The West Driefontein reclamation carbon-in-pulp plant; pilot plant testwork, design, commissioning and optimization

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Synopsis

Driefontein Consolidated Limited has a proud history in the South African gold mining industry dating back to March 1945 with the formation of the West Driefontein Gold Mining Company. The reclamation gold plant at West Driefontein was originally built as a uranium recovery plant in 1970. With the collapse of the uranium oxide yellow cake market, the uranium plant was closed in 1988 and successfully converted into a gold plant, recovering gold from repulped tailings dams[1].

The West Driefontein Reclaim plant utilized milling, leaching, conventional rotary vacuum filtration and cementation to recover the gold at a rate of 200,000 dry tons per month. The No. 1 tailings dam (at a head grade of 0.8 Au g/t) began to near the end of its life during 1996, and the next slimes dams to be treated, the No. 2 tailings dam (at a lower head grade of 0.56 Au g/t) was found too marginal for reprocessing using the filtration technology.

Alternate technologies were investigated, particularly the carbon-in-pulp (CIP) plant based on the Anglo-American Corporation (AAC) pump-cell technology at the Vaal Reefs Exploration and Mining Company's East gold plant which was operating profitably at lower head grades[2]. The AAC pump-cell technology is based on the carousel mode of operation[2].

The suitability of CIP technology for the West Driefontein Reclaim plant was investigated using a pilot plant pump-cell supplied by Kemix

The data gathered were utilized in sizing a full scale AAC pump-cell plant. This plant was motivated, built and commissioned on the 22nd of November 1996. Incorporating 6 eighty cubic metre AAC pump-cells. The West Driefontein Reclaim plant initially treated repulped slimes dam material. A subsequent change of feed material to current arisings (from the main gold plant) occurred in 1997 in order to convert mills for waste rock treatment. Currently the reclaim plant treats a combination of current arisings and waste rock (milled at the reclaim site).

The new CIP plant replaced twenty-seven rotary vacuum filters. A comparison between the filters and CIP in terms of operating costs was undertaken, as well as a performance analysis of the CIP plant to determine its flexibility in terms of variation of the throughput, pulp density, gold input, leaching efficiency prior to CIP, and the rate of carbon movement.

CIP pilot plant

The pilot plant test work was carried out utilizing a 1.7 m^3 pump-cell. The pilot plant testwork indicated the following:

- The carbon-in-pulp effectively recovered gold from the West Driefontein repulped slimes dam material
- Significant amounts of wood fibre necessitated the upgrading of pre-screening
- Extra gold dissolution of approximately 10% would be achieved
- Organic and inorganic poisoning did not extensively, nor irreversibly, foul the activated carbon. However, the activated carbon would require regeneration (thermally and acid washing).

Computer simulation

The results obtained from the pilot plant testwork were used for computer simulation. Various input parameters were utilized, such as throughput, pulp density, carbon loading and the required tailings value for the proposed full-scale AAC pump-cell plant.

Based on the above inputs, the computer simulation provided the following outputs:

- A six-stage AAC pump-cell plant
- An average adsorption of 55% per stage
- An overall adsorption of 99.4%
- A pump-cell will be on line for 12 days (thus, for six cells, the cycle is two days)
- A required carbon concentration of 28 g/l (2.1 tons of carbon per pump-cell)
- The gold lock-up in the worst case will be 8.26 kg for the AAC pump-cell plant.

A preliminary economic study indicated a monthly profitability of at least R700,000 with

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a payback period of about 14 months. A capital expenditure forecast of R8 million was proposed and, after approval, the full-scale plant was designed and built by Kemix (Pty) Ltd.

Due to the nature of the site (indoors) and the extra residue pumping requirements, the civil costs were higher than expected. The indoor site was chosen to utilize the existing overhead crane structures. The AAC pump-cell plant, due to its small foot-print, suited the indoor location, thus becoming an anomaly in the South African gold mining industry—an indoor CIP plant!

The full-scale six-stage carbon-in-pulp (CIP) plant was commissioned on the 22nd of November 1996. The CIP plant comprises two 12 m^2 Delkor linear screens, six 80 m^3 AAC pump-cells, two Vibramech vibrating carbon screens and various pumps.

The leached slurry gravitates from the tail leach tank onto the two linear screens that remove the oversize wood fibre and grit present in the pulp. The linear screen underflow is pumped, via a two-stage automatic sampler, to the carousel AAC pump-cell plant where gold adsorption onto activated carbon takes place. Once the head cell carbon has achieved a pre-determined gold loading value, the head cell is drained.

The entire contents of the cell are pumped (via a recessed impeller pump) over a vibrating screen to separate the loaded carbon from the slurry. The loaded carbon (overflow) is bagged and tagged before being sent to Leeudoorn Gold Mine—a division of Kloof Gold Mining Company (Leeudoorn) where it is eluted and then thermally regenerated. The carbon washing screen's underflow is pumped back into the head pump-cell.

The pump-cell tails gravitate onto the second vibrating screen to catch any carbon that may have escaped from the circuit. The underflow is pumped to tailings.

Performance analysis

After six months of operation, a comparison of operating costs for the six-stage AAC pump-cell plant to what had been replaced—twenty-seven conventional rotary vacuum filters—was undertaken. Operational data was also assimilated over the six-month period in order to perform an analysis of the CIP plant.

Comparison of CIP to conventional filtration technology

A comparison of the carbon-in-pulp (CIP) technology with the conventional rotary vacuum filtration technology is given in Table I.

The data are for the period 14th of August 1996 to the 21st of November 1996 for the filter plant, and 22nd of November 1996 to the 9th of June 1997 for the CIP plant. The values presented are averages for those periods.

For the period of analysis, the CIP plant (although having a higher feed total gold) reduced the residue total gold losses by 18.2 per cent (which equates to 0.059 Au g/t) which for 200,000 dry tons per month equates to 11.8 kg of gold per month.

The recovery of gold for the CIP plant was higher by 32.4 per cent (from 37 to 49). The residue dissolved gold values for the CIP were reduced by 52 per cent (from 0.027 to 0.013 Au mg/l). The operating costs were also reduced by 55 per cent from (R6.0/t to R2.7/t). This justified the conversion of the filter plant to CIP technology.

Table I

Comparison of conventional filtration with CIP technology

Parameter		Filtration technology	CIP technology	Increase (–) / Decrease
Feed total gold	Au g/t	0.517	0.525	1.5%
Residue total gold	Au g/t	0.325	0.266	–18.2%
Residue undissolved gold	Au g/t	0.297	0.253	–14.8%
Residue dissolved gold	Au mg/l	0.027	0.013	–51.9%
Recovery	%	37	49	32.4%
Operating expense (OPEX)	R/t	6.0	2.7	–55.0%

CIP performance analysis and optimization

A performance analysis was carried out on the CIP plant, covering the period from 22nd November 1996 (start-up) to 9th June 1997. The performance of the CIP plant is evaluated in terms of the effects of variation of the following parameters:

- Ore throughput
- Feed pulp density
- Feed total gold
- Leaching efficiency prior to CIP
- The rate of carbon movement.

The loaded activated carbon is eluted off-site at Leeudoorn gold plant. The amount of carbon eluted at Leeudoorn was found to be a constraint, being limited to two batches per week. Thus, the rate of carbon movement was not a variable during the performance analysis.

The effect of the above parameters on each other, on total gold and undissolved gold in residue, and on carbon concentration and gold loading were evaluated for the analysis period.

Effect of variation of throughput of ore

The AAC pump-cell CIP plant was designed to treat 200,000 t/month (average of 6,700 t/day) of tailings dam material. The throughput varied from 700 to 7,900 t/day with a mean of 5,600 t/day. The maximum throughput of 7,900 t/day equates to 237,000 t/month, almost 20% higher than design.

For the period of analysis two graphs were plotted. The first, Figure 1, shows the effect of lower than designed throughput (less than 6,700 t/day) and the second, Figure 2, shows the effect of higher than designed throughput (greater than 6,700 t/day) on the residue dissolved gold (Au mg/l).

From both these graphs, it is evident that the variation of throughput does not have a marked effect on the dissolved gold losses. Figure 2 shows that the AAC CIP pump-cell plant effectively managed higher than designed feed rates.

Effect of variation of feed pulp density

The feed pulp density varied from 1.16 to 1.55 kg/l over the analysis period. On a conventional CIP plant, the effect of

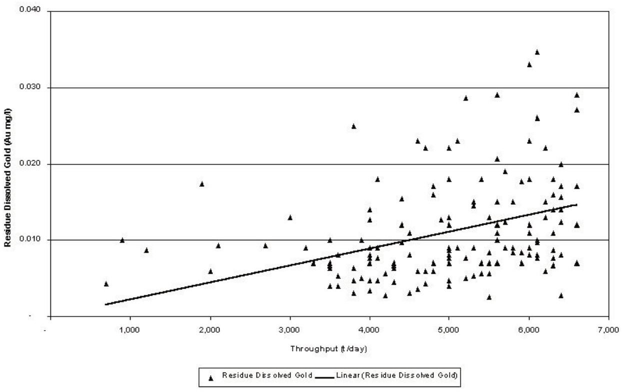

Figure 1—Variation of throughput of ore on residue dissolved gold, low throughput range 700–6600 t/day

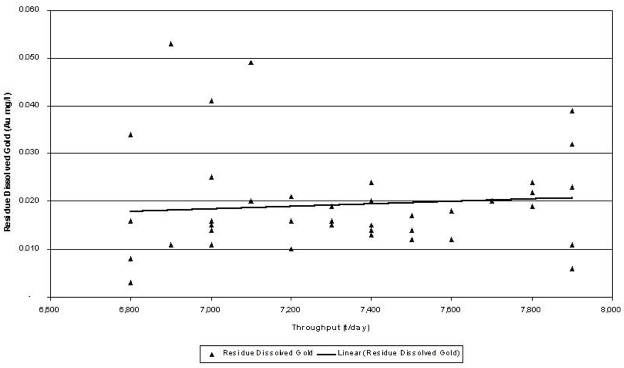

Figure 2—Variation of throughput of ore on dissolved soluble gold, high throughput range 6800–7900 t/day

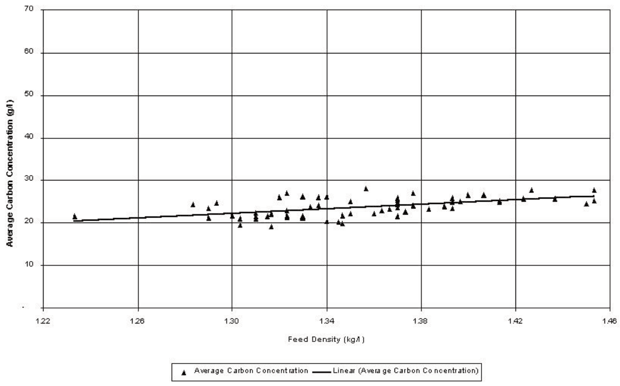

Figure 3—Variation of feed density on measured carbon concentration, low density range: 1.22 - 1.46 Kg/1, period 22 Nov. 96 to 31 Jan. 97, carbon input: 25 g/l

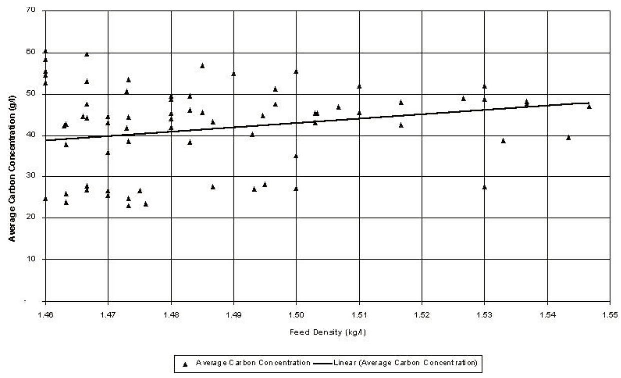

Figure 4—Variation of feed density on measured carbon concentration, high density range: 1.46–1.55 kg/l, period 1 Feb. 97 to 6 Jun. 97, carbon input: 45 g/l

density on carbon performance is an important factor since at lower densities (less than about 1.46 kg/l), the carbon tends to sink (thus the reported carbon concentration is lower) and adsorption is adversely affected. While at high pulp densities (greater than about 1.46 kg/l), the carbon tends to float (thus the reported carbon concentration is higher) and adsorption is again adversely affected. In both of the above cases, an increase in solution gold loss was experienced[3].

Figures 3 and 4 show that the effect of low (1.22 to 1.46 kg/l) and high (1.46 to 1.55 kg/l) feed densities on the AAC CIP pump-cell plant is only a marginal increase in the measured carbon concentration. This indicates that there is good mixing of the carbon in the pump-cells, which overcomes the tendency for the carbon to float or sink. The plant experienced pulp densities up to 1.60 kg/l after the analysis period, again demonstrating that the pump-cell circuit is flexible in operating under varying feed pulp densities.

Effect of variation of feed total gold

The effect of variation of feed total gold on the residue total gold is illustrated in Figure 5, which shows that the residue total gold is generally below about 0.300 Au g/t for feed total gold values ranging from 0.300 to 1.200 Au g/t. This demonstrates the flexibility of the CIP pump-cell plant in handling variations in feed gold tenors, especially when the variations are dramatic and sudden.

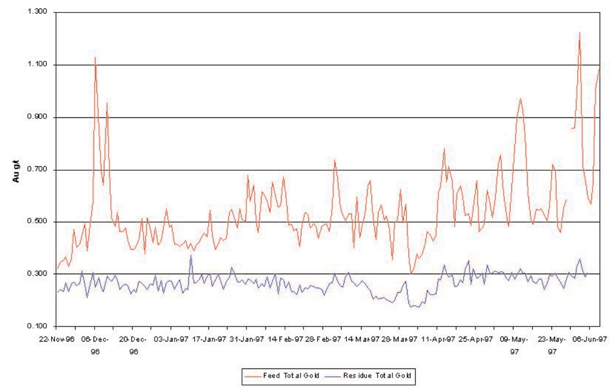

Figure 5—Variation of the CIP feed total gold and residue total gold

Total gold residue values of around 0.200 Au g/t for extended periods were expected, but were only achieved sporadically. This was due to the constraint in carbon movement. These effects are discussed in a later section.

Effect of variation of leaching efficiency prior to CIP

Poor leaching efficiency results in higher than predicted undissolved gold values in the pulp leaving the leaching circuit and feeding the CIP circuit. This is evident as extra

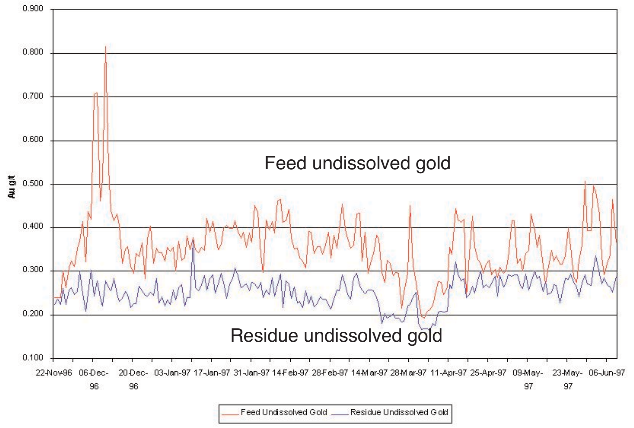

Figure 6—Variation of CIP feed undissolved gold and residue undissolved gold

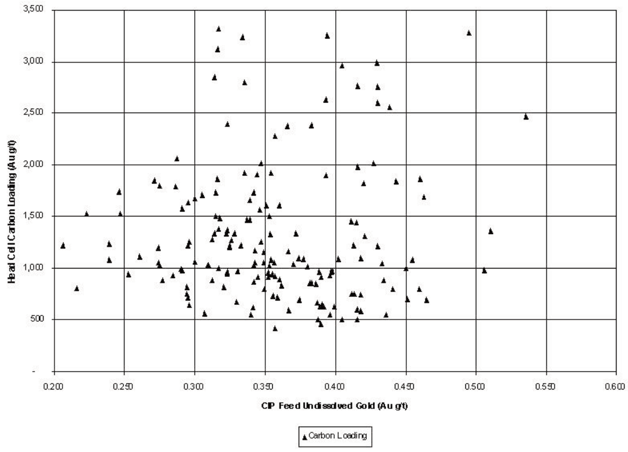

Figure 8—Variation of feed undissolved gold on head cell carbon loading

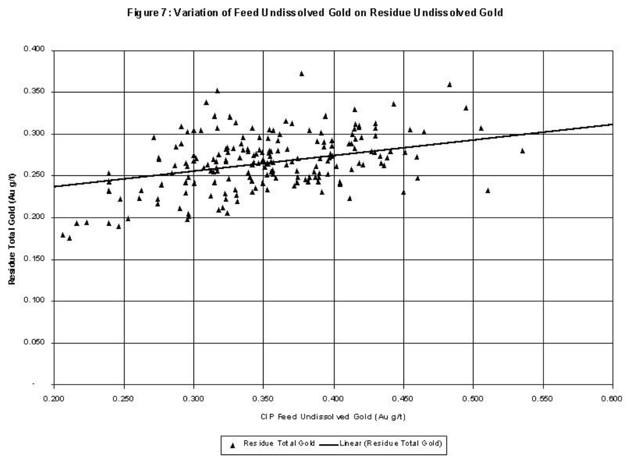

Figure 7—Variation of feed undissolved gold on residue undissolved gold

dissolution of gold from solids as the pulp passes through the CIP circuit as demonstrated in Figure 6. The extra gold dissolution for the CIP plant for the period 22nd of November 1996 to 9th of June 1997 was 27% on average.

The average CIP feed and residue undissolved gold values for the period are 0.357 and 0.253 Au g/t respectively. From Figure 6, around the 6th of December 1996, the undissolved gold feed to the CIP was relatively high, and averaged around 0.623 Au g/t, while the residue undissolved gold remained at 0.253 Au g/t, giving an extra dissolution of almost 60%.

The effect of the variation of the CIP feed undissolved gold on the CIP residue total gold and the head cell carbon loading is illustrated in Figures 7 and 8 respectively. Figure 7 shows that for increasing feed undissolved gold values there is a marginal increase in the residue total gold. Figure 8 shows that the residue total gold and the head cell carbon loading do not have a well defined relationship.

Effect of rate of carbon movement

The rate of carbon movement as mentioned earlier was fixed to twice a week. It would thus be expected that the carbon loads with gold until the head cell is drained; the loading value would then be low and increase until the cell was drained again. This would give a *saw-tooth* type of graph; Figure 9 shows this effect.

A comparison between Figures 9 and 5 relates gold in feed (Figure 5) to gold loading on carbon (Figure 9). The higher gold in feed matches higher gold loading on carbon. The 'upgrade' ratio of gold from feed to gold on carbon can be calculated from the data, and averages 5,000. This is much higher than expected (1,500 to 2,000) due to the low carbon movement rate.

From the 1st of February 1997, the feed total gold values increased (to above 0.500 Au g/t) when the treating of current arisings (West Driefontein main gold plant's residue) instead of tailings dam material, began. Since the rate of carbon movement was fixed, it was necessary to increase the head cell carbon concentration as well as the overall concentration to maintain low solution gold residue. The pump-cell profiles are shown in Figures 10 through 12.

Figure 10 shows the higher carbon concentration profile. Figure 11 shows the effect the higher carbon concentration had on the dissolved gold profiles. Before February 1997, the dissolved gold profile across the pump-cells was flattening out, but after the increased carbon concentration, the profile resumed the more desired shape. Figure 12 indicates that the carbon loading profiles remained normal.

Conclusions

From the results of the performance analysis undertaken at West Driefontein Gold Mine's Reclaim plant, it is evident that the AAC pump-cell plant is highly flexible in that it can handle variations in feed rates, pulp densities, and gold tenors. However, the rate of carbon movement was found to be the Achilles' heel of the Reclaim CIP plant because of the constraint of elution capacity at Leeudoorn. Subsequent to this study, the elution capacity has been up-rated to cater for the West Driefontein Reclaim plant's elution requirements.

The average dissolved gold loss for the analysis period was 0.009 Au mg/l, despite the limitations on the carbon movement rate, the undissolved gold loss averaged 0.253 Au g/t.

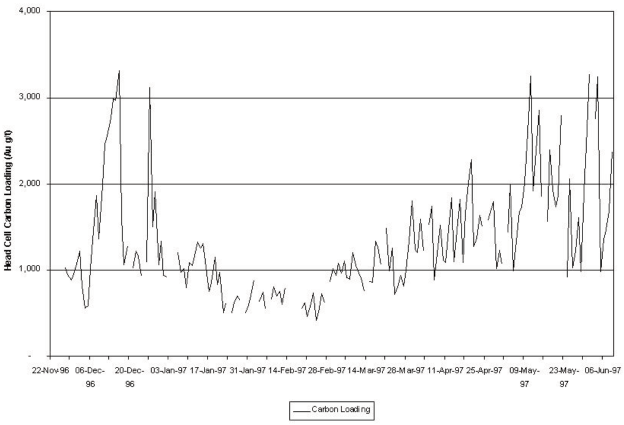

Figure 9—Variation of head cell carbon loading

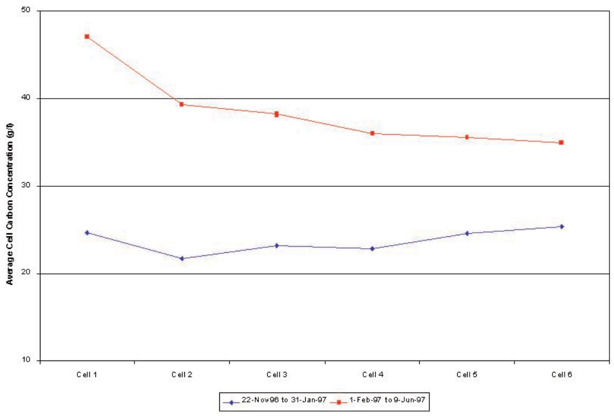

Figure 10—Carbon concentration profiles

The conversion of the West Driefontein Reclaim plant from filtration technology to CIP using AAC pump-cell technology has been fully justified in terms of improved gold recoveries, lower gold losses and lower operating expenses.

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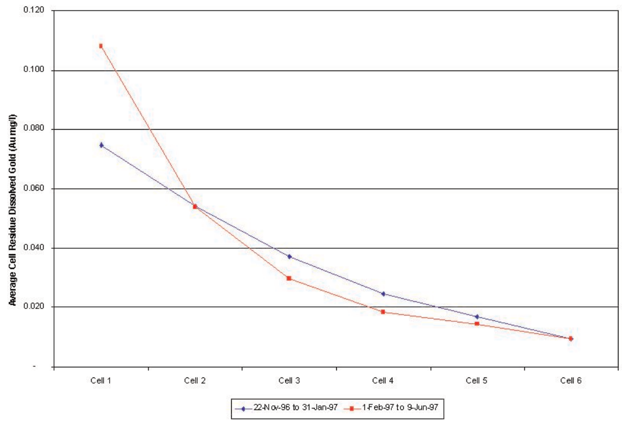

Figure 11—Dissolved gold profiles through CIP circuit

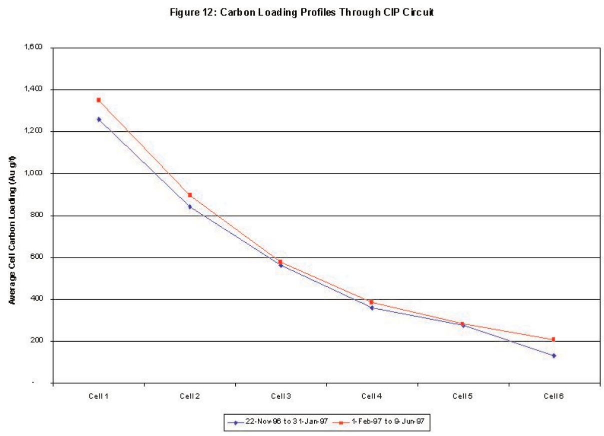

Figure 12—Carbon loading profiles through CIP cicuit

References

1. TWIDLE, T.R., KING, A.J., BRUCE, S.J., and UYS, L.J. The Conversion of the West Driefontein Uranium Plant to a Gold Reclamation Plant, MMMA Circular, No. 2 / 92, *Mine Metallurgical Managers Association of South Africa*, December 1992, pp. 29–52.
2. SCHOEMAN, N., ROGANS, E.J., and MACINTOSH, A.J., AAC pump-cells: A cost-effective means of gold recovery from slurries. *Hidden Wealth Conference*, Johannesburg, *South African Institute of Mining and Metallurgy*, 1996, pp. 173–179.
3. BUSON, G.D., Personal communication and operating information, Leeudoorn gold plant carbon-in-pulp circuit, 1995–1996. ◆

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