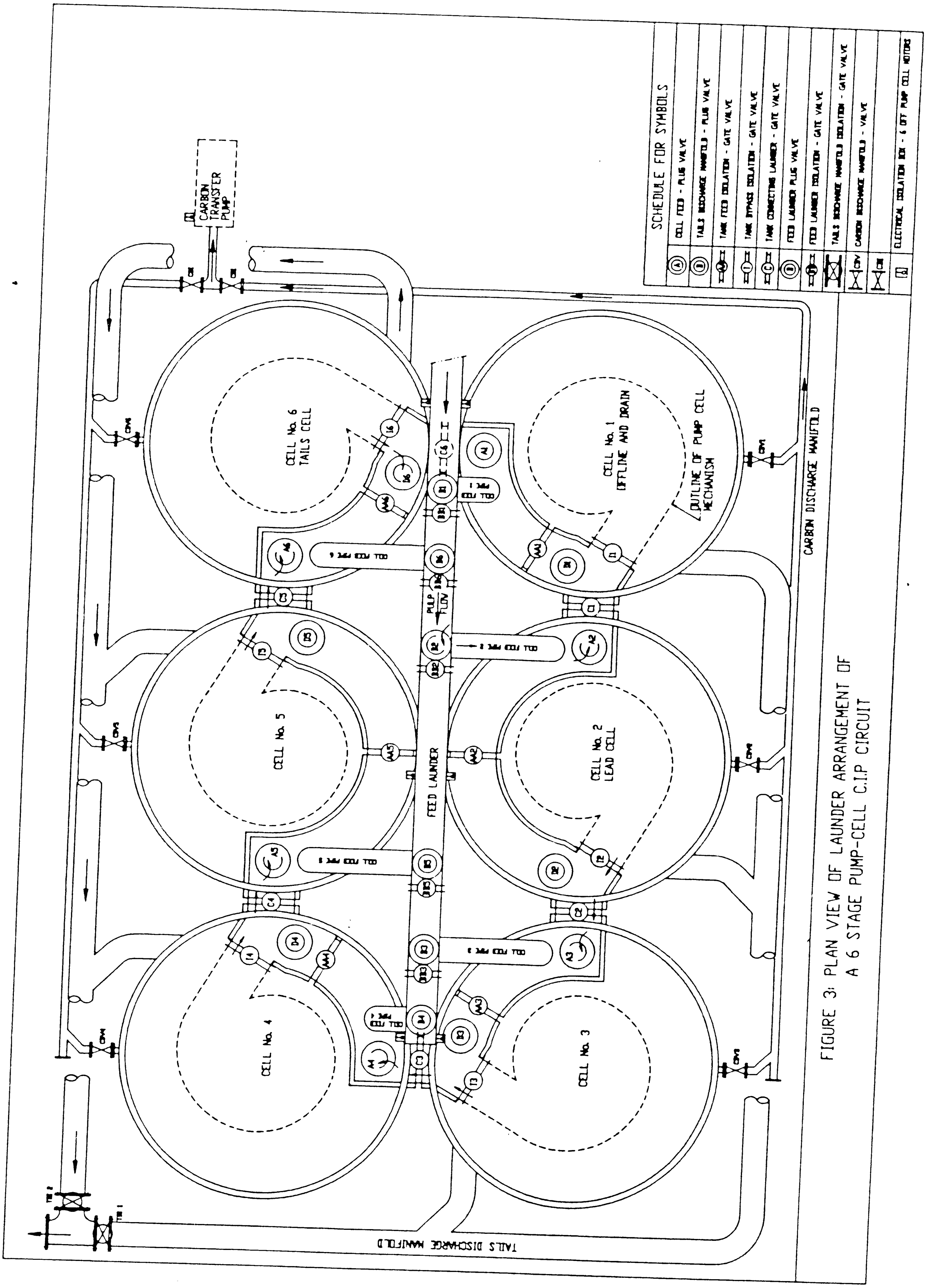

FIGURE 3: PLAN VIEW OF LAUNDER ARRANGEMENT OF A 6 STAGE PUMP-CELL C.I.P CIRCUIT

THE PUMP-CELL PLANT INSTALLED AT VAAL REEFS

The Pump-cell plant was originally a three stage plant treating filter plant residue. However, in 1993 the filtration plant was closed and the pump-cell plant rebuilt into the form it is today, to treat repulped and leached slimes dam material. The more important operating parameters are given in the table below. To this date there have been no operating problems of any importance, even though the plant is operating above design throughput.

TABLE 3 - VAAL REEFS NORTH No2 GOLD PLANT OPERATING PARAMETERS

Throughput	240 000 t/month
% Solids	50 %
Solution grade feeding CIP	0.3 to 0.5 ppm
Solution grade existing CIP	<0.01 g/t
Carbon Concentration	75 g/l to 80 g/l
Carbon usage (Total)	35 to 40 g/t
Effective volume per cell	$70m^3$
Interstage Screen	Mesh covering wedge wire

COMPARATIVE COSTING (FILTRATION PLANT STUDY)

A study was recently undertaken to compare the costs of a plant conversion to either CIL, CIP or pump-cell CIP. The conversion of an existing filter plant to carbon technology has site specific implications with regard to both capital and operating costs. In this study, a filteration plant with agitated leach pachucas was investigated, comparing the following scenario's:-

- The filtration plant and auxiliary equipment was shut, the leach circuit retained;
- Convert leach circuit to mechanical agitation and convert it to a Carbon-in-Leach plant;
- Retains air agitator leach circuit and build Carbon-in-Pulp circuit with adsorption contactors with one hour retention time;
- Retain air agitated leach circuit, and build a Carbon-in-Pulp circuit based on Pump-cell technology with a residence time of 12 minutes per cell.

The capital costs associated with the conversion of filter plants to carbon technology is influenced not only by the type of carbon plant selected, i.e. CIP or CIL, but also by the available infrastructure and the suitability of some of the existing equipment to match a selected carbon plant flow sheet. A high grade underground deposit was evaluated for this comparison. Extensive simulation test work on all three carbon technology options was carried out at the Anglo American Research Laboratories. Modeled data and relevant scale-up parameters were checked against existing operations.

The simulation testwork provided the process parameters and efficiencies required to estimate the required conditions for the three carbon technology options. Comparisons between the various carbon technologies can become complex and certain assumptions were made to simplify the comparison as follows:-

- Eight stages were selected for each of the options.
- The same overall soluble loss of $0.01gAu/m^3$ was applied to each carbon plant option.

Differences between the three options are therefore dependent on capital costs, gold loading on carbon and gold lock-up in the adsorption circuit.

The base parameters for the evaluation are given as follows:-

• Tonnage	• 2.4 million tons per annum
• Head grade	• 7.5g/t
• % Solids	• 50%
• Filter plant soluble loss	• 0.06-0.03mg/l
• Carbon plant soluble loss	• 0.01mg/l
• Operating cost saving	• 0.5-2.5 R/t
• Project life	• 15 years

The data modelling at the AARL based on the simulation testwork is given in table 4.

Using the parameters given in Table 4, Capital costs for the various options were estimated from various sources. Installation and erection costs are either based on similar installations or from other sources. The capital costs are as shown in Table 5.

Of particular interest in Table 5 is the effect of gold lock-up. The CIL option in this particular case is far less costly than the CIP option. The influence of gold lock-up, if included as part of the capital cost for evaluation purposes, makes the CIL option only marginally more attractive than the CIP option.

TABLE 4 - PARAMETERS FOR CARBON PLANT DESIGN

ITEM	UNIT	CIL	CIP	PUMP-CELL
No of stages	-	8	8	8
Carbon concentration	g/l	15	25	100
Soluble loss	mg/l	0.01	0.01	0.01
Total carbon inventory	tons	117	66	53
Gold lock-up	Kg	162	117	95
Slurry residence time per stage		*3.4hrs	1 hr	12 min.
Carbon gold loading	Kg/ton	6.7	8.5	9.1
Elution bed volume	ton	7.3	5.9	5.4

*Governed by the existing air agitated leach pachucas.

TABLE 5 - CAPITAL COST COMPARISON (R MILLION)

ITEM	CIL	CIP	PUMP-CELL
Wood chip screening	0.25	0.25	0.25
Preleach screening	0.50	0.50	0.50
Subtotal - prescreening	**0.75**	**0.75**	**0.75**
Civil	N/A	1.10	0.18
Mechanical agitators (8 of)	1.21	0.85	INC.
Interstage screens (8 of)	0.82	0.82	1.59
Transfer pumps (8 of)	0.17	0.17	INC.
Baffle plates and installation	1.00	INC.	INC.
Tanks and steelworks	-	2.77	2.01
O/h crane and installation	0.66	0.64	0.60
Subtotal - adsorption	**3.86**	**6.35**	**4.38**
Residue screening	0.50	0.50	0.50
Elution (AARL) regeneration (Rotary)	11.50	10.00	9.50
Fine carbon, water circuit	2.50	2.50	2.50
Instrumentation	1.00	1.00	1.00
Subtotal - elution	**15.50**	**15.00**	**14.50**
Subtotal - plant	**20.11**	**22.10**	**19.63**
Gold lock-up	7.29	5.27	4.28
TOTAL	**27.40**	**27.37**	**23.91**

The influence of the relatively small vessels required for the Pump-cell option, as well as the uncomplicated civil requirements, are reflected in the much lower capital requirements for the adsorption section of the Pump-cell option.

The comparison between the three carbon options shows a definite advantage when selecting the Pump-cell option. A similar advantage can be expected when selecting a carbon technology for a greenfields site. With recent trends in speeding up leach, thus reducing leach requiements, this is especially true.

The CIL option appears slightly more favourable over the CIP option. However, it must be stressed that this is site specific and does not reflect the operating flexibility that a CIP option offers.

CONCLUSIONS

The Pump-cell system is now proven carbon technology for gold operations as shown at both the Hartebeestfontein Gold Mine and Vaal Reefs Mining and Exploration Company installations.

Several recent installations have incorporated the Pump-cell, such as the Tambo Gold Plant (Barrick Corporation) in Chile which has recently been commissioned, Consolidated Murchison and West Driefontein reclaim plants currently being constructed.

It is believed that the Pump-cell has definite advantages over other types of carbon technology such as ease of operation, improved efficiencies, reduced operating costs and lower capital costs. The more recent installations should, with time, verify these claims.

ACKNOWLEDGEMENT

Some of the information in this paper has been taken from a paper to be presented at SAIMM Hidden Wealth Conference to be held in October 1996 in Johannesburg. Co-authors with John Rogans; Nic Schoeman and Alan McKintosh of the Anglo-American Corporation are gratefully acknowledged.

REFERENCES

(1) R.M. Whyte, P. Dempsey, and W. Stange. "The AAC Pump-Cell"- A novel approach to the Design and Operation of the CIP Gold Recovery Circuits - Randol Conference 1989, Sacramento.

(2) R.M. Whyte, P. Dempsey, and W. Stange. The Development and testing of the AAC "Pump-Cell" at Vaal Reefs Exploration and Mining Company. International Department Mining Conference. Innov. in Metall. Plant. Johannesburg 1990.

(3) Private Communication.

NOTE: PATENTS

COUNTRY	NUMBER
Argentina	321.462
Australia	90008/91
Brazil	9105024
Canada	2.058.532-3
Chile	1289-91
Colombia	352 762
Dom. Rep.	78856
India	947/MAS/91
Mexico	9102694
Namibia	91/0130
Peru	195049
Philippines	44230
South Africa	91/1342
Spain	9102860
U.K.	9127135.3
U.S.A.	5 238 117
U.S.S.R.	5010677.03
Zambia	48/91
Zimbabwe	16/91