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Intensive cyanidation for the recovery of coarse gold

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SYNOPSIS

This paper describes the operating practice and design features of an intensive-cyanidation plant at the East Gold Plant of Vaal Reefs Exploration and Mining Company Limited (V.R.E.M.). After the development of a cyanidation route for the treatment of gold-plant gravity concentrates by the Anglo American Research Laboratories (A.A.R.L.), a full-scale plant was commissioned at Western Holdings (Welkom Division) Gold Mine in March 1977, and the V.R.E.M. plant was commissioned in August 1981.

Although the gravity-concentration route does not now enjoy the prominence of former times, in an existing conventional plant the intensive-cyanidation route can successfully replace mercury amalgamation.

SAMEVATTING

Hierdie referaat beskryf die werkpraktyk en ontwerpaspekte van 'n aanleg vir intensiewe sianidisering by die oostelike goudaanleg van die Vaal Reefs Exploration and Mining Company Limited (V.R.E.M.). Nadat Anglo American se navorsingslaboratoriums (A.A.R.L.) 'n sianidiseerroete vir die behandeling van swaartekragkonsentrate afkomstig van die goudaanleg ontwikkel het, is daar in Maart 1977 'n volskaalse aanleg by die goudmyn van Western Holdings (Welkom Division) in bedryf gestel, terwyl die V.R.E.M. - aanleg in Augustus 1981 in bedryf gestel is.

Hoewel die swaartekragkonsentrasieroete deesdae nie soveel aandag geniet as in die verlede nie, kan die roete vir intensiewe sianidisering kwikamalgamering met welslae vervang in 'n bestaande konvensionele aanleg.

Introduction

Although the cyanidation route has reached a very high degree of efficiency, there are still advantages to be obtained from the extraction of as much gold as possible in the milling circuit. Adamson[1] cites these as including the following.

(1) There is a reduction in the gold locked up behind mill liners.

(2) Early removal of gold minimizes the effect of circuit upsets in the overall recovery process.

(3) The recovery of fine particles of osmiridium is possible (although this is currently of limited value).

(4) The leaching time has to be increased significantly if only the cyanidation route is followed.

(5) The overall plant soluble loss is reduced.

Current thinking is that the metallurgical circuits should be closed by the application of activated carbon to effluent streams[2], and advantage (5) thus does not assume its previous prominence. Furthermore, new plant designs, such as the No. 9 Shaft Gold Plant at Vaal Reefs Exploration & Mining Company Limited (V.R.E.M.), use run-of-mine milling, leaching, and carbon-in-pulp, and rule out gravity concentration altogether. These comments notwithstanding, in the older generation of gold plants, where there is a lack of flexibility (for example, space constraints that limit an increase in leaching retention time), the gravity-concentration route is a fact of life.

The conventional practice of mercury amalgamation has several disadvantages, the major ones being as follows.

(a) Mercury vapour is highly toxic and is a cumulative poison.

(b) Gold-mercury amalgam has a gold content of 45 per cent, increasing to 75 per cent after retorting, which represents a significant security risk.

(c) The process of amalgamation is relatively labour-intensive.

Motivated by these considerations, and as part of a continuing programme by the Anglo American Research Laboratories (A.A.R.L.) to improve the recovery of gold in the gravity circuit, work commenced on the development of an alternative process to the amalgamation route.

Extensive testwork, which is well-documented[3], proved that an alternative route utilizing cyanidation was technically feasible, and, following from this work, a full-scale plant was commissioned at Western Holdings (Welkom Division) in March 1977. V.R.E.M., in conjunction with the A.A.R.L., conducted their own testwork, and in May 1980 a contract for the design, manufacture, delivery, installation, testing, and commissioning of a complete intensive-cyanidation plant was awarded for construction at the East Gold Plant.

Description of the Process

The specific requirements of the circuit at the East Gold Plant, together with the space constraints, mineralogical considerations, financial evaluations, and experience gained on the Welkom circuit, led to the acceptance of the circuit illustrated in Fig. 1.

The gravity gold concentrate is pumped from the mill building to a storage vessel at the head of the smelt-house. From here, a measured batch (usually 3 or 4 t) is fed to one of the two leaching reactor vessels. Barren solution from the precipitation-Stellar filters (3,5 m^3) is then introduced, followed by 500 litres of 30 per cent (m/m)

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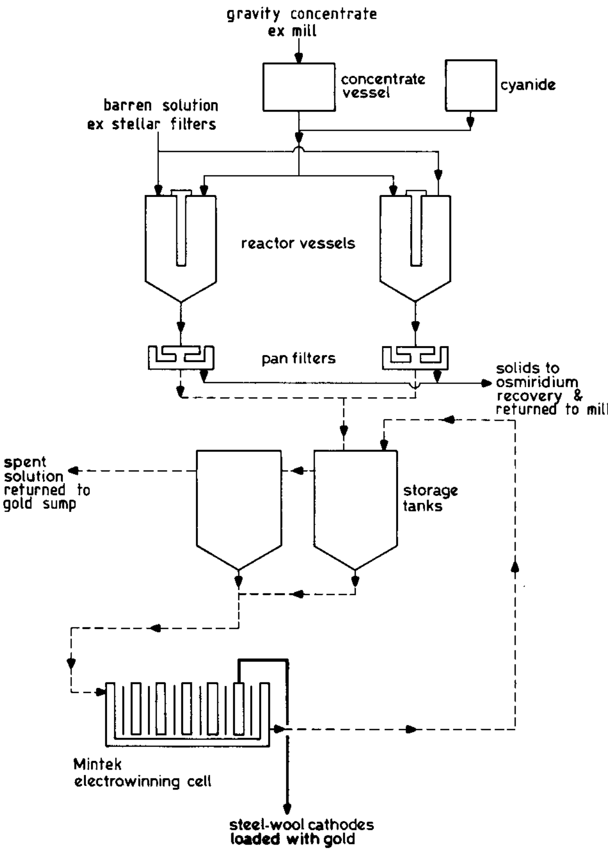

Fig. 1—Intensive-cyanidation circuit

sodium cyanide solution. The agitator is started, and leaching takes place for the desired residence time of 17 hours. Oxygen at a flowrate of 10 l/min is introduced, and the temperature is controlled at between 30 and 35 °C by means of heating elements. After leaching, the contents of the reactors are gravity-fed to pan filters, and controlled filtration with multiple cake-washing takes place. The filters are then tilted, and the solid cake is hosed into a sump and to a three-deck table for the recovery of osmiridium. The table tailings are returned to the milling circuit.

The filtrate is collected via a filtrate-receiver vessel and then pumped to the pregnant-solution tanks. The solution is pumped at a measured rate of 70 l/min to the electrowinning circuit, where the gold is recovered on steel-wool cathodes. The electrolyte is recycled, and spent solution is pumped back into the gold sump of the main circuit for the recovery of the gold by conventional zinc precipitation.

Design Features

Gravity-concentration Circuit

The circuit is conventional, the underflow from the tertiary mill cyclones being fed to four banks of five Johnson barrels, and from there to four endless-belt concentrators. A Sweco screen with a 1 mm screen cloth removes steel wire and coarse oversize material from this stream prior to two-stage pumping to the smelt-house. Retained solids are recycled to the mills. Before the recent installation of this screen, the following problems were encountered.

(1) The feed line choked periodically.
(2) The pan filter cloth was damaged by pinhole tears.
(3) Material settled in the leaching reactors, leading to poor agitation, and hence to lower dissolution.

As cited by Davidson *et al.*[3], it is likely (although unquantified) that the presence of quantities of iron led to the lower gold dissolution and increases in the consumption of cyanide.

Reactor Vessels

The two vessels are of 6 m^3 capacity (3,85 m by 1,5 m in diameter) rubber-lined mild-steel shells with conical bases. The turbine is a departure from the flotation-cell mechanism of Welkom Mine, and attempts to operate at lower power and with less violent agitation. As shown in Fig. 2, the motor drives two impellers. The top impeller is designed to provide agitation at the liquid–gas interface and thus enhance the reactions. The lower turbine, situated within a draught tube, provides agitation and suspension of solids.

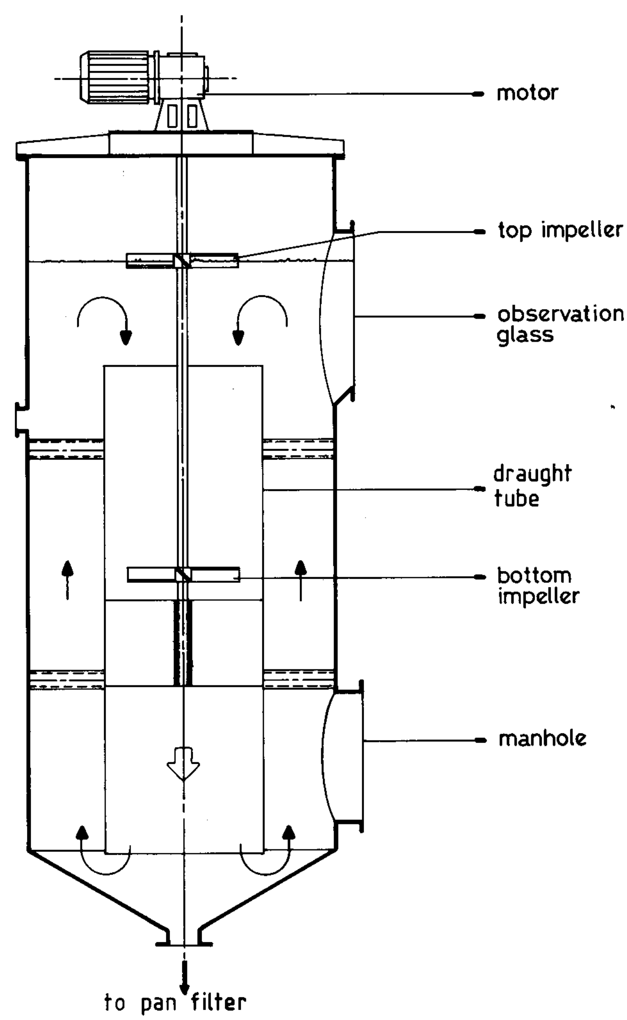

Fig. 2—Arrangement of the reactor in section

However, at the time of commissioning, the gold dissolution was poor initially, and various changes had to be incorporated to produce satisfactory results. The diameter of the turbine was increased, and a larger drive unit was fitted to increase the speed from 125 to 155 r/min. The blade pitch was changed several times, and eventually an angle of 32° was chosen. The slots on the side of the draught-tube were sealed and the baffle removed.

Pan Filters

Experience at Welkom Mine had demonstrated that, in this application, continuous filters posed feeding problems, and thus batch filtration by means of tilting-pan filters was incorporated into the design.

The vacuum system proved to be too intense, and caused severe buckling of the wooden support grating for the cloth, which had to be supplemented by additional steel bracing. This problem having been overcome, filtrate was so strongly drawn through the system that it did not report to the pregnant-solution storage, but entered the vacuum system. Changes to the configuration of the vacuum piping were then made, and the sealing was improved by additional caulking of beading round the cloth. These measures resolved the problems.

Electrowinning

The initial design incorporated A.A.R.L. type cells utilizing concentric chambers separating catholyte (pregnant solution) from anolyte (24 per cent sodium hydroxide) by means of a semi-permeable cation-exchange membrane. The cell design is illustrated in Fig. 3. Although the fundamental design is sound, and the units have been shown to give high recovery efficiencies[3], their lack of robust construction proved to be a failing. The initial P.V.C. design was replaced by G.R.P. construction following severe cracking of the pipe connections at the cell, and a degree of warping at temperature. Bolts securing the top of the cell had to be enlarged because the originals did not provide a tight enough seal. The means of securing the membrane to its frame proved flimsy, and the membranes (costing R700 each) frequently ruptured if extreme care was not taken in handling. For access, and to enhance gravity flow, it later proved desirable for the electrowinning facility to be rehoused at the level of the top of the reactor vessels.

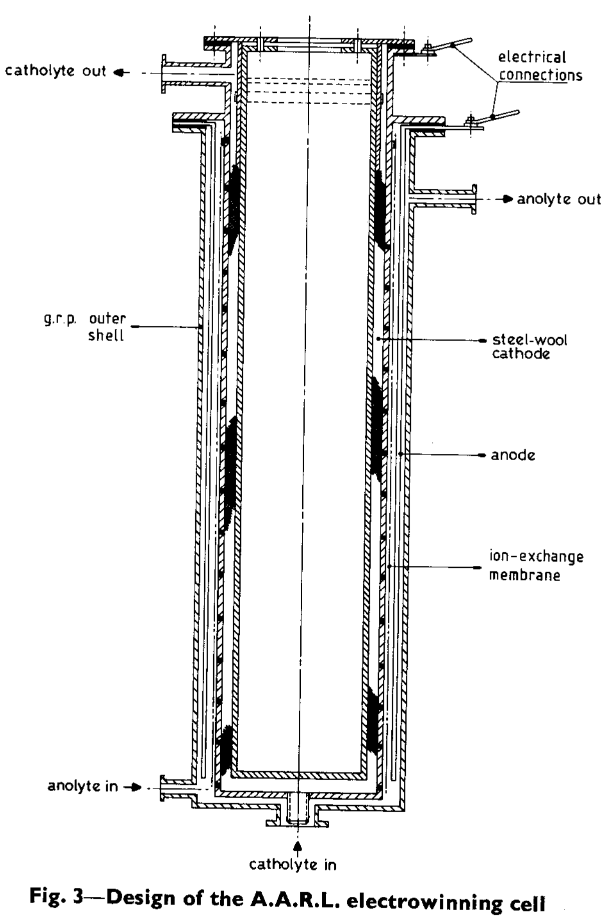

Fig. 3—Design of the A.A.R.L. electrowinning cell

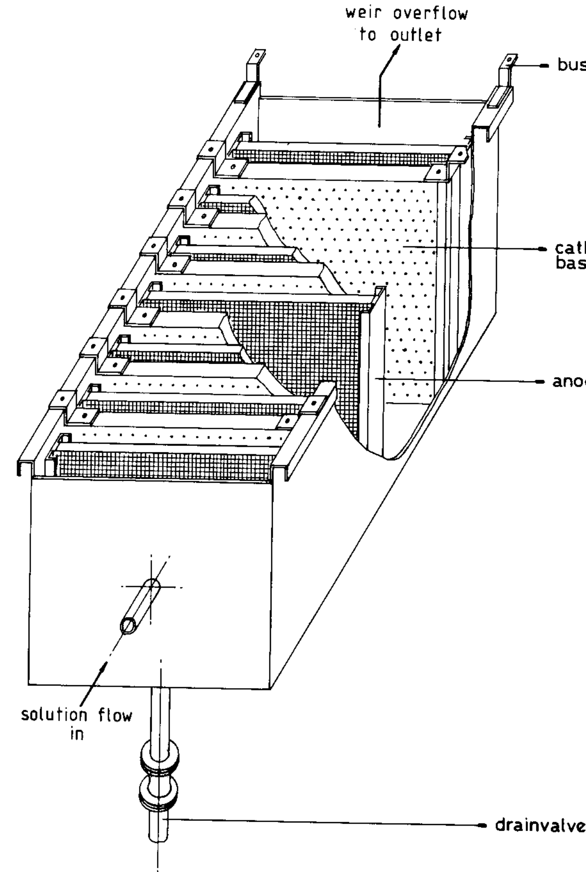

Fig. 4—Design of the Mintek electrowinning cell

In parallel with these changes, the opportunity arose, in conjunction with the Council for Mineral Technology (Mintek), to test a new design of cell (Fig. 4). The satisfactory operating results obtained with this unit are well documented[4] and will not be repeated here. The final layout of the electrowinning facility thus consists of a Mintek cell with the facility to use a modified A.A.R.L. cell as a scavenger unit. The modified A.A.R.L. cell has no membrane, and no separate anolyte and catholyte.

Smelting

It was originally intended that a dedicated furnace should be designed solely for the smelting of cathodes on a daily basis, but this proved unnecessary, and the calcined cathodes are smelted twice weekly with the normal smelt in electric-arc furnaces. No change in the quality of the bullion has been discerned.

Operating Parameters and Results

Under plant conditions, particularly in the production atmosphere of the final stage of the recovery process, it is most difficult for well-controlled scientific experiments to be conducted to prove definitively the relationships between specified variables. The operating parameters presented below are thus intended only to describe the empirically determined factors that give the best results in the majority of cases in view of the fluctuating grade of concentrates delivered to the plant.

Addition of Oxygen

For a given reaction time, gold dissolution was enhanced by the addition of oxygen to the vessel. Although, as shown by Davidson *et al.*[3], air would give a comparable residual gold value at the long contact times employed, it is considered prudent that an oxygen flow of 10 l/min should be used, one cylinder being consumed per leaching batch.

Temperature

The reactors are each fitted with two banks of three heating elements within stainless-steel pipes. Temperatures in the range 30 to 35 °C were found to give the best results.

Addition of Cyanide

Although potassium cyanide was originally provided for, sodium cyanide was adopted for reasons of cost and convenience, and there have been no deleterious effects on the dissolution. The normal addition is 500 to 700 litres of 30 per cent (m/m) sodium cyanide solution per batch, to correspond to an addition of about 50 kg/t.

Solution pH

The ph value is normally controlled between 12 and 13 for optimum results.

Electrowinning

Loosely woven steel wool (300 g) is packed into each cathode basket, and the solution is circulated at 71 l/min for 17 hours. A current is applied through a dedicated rectification system, and a gold loading of 4 : 1 occurs on the 6 cathodes. The 7 anodes are of 5 mm mesh 304 stainless steel. Stripping/unloading and recharging of the cell take only some 2 hours before the cell is back on line.

Concentrate

Normally, each batch consists of between 3 and 4 t as measured approximately by means of a vessel situated above the leaching reactors.

Filtration

A wash ratio of 1,35 is used on the leached concentrate. Although a value for soluble loss was not quoted, early work showed this to have been low. Periodically a black, oily deposit has appeared on the surface of the cake that markedly hinders the rate of flotation. The deposit was originally thought to be flocculant from downstream operations, but this has not yet been proved and, indeed, recent testwork goes against this theory.

In the discussion of operating results (Table I), cognizance must be taken of certain salient points. In the initial commissioning stages, the problems were compounded by various upstream effects as the result of a parallel project to uprate the gravity-concentration circuit in the mill. These resulted in very variable amounts of concentrate, gold tenor, size distribution, slime presence, and tramp metal content, at the limits of which the plant could not cope. The intensive-cyanidation plant is still very sensitive to such effects, and a survey over 24 days recently showed a concentrate headgrade that varied between 486 and 20 819 g/t (a mean of 6121 and a standard deviation of 4443). Naturally, this can lead to extreme variability in leaching, and subsequently in electrowinning, efficiencies. The optimization of the gravity circuit remains an ongoing project.

Furthermore, there is built-in safety in the recycling of spent solution and leach residues. Leach tailings, after the osmiridium has been recovered, are routed back to the mill, and would thus subsequently be leached in the normal circuit. Spent electrowinning solution is sent to the gold sump, and from there to the Stellar precipitation filters. At times when changes were being made to the electrowinning circuit, pregnant solution was fed direct to the gold sump without any major increases in the tenor of the barren solution, showing an alternative route should electrowinning not be desired.

Accounting in the circuit is complicated by the difficulties inherent in the representative sampling of extremely variable high-grade materials[3], from both the concentrate and the leach tailings. Thus, a relatively minor sampling error can be readily magnified into a poor leaching efficiency. Representative sampling of the pregnant solution is also not straight-forward, and this can lead to significant variations in electrowinning efficiency.

It is important that the results as quoted should be regarded as representing a 'once-through efficiency'. As already stated, the leach residues are recycled to the mill, and will thus be routed to the conventional leach with its attendant dissolution of more than 95 per cent. Spent solution, by being routed to the precipitation circuit, will, in turn—on the basis of the current tenors of barren solution—be subject to a higher recovery, of about 99 per cent. These comments put the operating results quoted in Table I into better perspective.

Benefits of Intensive Cyanidation

The formerly labour-intensive method of amalgamation with mercury has now been almost totally phased out, save for a limited amount applied monthly to the arisings from mill clean-up. This in itself has allowed for the labour force to be reduced from 11 to 9, and the possibility exists for further savings once the work has been rescheduled. The rising cost of labour makes such savings in working cost highly significant.

The concentrations of mercury in urine analyses decreased by 74 per cent within six months of the change-over. Analyses are now conducted quarterly instead of monthly, and most results are consistently below the limit of the detection method. Such environmental

TABLE I

MONTHLY OPERATING RESULTS FOR INTENSIVE-CYANIDATION PLANT (ONCE-THROUGH ACCOUNTING BASIS)

Month	Leaching efficiency %	Electrowinning efficiency %	Percentage milled gold to circuit %	Concentrate per day t
1982				
January	96,26		15,07	5,96
February	93,58		12,83	6,40
March	97,06		17,96	6,54
April	97,47		15,06	6,62
May	96,42	Values	18,08	5,15
June	96,50	not	16,58	5,19
July	97,37	reported *	18,26	4,50
August	98,22		17,80	4,40
September	97,96		18,90	4,30
October	98,70		19,17	4,77
November	98,50		18,27	3,92
December	99,02		17,40	3,39
1983				
January	98,50		17,40	4,27
Febuary	97,32	98,72	18,82	5,50
March	97,39	98,40	18,27	5,00
April	96,72	98,77	18,62	6,73
May	98,54	96,73	17,87	5,42
June	97,41	91,21†	18,49	6,35
July	97,80	89,22†	15,85	5,85
August	97,60	92,54 †	15,99	6,80
September	98,19	98,42	17,56	5,70
October	94,19	95,82	18,17	5,40
Mean	97,31	95,54	17,38	5,37
Standard deviation	1,35	3,64	1,56	0,98

* Owing to the many changes in the electrowinning circuit over this period, results are not quoted here.

† Severe electrical failures encountered. New rectification system purchased after this.

aspects, although largely unquantifiable, are highly significant in protecting the health of the workforce.

No breaches in security have been recorded in the smelt-house since the plant was installed, and surveillance of the overall operations by the smelt-house foreman is very much easier than before.

Acknowledgements

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Copper and alloys

The Deutsche Kupfer Institut, together with the Deutsche Gesellschaft fur Metallkunde e.V., are organizing a symposium entitled 'Copper and Copper Alloys: Properties, Manufacture, Uses', which will be held in Bad Nauheim on 25th and 26th April, 1985.

The main topics are the properties, uses, new developments, and future trends of copper and copper alloys used in the electrical, measurement and control, precision, optical, and mechanical-engineering industries. In the discussion of these topics, particular attention will be paid to aspects of economics and quality.

The symposium will be of interest to engineers, technicians, physicists, metallurgists, and materials technologists involved in the areas of finishing, semi-finished products, application, design, and research and development.

Further information can be obtained from Deutsche Gesellschaft für Metallkunde e.V., Adenauerallee 21, D-6370 Oberursel 1. Tel.: 06171/4081.