

The Performance Of The AAC Pumpcell Circuits At The Gold Fields Limited Driefontein And Kloof Operations

A. Dippenaar, Plant Manager
Gold Fields Limited
Arno.Dippenaar@goldfields.com.au

M.R. Proudfoot, Metallurgist
Kemix (Pty) Ltd
mproudfoot@kemix.com

Abstract. This paper describes the AAC Pumpcell as an alternative approach to conventional counter current adsorption circuits. The Gold Fields Limited adsorption circuits on the Driefontein and Kloof Regions are discussed. Reference is made to comparing the Kloof No. 2 Carbon-In-Pulp (CIP) adsorption circuit's performance to the comparative AAC Pumpcell circuit at the Driefontein No. 2 Plant.

1. INTRODUCTION

1.1 Development Of The AAC Pumpcell Concept

During the late 1980's Anglo American Corporation of South Africa Limited (AAC), embarked on a project to develop an alternative approach to the design of the Carbon - in - Pulp (CIP) adsorption circuit [3].

Resulting from a successful pulp screening campaign conducted by AAC, the mechanically swept AAC NKM interstage screen was developed. Kemix (Pty) Ltd made a number of improvements to the AAC NKM interstage screen resulting in the development of the Mineral Processing Separating Pumping (MPS (P)) Interstage Screen. The success achieved in the development of this mechanically swept interstage screen contributed to the formation of the AAC Pumpcell concept.

The formation of the AAC Pumpcell concept was based on the supposition that improved carbon performance could be achieved by employing the carousel mode of operation. The carousel mode of operation involves keeping the carbon in a discreet batch within each contactor and rotating the pulp feed and discharge positions. As carbon is managed in a batch format, the interstage transfer of carbon and subsequent inventory balancing is eliminated. The pulp feed and tailings discharge positions are rotated in such a manner that the counter current movement of

carbon relative to pulp is simulated without physically having to pump carbon through the circuit [1], [2], [3].

The benefit associated with the carousel mode of operation is that backmixing associated with conventional counter current CIP circuits is eliminated. The interstage transfer of carbon results in backmixing, which is the dilution of the gold solution tenor. As the rate of gold adsorption is influenced by the concentration of gold in the bulk solution, the dilution of the bulk solution will negatively impact on the rate of adsorption. Hence carousel configuration can enhance the rate of adsorption relative the conventional counter current approach [1].

Coupled to the carousel configuration the AAC Pumpcell design and operating philosophy is based on the fact that the circuit is operated at increased carbon concentrations and reduced residence time relative to conventional counter current CIP circuits. As the rate of gold adsorption is influenced by the external surface area of the carbon an increase in carbon concentration will improve the rate of adsorption [1].

The first production scale AAC Pumpcell Plant was installed at the West Witwatersrand Gold Mine in 1990. Following this installation a number of engineering modifications were incorporated in the design of the second generation AAC Pumpcell Plant, which was installed at the Anglogold Ashanti Vaal River Region in 1993.

To date nineteen AAC Pumpcell circuits have been installed internationally. There is no standard AAC Pumpcell design, each application is evaluated with the aim of optimizing the active volume of the cell, the number of the adsorption stages required, the carbon concentration and the carbon elution rate (loading cycle). Of the AAC Pumpcell plants installed to date, the active volume of the cells range from 20 m³ to 200 m³ providing an approximate residence time of 15 minutes per stage. The number of stages installed typically varies from six stages for lower grade operations (<6 g/t Au) to eight stages for the higher grade operations (> 6 g/t Au). Carbon concentrations vary between 22 - 60 g/l. Depending on the application, the carbon elution rate or the loading cycle involves the daily movement of carbon on the higher grade operations, to the movement of carbon every alternative day on the lower grade operations.

1.2 AAC Pumpcell Description

The AAC Pumpcell is a carbon adsorption circuit which employs an alternative carbon management philosophy to that typically associated with counter current CIP circuits. This concept involves managing carbon in a batch format and operating the circuit in the carousel mode.

The AAC Pumpcell circuit consists of a number of tanks or cells, Pumpcell mechanism, feed launder, loaded carbon manifold, internal launder and a series of gate and plug valves.

The Pumpcell mechanism has a single drive unit which combines the functions of pumping, screen cleaning and agitation.

The Pumping Impeller, see Figure 1: AAC Pumpcell Mechanism, is designed to handle high flow rates at a low tip speed and operates in a stable manner over a wide range of flow conditions. This impeller develops a head in the open volute which is connected to the Pumpcell internal launder system. The head generated is sufficient to overcome launder losses and facilitates the flow of pulp to the next cell.

The Pitch Blade Turbine ensures that the pulp contained within the screen is maintained in a fully suspended state, even in the event of no pulp flow through the mechanism. The AAC Pumpcell mechanism can therefore operate at reduced pulp flow rates without the settling of pulp occurring inside the cylindrical screen. In the event of a plant stoppage, the pulp contained inside the screen may settle, but will be re-suspended when the drive unit is restarted.

The Rotating Cage sets up a pulse and sweeping action around the perimeter of the screen. This reduces the possibility of carbon or grit, pegging the screen aperture, which in turn ensures the pulp flow rate through the screen is maintained.

The Screen is manufactured from stainless steel wedgewire. A Hydraulic Seal is attached to the bottom of the screen and surrounds the shaft. The seal is in a static pipe, which passes through the centre of the Pumping Impeller and extends beyond the pulp operating level.

The feed launder, discharge manifold and internal launder arrangements are integral to the carousel mode of operation. The individual cells are connected by an external launder. The feed launder and discharge manifold allow any cell to be either the head or tail cell in the carousel sequence. Feed pulp is directed to the head cell while residue pulp is directed out of the circuit via the residue manifold. Once the desired gold on carbon loadings have been achieved in the head cell, this cell gets isolated and feed pulp and is directed to the next cell in the carousel sequence. The entire content of the head cell is screened to separate the loaded carbon from the pulp. The screened pulp is returned to the feed launder. The loaded carbon is eluted and regenerated prior to returning to the circuit. The regenerated carbon is added to the isolated cell which gets brought back on line as the new tail cell in the carousel sequence.

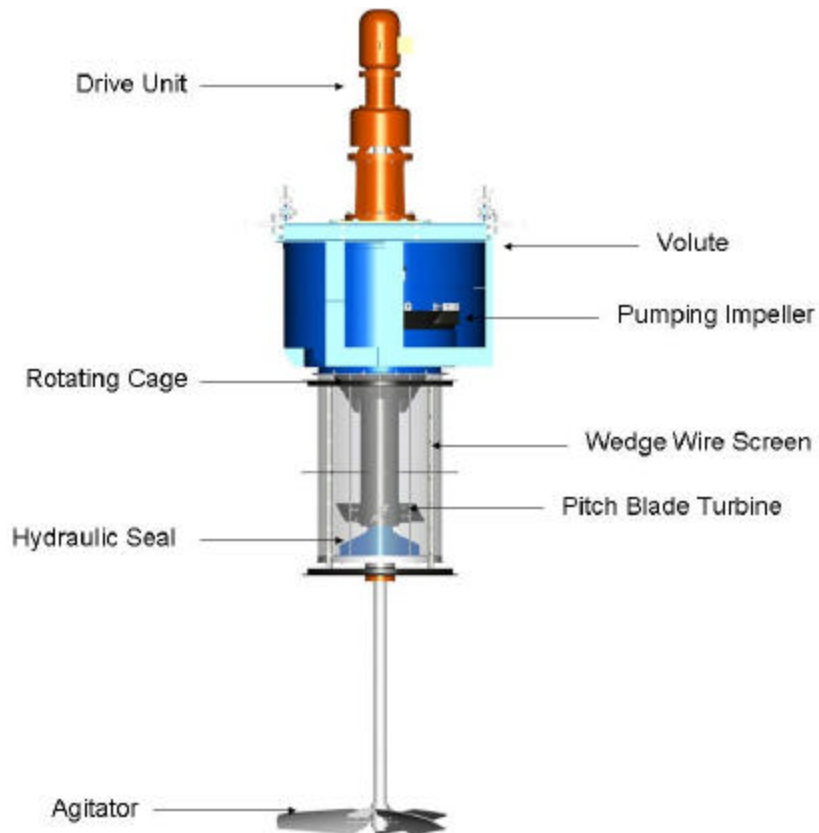


Figure 1: AAC Pumpcell Mechanism

1.3 Benefits Associated with the AAC Pumpcell

The most significant benefit of the AAC Pumpcell is the elimination of backmixing [2]. As carbon is managed in a batch format the interstage transfer of carbon is not required. This contributes to maximising the loaded carbon grade, in that upgrade ratios achievable in AAC Pumpcell are higher relative to that achieved on comparable CIP or Carbon – In – Leach (CIL) circuit. The upgrade ratio is the ratio of gold in solution feed to the adsorption circuit to gold on loaded carbon. A higher upgrade ratio means that carbon in the adsorption circuit is able to load gold to higher loadings, thus less carbon is required.

Maximising upgrade ratio's reduces the carbon inventory and number of elutions required. Elution costs are based on "per ton of carbon", the cost to elute activated carbon will not change irrespective of gold loading values on carbon. The result of increasing upgrade ratios reduces the amount of carbon

required to adsorb the gold. Less elution requirements result in a cost saving [1].

Carbon management in an AAC Pumpcell circuit is simplified as the carbon is managed in a batch format. As the interstage transfer of carbon is not required, the balancing of the carbon inventory along the adsorption circuit is not necessary.

The batched carbon management system simplifies the control of gold loading profiles. In the event of returning a poorly eluted batch of carbon to the tail of the AAC Pumpcell circuit, this batch can be discreetly managed through the circuit or discreetly removed and returned to elution. In a counter current operation the poorly eluted batch of carbon will be diluted with the carbon in the circuit resulting in a negative impact on the gold loading profiles.

2. DESCRIPTION OF DRIEFONTEIN AND KLOOF OPERATIONS

The *Driefontein Gold Mine* boasts an underground reserve base of 23.1 million ounces and approximately 0.51 million ounces

located on surface. Three gold plants with varying design capacities are currently employed to treat these reserves. The plants utilise SAG milling, high rate thickening, air agitated leaching, CIP (AAC Pumpcells) and a Zadra Elution circuit as a central toll treatment facility. Total mill capacity is 550 000 ton per month delivering an actual gold production ranging between 3 000 to 3 300 kg per month.

The No. 1 Plant treats 230 000 ton per month of underground ore produced from four shafts

at an average head grade of 9 - 11 grams per ton (Au). The No. 2 Plant treats a fifty percent blend of underground ore and screened / upgraded rock dump material at a rate of 200 000 ton per month having an average head grade of 4 - 4.5 grams per ton (Au). The No. 3 Plant treats rock dump material at a rate of 120 000 ton per month having an average head grade of 0.9 - 1.1 grams per ton (Au). The described Driefontein Gold Mines parameters are displayed in Table 1: Driefontein design parameters.

Table 1: Driefontein design parameters

Driefontein			
	No. 1 Plant	No. 2 Plant	No. 3 Plant
Tons Milled (ton / month)	230 000	200 000	120 000
Ore Type	Underground	Underground and Surface	Surface
Head Grade (g/t)	9 - 11	4 – 4.5	0.9 - 1.1
Gold Produced (kg/month)	2 000 – 2 300	800 – 1 000	100 - 130
Gold Produced (oz '000's/month)	71 - 81	28 – 35	3.5 - 4.6

Table 2: Kloof design parameters

Kloof			
	No. 1 Plant	No. 2 Plant	No. 3 Plant¹
Tons Milled (ton / month)	180 000	125 000	112 000
Ore Type	Underground	Underground and Surface	Surface
Head Grade (g/t)	9 - 10	5 - 6	0.7
Gold Produced (kg/month)	1 620 – 1 800	550 - 660	50 - 100
Gold Produced (oz '000's /month)	57 - 63	19 - 23	1.8 - 3.6

The *Kloof Gold Mine* generates between 2 400 to 2 700 kg of gold per month from a reserve base of 26.9 million ounces of gold underground and 0.349 million ounces of surface reserve. Until recently surface and underground resources were treated by three plants utilising different comminution strategies. The No. 1 Plant is dedicated to treating 180 000 ton per month of underground ore through a conventional three stage crushing and two stage milling circuit. The milling circuit consists of two Primary Rod mills and four Secondary Pebble Mills. The downstream processes consists of conventional thickening, air agitated leaching, and an AAC Pumpcell circuit. A central AARL elution facility is situated at the No. 2 Plant. The No. 2 Plant utilises two closed circuit

SAG mills, conventional thickening, leach and a conventional CIP circuit to process 120 000 – 130 000 tons per month of underground and surface material to produce 550 – 660 kg per month of gold from a head grade of 5 – 6 grams per ton (Au). The No. 3 Plant, until it's recent closure, treated a combination of underground and surface material at a marginal grade utilising a conventional three stage crusher plant, two stage primary ball mills and secondary pebble mills, conventional pulp thickening, air agitated leach Pachucas and a CIP circuit (AAC Pumpcell). The No. 3 Plant used to process 112 000 ton per month at an average head grade of 0.7 gram per ton (Au) to produce 50 – 100 kg per month of gold. The closure of No. 3 Plant occurred during the 2004/5 financial year due the negative impact

¹ No. 3 Plant closure during 2005 financial year.

an escalation in dump screening and transportation costs had on the margins and rendering the operation non-economical. The described Kloof Gold Mines parameters are displayed in Table 2: Kloof design parameters.

3. COMPARISON BETWEEN THE KLOOF, DRIEFONTEIN AND BEATRIX OPERATIONS

The stated benefit of the AAC Pumpcell is the ability to maximise upgrade ratios thus delivering optimal gold on carbon loadings without sacrificing solution residue tenor. The comparative plant performances for the Driefontein, Kloof and Beatrix gold plants are presented in Table 4: Comparative plant performances – operational (2005). The upgrade ratios achieved for the Driefontein No. 2 Plant and the Kloof No. 1 Plant are 1 594 and 1 462 respectively. The upgrade ratios achieved at the AAC Pumpcell circuits are significantly higher than that achieved at the CIP circuits. Figure 2 and Figure 3, depict the average carbon and solution profiles maintained at the Driefontein No. 2 Plant and the Kloof No. 1 Plant. From these graphs it is evident that high loaded carbon grades are achieved while maintaining solution residue tenors of below 0.010 mg/l Au.

The AAC Pumpcell circuits at the Driefontein No. 2 and the Kloof No. 1 are a 6 stage x 100m³ and an 8 stage x 100m³ circuits respectively. The notable difference between the two operations is that the Kloof No. 1 plant operates at a higher solution feed tender of 10.2 mg/l Au compared to 5.0 mg/l Au processed at the Driefontein No. 2 Plant. The higher head grade experienced at the Kloof No. 1 Plant necessitates the installation of an eight stage circuit. Due to stage efficiencies averaging at 60 %, the Kloof No. 1 AAC Pumpcell achieves acceptable residue solution values after stages six and seven.

The stage efficiencies achieved on the head cell of the Driefontein No. 2 Plant and the Kloof No. 1 Plant are 63% and 60% respectively, while stage efficiency in excess of 60% are achieved in the second stage of the carousel circuit.

Reviewing the data in Table 4, it is evident that the solution residue tenor exiting the AAC Pumpcell operations is consistently lower than 0.01 mg/l Au. The solution residues exiting the

Kloof No. 2 and Beatrix CIP circuits are in excess of 0.02 mg/l Au. In order to optimize the solution residue tenor exiting an adsorption circuit, both the gold on carbon loadings and activity of the regenerated carbon must be consistently maintained at acceptable levels. The regenerated carbon exiting the Driefontein Zadra elution and regeneration circuit consequently yields gold on carbon loadings less than 50 g/t Au and activities of 85% (relative to virgin carbon).

For purposes of comparing a CIP and AAC Pumpcell adsorption circuit, the Driefontein No. 2 AAC Pumpcell and the Kloof No. 2 CIP circuit are used as examples. The solution profiles for the two operations are depicted in. The stage efficiencies achieved in the AAC Pumpcell circuit are significantly higher than those achieved on CIP circuit resulting in a solution residue of 0.008 mg/l and 0.022 mg/l respectively.

The gold on carbon loadings for these operations is depicted in Figure 5: Conventional CIP vs. AAC Pumpcell carbon profiles. The gold on carbon loading and associated upgrade ratios achieved at the Driefontein No. 2 Plant (AAC Pumpcell) and the Kloof No. 2 (CIP) are 7 172 g/t Au at an upgrade ratio of 1 594 and 6 485 g/t Au at an upgrade ratio of 1 013 respectively. The AAC Pumpcell achieved a higher gold on carbon loading despite the fact that feed solution tenor to the CIP circuit is higher at 6.4 mg/l compared to the 5.0 mg/l for the AAC Pumpcell circuit.

85% of the gold contained in the AAC Pumpcell circuit is loaded on the 8 tons of carbon contained on the first two adsorption stages. Each adsorption stage in this AAC Pumpcell circuit contains 4 tons of carbon. In the comparative CIP circuit 65% of the gold in inventory is loaded on 10 tons of carbon. The comparative carbon inventory for the Kloof No. 2 Plants CIP circuit and the Driefontein No. 2 Plants AAC Pumpcell circuit is 38 tons and 21 tons respectively. The ability of the AAC Pumpcell to maximise upgrade ratios and reduce carbon inventories is substantiated by this example.

In the example comparing the CIP and the AAC Pumpcell, it is noted that the AAC Pumpcell delivered improved solution residue tenor, higher upgrade ratio and associated gold on carbon loadings while employing two

less adsorption stages and having a reduced total carbon inventory.

It must be noted that the operating philosophy of the AAC Pumpcells at Driefontein and Kloof involve minimising gold lock up by following a defined elution frequency. At times these

circuits have been operated with the view of maximising gold loadings. For example, the Kloof No. 1 Plant has achieved consistent gold on carbon loadings of 22 000 – 25 000 g/t Au from a solution feed tenor of 10 mg/l Au without sacrificing solution residue tenor.

Table 3: Comparative plant performances - design

	Drie- fontein No. 1	Drie- fontein No. 2	Drie- fontein No. 3	Kloof No. 1	Kloof No. 2	Kloof No. 3	Beatrix
Throughput (t/month)	230 000	200 000	120 000	180 000	125 000	112 000	85 000
Head Grade (g/t Au)	9 - 10	4 - 5	0.9 – 1.1	9 - 10	5 - 6	0.5 – 1.0	5
Dissolution (%)	98	97	95	98	98	92	96
Adsorption Circuit	8 Stage 125m ³ AAC Pumpcell	6 Stage 100m ³ AAC Pumpcell	6 Stage 80m ³ AAC Pumpcell	8 Stage 100m ³ AAC Pumpcell	8 Stage 220 m ³ CIP Circuit	6 Stage 70m ³ AAC Pumpcell	6 Stage 500m ³ CIP Circuit
Elution Facility	Zadra (10 ton column)			AARL (4 ton column)			Zadra (10 ton)

Table 4: Comparative plant performances – operational (2005)

	Drie- fontein No. 1	Drie- fontein No. 2	Drie- fontein No. 3	Kloof No. 1	Kloof No. 2	Kloof No. 3	Beatrix
Solution Feed Tenor (mg/l Au)	8.5	4.5	0.6 – 1.5	10.2	6.4	0.7	5.5
Solution Residue Tenor (mg/l Au)	0.008	0.008	0.005	0.009	0.022	0.004	0.020
Loaded Carbon Grade (g/t) Au	10 617	7 172	1500- 3500	14 920	6 485	1 500	4 400
Upgrade Ratio	1 251	1 594	2333	1 462	1 013	2 143	800
Carbon Concentration (g/l) C	45	35	25	60	21	22	14
Carbon Inventory (tons)	56	21	13	48	38	10 - 12	25
Carbon Consumption (g/t)	25			35			50
Operating Cost R/t C smelted)	2 450			3 250			

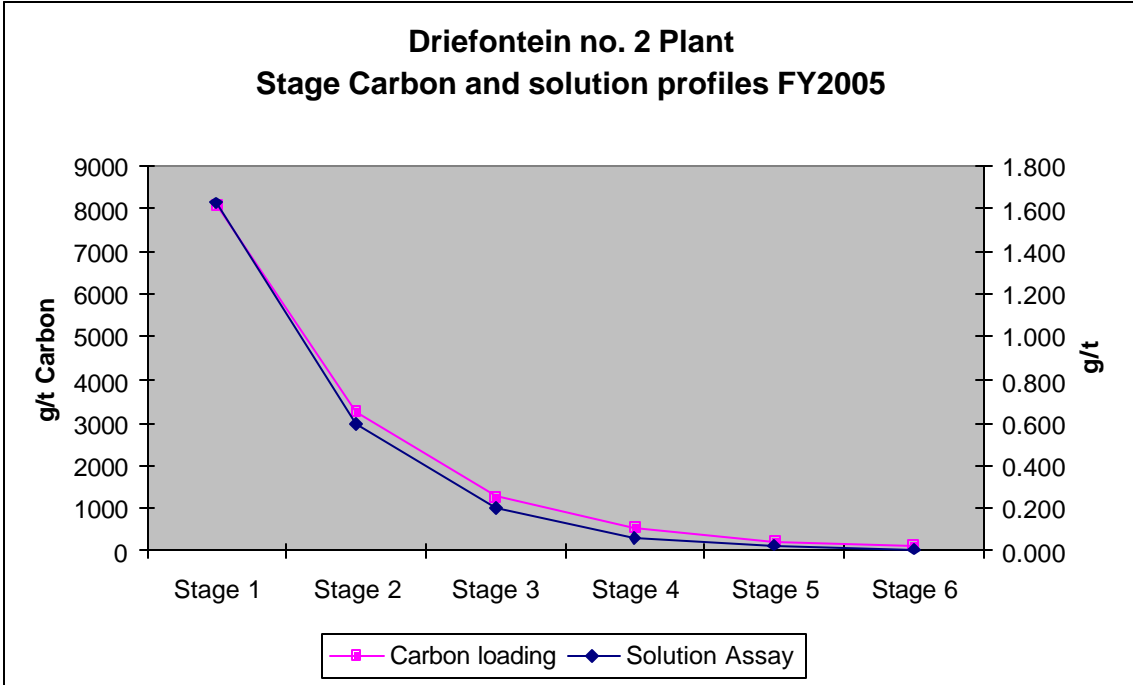


Figure 2: Driefontein No. 2 plant carbon and solution profiles

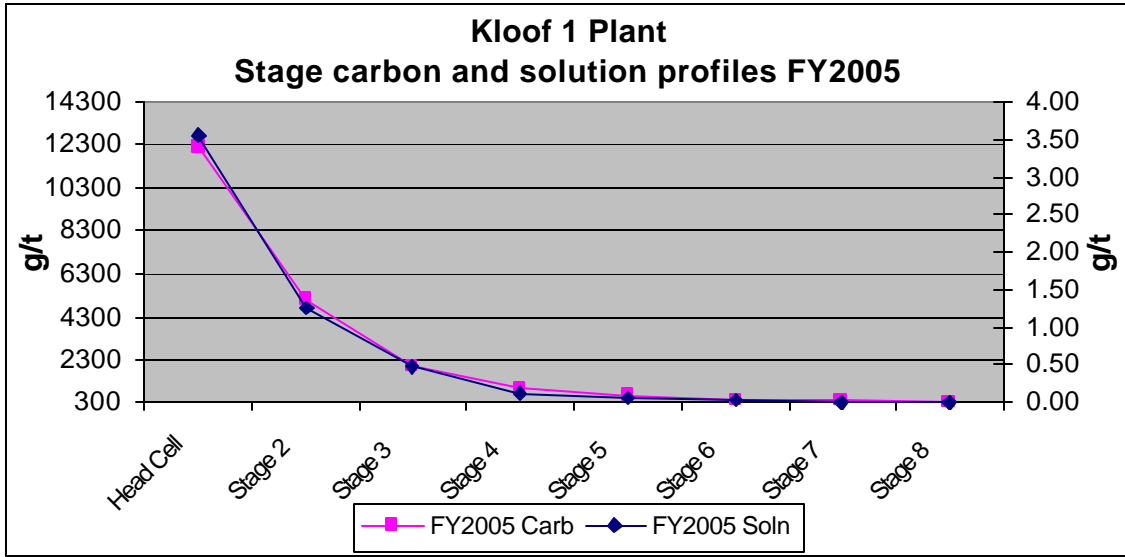


Figure 3: Kloof No. 1 plant carbon and solution profiles

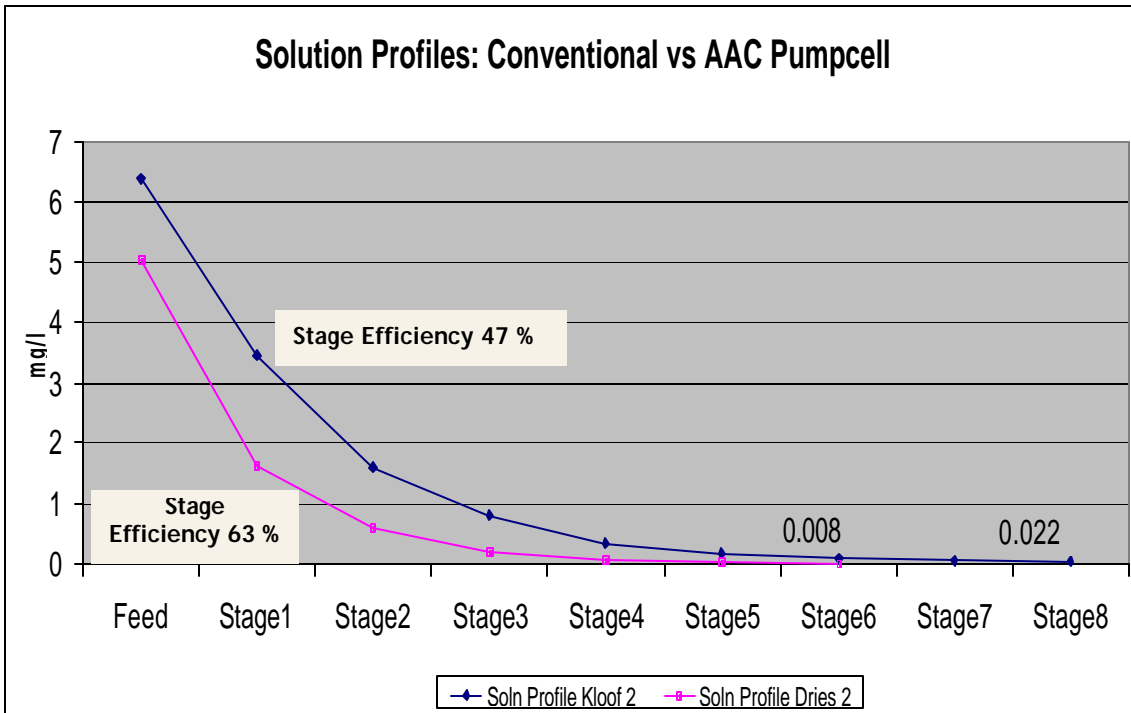


Figure 4: Conventional CIP vs. AAC Pumpcell solution profiles

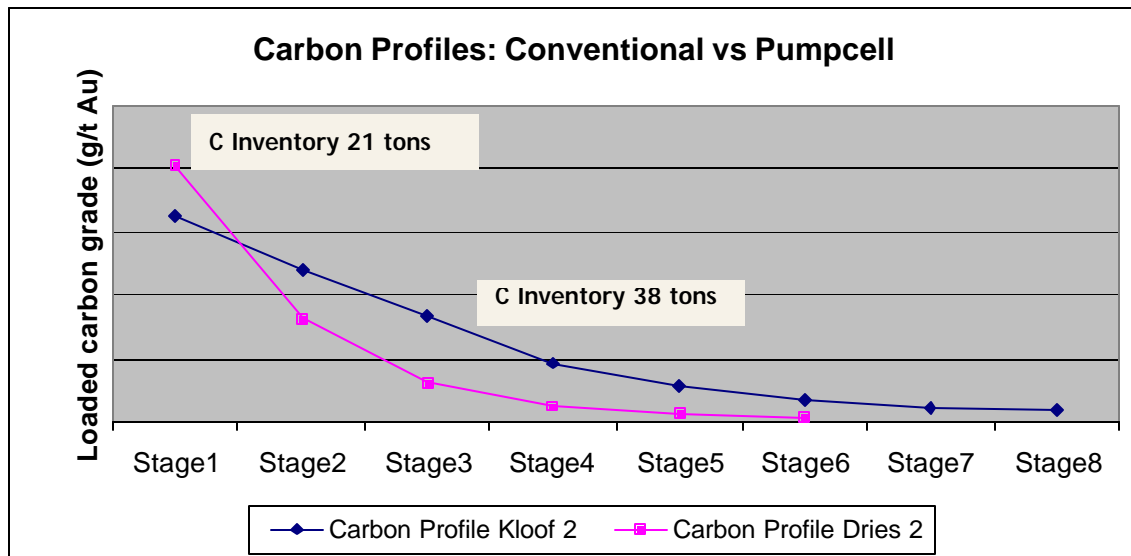


Figure 5: Conventional CIP vs. AAC Pumpcell carbon profiles

4. EXPERIENCES

The draining cycle on the carousel plant involves the batch transfer of an inventory of loaded carbon from the head cell and the subsequent carousel sequencing resulting in that cell becoming the tail cell in the sequence. Careful management of this

transition is essential, as any residual lower activity loaded carbon remaining in the head cell will combine with the higher activity regenerated or virgin carbon. As there is relationship between the solution tenor and the carbon gold loading, this 'contamination or dilution' will result in decreased stage efficiencies, thus negatively impacting on dissolved gold losses. It is therefore

imperative to ensure that the head cell is drained thoroughly, by either manual cleaning and hosing the flat bottomed tank or through design i.e. installing sloped bottoms with water sprays. The installation of sloped bottoms has become common practice on all the recent AAC Pumpcell installations.

Irregular AAC Pumpcell solution residue profiles and non-typical carbon profiles have been found to be directly attributed to either inefficiencies in carbon elution and regeneration or simply leakage or short circuiting from the head cell to the tail cell. The short circuiting occurred as a result of the gate valve between the head and tail cell not sealing completely. This observable fact is highlighted as the carousel principle relies on the opening and closing of gate valves to affect the carousel sequencing. As any form of leakage through the gate valves negatively impacts on the overall performance of the AAC Pumpcell circuit this occurrence required remedial action. The gate valve design incorporates a cam arrangement which ensures that the gate valve spade is compressed against the rubber lined sealing surface of the valve. This cam arrangement can be adjusted during operation if it is noted that a gate valve is leaking. A further design initiative has been to allow for the installation of a double gate valve arrangement between cells. This allows for a dead zone between the head and tail cell which effectively eliminates the possibility of the occurrence of short circuiting between the head and tail cell.

A further initiative to detect and prevent pulp short circuiting was the installation of weep valves on the AAC Pumpcell feed pipes. This facility allows the operator to detect if feed material is inadvertently being directed to the incorrect Pumpcell in the carousel sequence. The directing of the feed material to the incorrect Pumpcell, results in the bypassing of a number of stages which will negatively impact on the efficiency of the adsorption circuit.

The operating density of pulp in the adsorption circuit has an effect on the distribution of the carbon within the contactor and ultimately impacts on the efficiency of the circuit. On the operations described in this paper the typical pulp density in the adsorption circuit is 1.350 – 1.550 t/m³. When operating outside this density window the

carbon tends to sink or float. Operations that are not able to operate at a pulp density of at least 1.400 t/m³ tend to experience carbon distribution problems. The carbon tends to sink resulting in reduced carbon pulp content.

Agitation intensity in an adsorption circuit is expressed as power adsorbed (Watts) per cubic metre of pulp. A typical CIP plants adsorbed power is 20 – 30 W/m³ while the adsorbed power in an AAC Pumpcell is in the 40 – 55 W/m³ range [1]. This allows the AAC Pumpcell circuit to operate under a wider density range than the comparative CIP circuit.

5. CONCLUSION

The Gold fields operations highlighted in this paper have been able to achieve optimal results from their adsorption circuits. Although AAC Pumpcell technology does offer certain benefits when compared to conventional CIP or CIL operations, it is the application of this technology and the development and implementation of good operational practices that have contributed to the results displayed.

6. ACKNOWLEDGEMENTS

The authors would like to thank all those that contributed to this paper, namely the Gold Fields personnel of the Driefontein and Kloof regions and Kemix Pty Ltd. The authors would also like to thank Gold Fields Limited for permission to publish this paper.

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