Hopper clarification of gold pregnant solution at Vaal Reefs South

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SYNOPSIS

High-rate floc-blanket clarification of gold pregnant rotary filtrate was introduced at the Vaal Reefs South gold plant of the Anglo American Corporation during February 1978.

A daily 12 000 to 15 000 t of filtrate, with an average suspended-solids concentration of 350 mg/l, is continuously clarified to a concentration of less than 25 mg/l of suspended solids in a modified plant pachuca (10 m in diameter) at throughput rates of 7,7 to 8,5 m^3/m^2.h by the addition of 5 g/t of ferric chloride inorganic coagulant and 0,2 g/t of Superfloc N100 flocculant. The pachuca overflow is then clarified further in seven Stellar candle pressure filters of 54,5 m^2 surface area to under 5 mg/l of suspended solids.

The combined clarification cost when the hopper clarifier is used in conjunction with the Stellar filters is R0,0032 per ton of liquid treated, which is approximately 60 per cent lower than the cost of Stellar filtration on its own. The savings are mainly due to the reduced use of filter pre-coat, the consumption of which has dropped by 70 per cent since the introduction of hopper clarification.

SAMEVATTING

Hoë volume vlokkombersverheldering van gouddraende trommelfilterfiltraat is deur Anglo American Corporation se Vaal Reefs-Suid goudaanleg gedurende Februarie 1978 in gebruik geneem.

'n Daaglikse 12-15 000 ton van die filtraat, wat gemiddeld 350 mg/l deeltjies in suspensie bevat, is deurlopend verhelder tot minder as 25 mg/l deeltjies in suspensie in 'n gewysigde aanlegverhelderingstenk (10 m deursnee) teen deurvloeitempos van 7,7-8,5 m^3/m^2 uur deur die byvoeging van 5 g/t yster(III)chloried anorganiese koaguleermiddel en 0,2 g/t Superfloc N100 flokkuleermiddel.

Die verhelderingstenk oorloop is daarna verder verhelder tot onder 5 mg/l deeltjies in suspensie in sewe Stellar kers drukfilters met 'n oppervlakarea van 54,5 m^2.

Die koste van die gekombineerde verhelderingsproses deur die gewysigde verhelderingstenk saam met die Stellar filters te gebruik is R0,0032 per ton vloeistof behandel, wat ongeveer 60 persent minder is as die koste in die geval van direkte Stellar filtrasie alleen.

Die besparings is hoofsaaklik toe te skryf aan die vermindering van die gebruik van filter voorlaagmateriaal wat 70 persent laer is sedert die ingebruikneming van die gewysigde tenk verhelderingsproses.

Introduction

Before gold can be precipitated from gold-bearing (pregnant) rotary filtrate, the relatively high concentration of suspended solids (between 150 and 1100 mg/l but on average 350 mg/l) has to be reduced to less than 5 mg/l. At Vaal Reefs South, this final polishing step is conducted in seven Stellar pre-coat pressure filters of 54,5 m^2 surface area at a feed rate of 90 to 120 m^3/h. The filtration cycle is complete when the terminal pressure of 400 kPa (4 bar) is reached. Under these operating conditions, the times of the Stellar-filter cycles averaged 4 to 6 h, and the cost was approximately R0,009 per ton of solution filtered.

It was suggested that, if the solids content of the feed to the Stellar filters could be reduced by some inexpensive means, the filtration cycle times could be increased to such an extent that an overall decrease in operating costs could be achieved. Several clarification processes were therefore investigated at the Anglo American Research Laboratories (AARL).

The commercial availability of ferric chloride in South Africa (supplied by Klipfontein Organic Products as a 43 per cent solution), combined with the adaptation of the PCI (Patterson Candy International, now Portals) system of clarification by floc-blanket hopper, made for a highly effective and cheap clarification process.

Because of its promise, a laboratory feasibility study of the hopper-clarification process was undertaken and completed in mid-1976. Pilot-plant tests, using a 2,44 m diameter hopper-bottomed floc-blanket clarifier coupled to a Stellar test filter of 0,56 m^2 surface area, were conducted at Vaal Reefs South between October and December 1976.

These pilot-plant tests confirmed that the hopper-clarifier process, with the addition of 5 to 6 g/t of ferric chloride and 0,2 g/t of Superfloc N100 flocculant, was capable of continuously clarifying the pregnant rotary filtrate to a solids concentration of less than 15 mg/l. This result was achieved at throughput rates of between 6,5 and 8,5 m^3/m^2. h and indicated that there was a potential to increase the cycle times of the Stellar filters by at least 233 per cent. An increase of this order would mean that the overall cost of combined preclarification and Stellar filtration could be reduced to R0,0045 per ton of solution filtered.

As a result of the successful pilot-plant tests, it was decided to modify a standard plant pachuca of 10 m diameter and to use it as a full-scale preclarifier.

This paper describes the operating experience obtained between February and June 1978 at Vaal Reefs South using the preclarification–filtration process. The costs of modifications to the equipment and operating costs are also given.

Previous Clarification System

The original standard design for the clarification of filtrate from the twenty rotary-drum filters (each of 93,5 m^2 surface area) provided for the collection of the

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gold-bearing solution in a surge tank of 18,3 m diameter and 3,2 m depth before clarification by a battery of seven Stellar filters. The concentration of suspended solids in the unclarified filtrate solution varied between 100 and 1000 mg/l.

The Stellar filters each have a filter area of 54,5 m^2, rated at a maximum of 150 m^3/h. This figure decreases to 90 m^3/h over an operating period of six hours.

The disadvantages of this clarification system, which are numerous, include the following.

(a) The short intermittent clean-up periods of the Stellar units are labour-intensive and, because of the amount of filter-aid (pre-coat) used, costly.

(b) The amount of solution and sludge generated by frequent clean-ups places an appreciable load on the leaching system.

(c) The surge tank for unclarified solution must be cleaned of settled solids twice a month, during which operation the treatment section must be taken off-line.

Modified Clarification System

In the modified clarification system, a converted plant pachuca of 10 m diameter is placed between the rotary-drum filters and the Stellar surge tank. This pachuca, now called the hoppper clarifier, is used for the pre-clarification of a daily 12 000 to 15 000 t of rotary filtrate to a suspended-solids concentration of less than 25 mg/l. The preclarified overflow is transferred by gravity to the Stellar surge tank, while the excess sludge is pumped back to the leach pachucas.

Modifications to the pachuca included the installation of an overflow launder, sludge-collecting half-cones, sludge tank, feed inlet and overflow pipes, valves, facilities for the storage, make-up, and dosing of reagents, and several sampling points. Use was made of existing installations such as the flocculant make-up system, as well as of in-plant labour. Thus, the charges for labour and the costs of available equipment are not included in the costs given below.

The detailed costs for the modification of the hopper clarifier are as follows:

	Material costs (May 1978) (*Labour charges not included*)
Pipes	R
16 lengths 25 mm mild steel	91,84
15 lengths 50 mm mild steel	246,30
2 lengths 50 mm Durapipe	13,92
7 lengths 150 mm mild steel	382,90
1 length 150 mm mild steel rubber lined	214,02
2 lengths 150 mm rubber-lined bends	202,32
6 lengths 300 mm mild steel	1 200,00
7 lengths 350 mm mild steel	1 440,00
12 lengths 450 mm mild steel	3 200,00
	R6 991,30
Valves	R
5 25 mm Saunders	63,00
8 50 mm Saunders	316,76
7 150 mm Saunders	1 273,79
4 150 mm Saunders (air operated)	1 704,00
1 350 mm Beta	340,30
1 300 mm non-return	650,30
	R4 351,15
Tanks	R
1 ferric chloride storage (fibre glass) tank	4 500,00
2 ferric chloride mixing tanks (rubber lined)	1 600,00
1 Sludge tank	600,00
	R6 700,00
Pumps	R
1 Metripump KV/48/D45/P	550,00
1 CD 30 Monopump	507,00
	R1 057,00
Miscellaneous	R
4 half cones (material and roll)	280,00
Overflow launder material	400,00
	680,00
Total	R19 779,45

Description of Settler Operation

Pregnant rotary filtrate is pumped from the filtrate receiver by a CD frame pump through a 350 mm diameter pipe to the bottom of the hopper clarifier at a continuous rate of 550 to 660 m^3/h and at the process pH of between 10,8 and 11,2.

Ferric chloride coagulant is injected by a KV/48/D45/P Metripump into the hopper feed pipe 10 to 15 m up-stream of the clarifier, at a dosage rate of between 5 and 6 g/t. The coagulant is diluted to a 10 per cent solution in rubber-lined mild-steel tanks from a 43 per cent stock solution stored in a 20 t fibre-glass stock tank.

Superfloc N100 non-ionic flocculant — made up to 0,1 per cent solution in an existing flocculant make-up plant — is pumped by a CD 30 Monopump into the bottom of the hopper clarifier at a dosage rate of 0,2 g/t.

The required energy (or turbulence) for the completion of the coagulation–flocculation process is supplied by the feed velocity. This is about 1,8 m/s in the feed pipe, and about half of this value at the bottom of the hopper clarifier. Coagulation, which really controls the clarity of the final overflow, is completed in 5 to 8 seconds in the feed pipe, and flocculation, which determines the settling rate, is completed in the highly turbulent bottom section of the hopper in about 1 to 2 seconds. The feed velocity, which diminishes to between 7 and 8,5 m^3/m^2. h at the widest diameter of the hopper clarifier, is sufficient to keep the floc-blanket in a fluidized state. In this condition the floc-blanket acts as a porous filter, and helps to collect and agglomerate any fine (or colloidal) solid particles. This results in a well-clarified overflow. Excess sludge is removed from the top of the blanket through the four peripheral sludge-cones situated in the cylindrical part of the hopper.

Owing to the shallow blanket (5 m) and narrow diameter (2,4 m), the removal of topside sludge proved adequate under pilot-plant conditions. However, during full-scale plant operations, it was found that bottom desludging was necessary to obtain the best possible results from the process. Because of some coarse particles in the hopper feed (resulting from holes in the filter cloth, etc.), as well as the continuous agglomeration process taking place in the hopper clarifier, the floc-blanket became stratified. The heavier agglomerates and the coarse solids in the feed sank progressively towards the bottom of the blanket, from which they had to be removed before they could form a heavy, near-impenetrable layer. Such a layer would give rise to uneven flow patterns, loss of fluidization, and channelling in the floc-blanket, all of which result in contamination of the clarifier overflows.

In practice, a daily 5 minutes of pumping from the bottom of the hopper by a B frame pump at a rate of 2 to 2,5 m^3/min is sufficient to remove most of the accumulated coarse solids. At present, the topside sludge-cones do not collect as much excess sludge as expected, though the bottom desludging removes only 50 to 60 per cent of the daily input of solids. The sludge-cones should be lowered into the conical part of the hopper clarifier (to lower the blanket depth to under 8 m and the mean diameter to well under 10 m) to fulfil their intended purpose.

Fig. 1 shows the hopper clarifier, and Fig. 2 the flowsheet and general layout for the process.

Operation of Modified Clarification System

The average solids content of the overflow of the hopper clarifier for the period February to June 1978 was approximately 27 to 30 mg/l. During that period, there were several stoppages, the last being between 15th April and 15th May, 1978 — mainly for further modifications. The first undisturbed run took place during June 1978, giving an average solids concentration in the hopper overflow of 20 to 25 mg/l. The results are listed in Table I.

Some of the results given in Table I were obtained under varying experimental conditions: the frequency of bottom sludge discharges was varied from once a day to once a week, and 5-minute daily bottom discharge was introduced on 23rd June, 1978. It is encouraging to note, that, even when the floc-blanket went completely out of control and overflowed, as happened on 5th June, contamination of the overflow was not too severe.

The effect of hopper clarification on the Stellar filtration process has been better than expected. The Stellar filter runs between clean-ups had been of 5 to 6 h average duration during 1977. Since the introduction of hopper clarification, the following average Stellar-filter cycle times have been recorded:

(a)	1 to 28 February, 1978	28 h
(b)	1 to 31 March, 1978	27 h
(c)	1 to 14 April, 1978	27 h
(d)	15 to 30 April, 1978	7 h (hopper clarifier off-line)
(e)	1 to 15 May, 1978	5 h (hopper clarifier off-line)
(f)	16 to 31 May, 1978	13 h (hopper started up on 15 to 16/6/78)
(g)	1 to 30 June, 1978	34 h

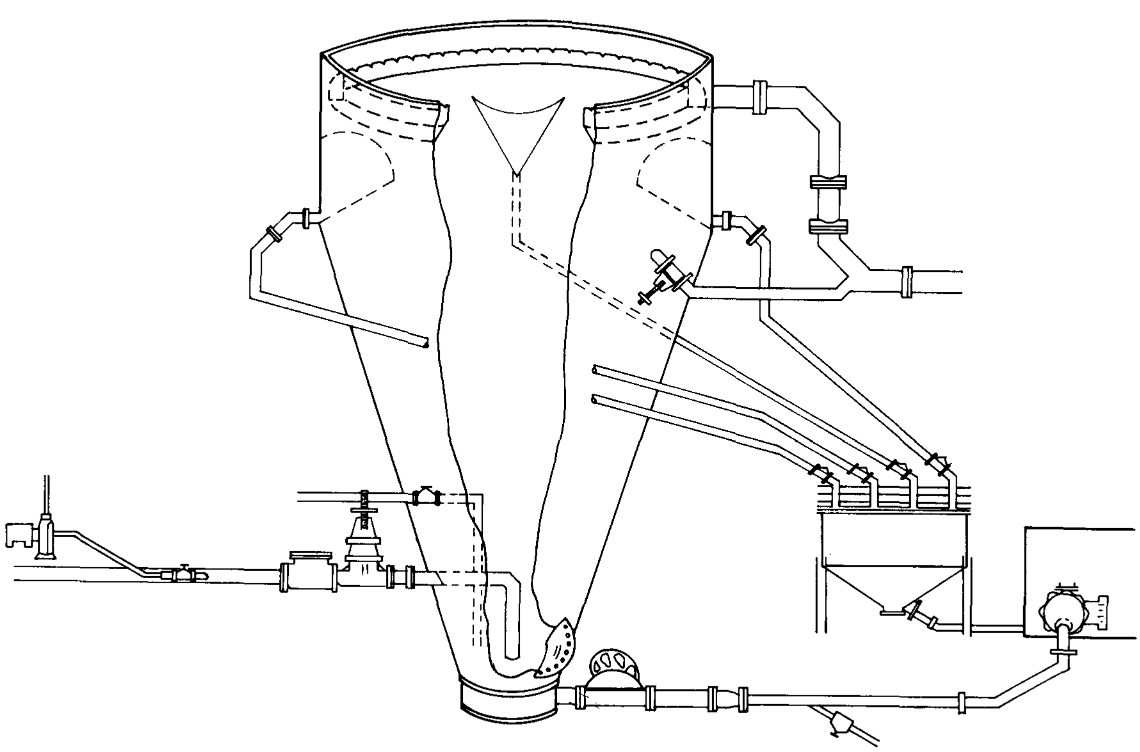

Fig. 1—Hopper clarifier (not to scale)

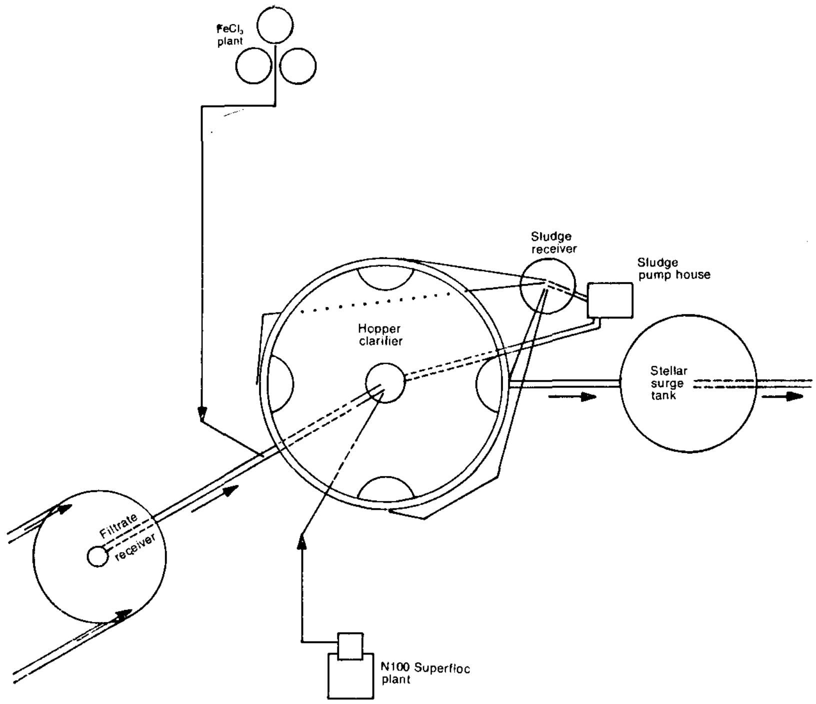

Fig. 2—Flowsheet for the modified clarification process

TABLE I

RESULTS OF HOPPER CLARIFICATION, JUNE 1978

Date June 1978	Solids in feed mg/l	Solids in overflow mg/l	Date June 1978	Solids in feed mg/l	Solids in overflow mg/l	Date June 1978	Solids in feed mg/l	Solids in overflow mg/l
1	94	0	11	202	4	21	324	11
2	149	29	12	147	36	22	539	58
3	121	5	13	410	24	23	170	17
4	160	34	14	436	34	24	412	21
5	811	145	15	209	54	25	497	16
6	255	16	16	344	48	26	194	26
7	704	25	17	126	9	27	172	17
8	75	13	18	274	25	28	459	8
9	352	30	19	301	20	29	163	8
10	125	1	20	290	6	30	471	11

Although the average concentration of suspended solids in the hopper overflow is higher than it was during the pilot-plant tests, the increases in filter cycle time are better now than those obtained during that period. The reason for this must be the extra settling taking place in the Stellar surge tank. This, in effect, produces an average solids concentration in the Stellar feed of well under 15 mg/l. Cycle times of up to 113 hours have been recorded. The 'predicted performance' given in Table II leaves no doubt that the low solids content of the feed is responsible for the extra improvement. This, of course, is easily explained: the solids in the hopper overflow are partially flocculated, and settle easily to the bottom of the quiescent Stellar surge tank.

The equation modelling the average results from the test results is as follows[1]:

$$P=0{,}515+0{,}0306\left(\frac{W.Q^2.\theta}{A^2}\right)^{0{,}7292}\text{ bar (or }\times\text{ 100 kPa)}$$

(The above equation is valid only for a solids concentration range in the feed of 2 to 15 mg/l.)

The equation for a solids concentration range of 270 to 360 mg/l in the feed is as follows:

$$P=0{,}515+2{,}322\left(\frac{W.Q^2.\theta}{A^2}\right)^{0{,}2163}\text{ bar (or }\times\text{ 100 kPa)}$$

where P=pressure across filter, kg/m²
W=solids content of feed, kg/m³
Q=flow-rate, m³/h
θ=filtration time, h
A=surface area of filter, m².

A mean filter cycle time of, say, 30 h at a flow-rate of, say, 100 m³/h implies a solids concentration in the feed of about 7 mg/l. At 25 mg/l average solids concentration in the hopper overflow, the maximum cycle time would be in the range 12 to 15 h. Therefore, the solids in the Stellar feeds during the 5-month period were in effect between 5 and 15 mg/l.

Operating Costs and Savings

The introduction of the hopper clarifier into the clarification circuit increased the Stellar-filter cycle times and in effect lowered the labour intensiveness of the whole system. However, there will be no visible savings on labour since the present Stellar-filter operator will still be needed. He will also be able to look after the hopper clarifier.

The savings on operating costs achieved by the use of the hopper clarifier are given in Table III, in which a comparison is made between the average costs during 1977 and the 5-monthly average since the introduction of the hopper clarifier.

Clearly, the introduction of the preclarifier has led to a 62,8 per cent saving, or R65,86 per day, i.e. R24 000,00 per annum.

Miscellaneous Observations

The viability of hopper clarification is mainly attributable to the availability, low cost, and low usage of ferric chloride. This coagulant is effective at doses of 5 to 6 g/t, while other coagulants such as alum are effective only at dosage rates between 20 and 30 g/t. The delivered price of ferric chloride at Vaal Reefs is R135 per ton (100 per cent basis). Delivery is by road tanker in the form of a 43 to 44 per cent solution.

The first requisite for successful clarification is a de-aerated feed stream. At Vaal Reefs South, this is achieved by ensuring that the feed pump suction is continuously flooded.

Feedline velocities of above 1,5 m/s are maintained at all times. Therefore, additional mixing equipment, such as stirrers, baffles, in-line mixers, is not required. Any of the equipment mentioned can be used in systems where feed velocities are below 0,7 m/s.

TABLE II

PERFORMANCE PREDICTION FOR 54,5 m^2 STELLAR FILTER AT VARIOUS CONCENTRATIONS OF SOLIDS IN THE FEED

Flowrate m^3/h	Solids in feed 2 mg/l	Solids in feed 6,58 mg/l	Solids in feed 11,0 mg/l	Solids in feed 300 mg/l
	Filtration time h	Filtration time h	Filtration time h	Filtration time h
70	200,6	61,0	36,5	13,2
80	153,6	46,7	27,9	10,1
90	121,4	36,9	22,1	8,1
100	98,3	30,0	17,9	6,5
110	81,2	24,7	14,8	5,3
120	68,3	20,8	12,4	4,5
130	58,2	17,7	10,6	3,8

The position of the feedline in relation to the hopper bottom is important if (as at Vaal Reefs) flocculation is performed in the hopper. It was found that a vertical central feed pipe situated 0,9 to 1 m above the hopper bottom is the most suitable. If the flocculation is completed in the feed pipe, other feed arrangements are also permissible.

It is normal practice in the purification of potable water for the time interval between the addition of the coagulant and that of the flocculant to be at least 15 s. However, this is an arbitrary figure and depends on the type of reagents used, the type of solids to be coagulated, pH conditions, mixing speeds, etc. In the hopper-clarification process, a time difference of about 5 to 8 s seems to be perfectly adequate.

The advantage of the coagulation–flocculation process over a straight flocculation process is that the fines are collected by the inorganic electrolyte, i.e. by the ferric chloride, and not by an excess of organic long-chain flocculant. Thus, the blinding of secondary filters is avoided.

The fines at Vaal Reefs consist mostly of colloidal quartz, sericite, and chloritic material, which owing to their fineness may cause problems during the start-up of a clarifier. However, once most of these circulating fines have been removed by coagulation, the quartz content of the whole gold circuit drops. The long-term effects of this can be seen in the smelter, where the effects of the lower silica content coming off the precipitation Stellar filters are already noticeable. Furthermore, since the introduction of the hopper, the frequency of acid washes is lower, precipitation Stellar clean-ups are becoming less frequent, and there is an indication that six clarifier Stellar filters will be able to handle the daily tonnage. Thus, some of the Stellar filters may be freed for use in the precipitation process.

Though not all the long-term effects of the process are yet known — and therefore the conclusions of this report could be premature — it was felt that the technical and economic advantages of the hopper coagulation–flocculation process should be publicized as soon as possible. This is especially important because completed pilot-plant tests have indicated that similar results and savings can be obtained in the clarification of uranium pregnant solutions.

Summary and Conclusions

Hopper clarification of gold pregnant solution at Vaal Reefs South has operated successfully for about 5 months. The process is based on the formation of a floc-

TABLE III

COMPARISON OF THE TWO CLARIFICATION SYSTEMS

	Conventional system Average Jan. to Dec. 1977	Preclarification system Average Feb. to Jun. 1978
Stellar clean-ups per day, no.	42	9
Dicalite pre-coat per day, kg	325,5	75
Cost of Dicalite per day, R	104,16	24,00
Ferric chloride per day, kg	—	60
Cost of ferric chloride per day, R	—	8,10
Superfloc N100 per day, kg	—	2,5
Cost of Superfloc N100 per day, R	—	6,20
Total cost per day, R	104,16	38,30
Cost per ton of solution treated, R	0,0086	0,0032

blanket, which is obtained by the combined use of ferric chloride coagulant, Superfloc N100 flocculant, and the maintenance of a 7,7 to 8,5 $m^3/m^2.h$ rising velocity in a converted 10 m diameter pachuca. The costs involved in the conversion of the equipment — approximately R20 000 — can be recovered over a period of one year on plants where the secondary filters are leaf clarifiers or pre-coat pressure filters. This is because the process savings emanate mostly from reduced consumption of pre-coat.

To date, experience shows that the daily savings in operating costs amount to between R65 and R66, which is equivalent to an annual saving of R24 000. The system is less labour-intensive than the conventional system, and is able to handle large fluctuations in the rate and solids content of the feed.

Although the present installation is operated manually, future installations will be partially or completely automated.

Acknowledgements

The authors wish to thank the Management of Vaal Reefs Exploration and Mining Co. Ltd and of the Anglo American Research Laboratories for permission to publish this paper.

Reference

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