Mintek-BacTech's bacterial-oxidation technology for refractory gold concentrates: Beaconsfield and beyond

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Synopsis

Mintek and BacTech have joined forces to provide the metallurgical industry with bacterial-oxidation processes for the treatment of sulphide ores. The processes are aimed at both refractory gold-bearing and base-metal concentrates. Previously, BacTech had commercially implemented the refractory gold process at the Youanmi Gold Mine in Western Australia. More recently, the process has been incorporated in the Sulphide Treatment Plant at the Beaconsfield Gold Mine in Tasmania, Australia. In addition, Mintek and BacTech have recently signed an agreement with the Laizhou Gold Metallurgy Plant in China's Shandong Province, which will see the third commercial realization of the technology for refractory gold. Development of the base-metal technology is the subject of several papers in the proceedings of this colloquium.

The implementation of the refractory gold technology at Beaconsfield is discussed in detail. Some important aspects that are covered include:

- Test work, and the choice of bacterial culture
- Process design choices, and the advantages of the Mintek-BacTech process
- Inoculum build-up
- Plant commissioning
- Plant performance.

Besides the Laizhou project, Mintek and BacTech are currently investigating several other commercial prospects for the technology. These include the use of the technology for a gold-copper deposit, where the production of both gold and copper is envisaged.

Introduction

The sulphide treatment plant at the Beaconsfield gold mine in Tasmania, Australia was commissioned recently, and includes a bacterial-oxidation plant that incorporates technology supplied by Mintek and BacTech.

Mintek-BacTech bacterial-oxidation technology

Over a number of years, Mintek and BacTech independently developed their own technologies in the field of bacterial oxidation[4,6–8]. In 1997, an alliance was formed that combines this expertise and broadens the range of services available. The agreement provides for Mintek and BacTech to apply their combined bacterial-oxidation expertise to better serve the needs of industry by supplying bacterial cultures, test work and consulting services, and front-end process-engineering packages for gold and base-metal projects.

Both organizations have significant experience in the large-scale operation of bioleaching plants. Mintek has an extensive database accumulated from the operation of a 20 t/d capacity plant at the Vaal Reefs Gold Mine in conjunction with Anglo American Corporation of South Africa[3,5]. BacTech's technology has been used at the Youanmi Deeps project in Western Australia to treat refractory gold concentrates at a throughput of over 40 000 t/a, achieving recoveries of between 93 and 95 per cent[1,2].

A brief history of gold at Beaconsfield

Gold was first discovered at Beaconsfield in 1877. After the initial discovery, Beaconsfield became a thriving mining town as the nature of the deposit was realised and the news of the discovery spread. Further prospecting and development confirmed that the Tasmania Reef deposit was extensive and rich.

Underground mining began in 1879. Advanced mining techniques for the day were used to sink and develop three main shafts, the Hart Shaft, the Main Shaft and the Grubb Shaft, to access the reef and begin gold production. Mining operations were soon stretched to the limit, as the shafts suffered continual flooding—the result of an enormous underground reservoir. Even with powerful and sophisticated pumping machines, production was continually halted for months at a time.

In 1903 an English consortium took control of the operation and installed what was

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believed to be the most powerful pumping plant in the world, designed to overcome previous flooding difficulties. The pumps were highly complex and, with continual interruptions from flooding, took years to install. Costs of breaking and hauling ore also rose as the mine developed. These and other factors resulted in the cost of production exceeding the value of the gold recovered. Eventually, after producing 854 000 ounces of gold obtained from the more than 1 million tonnes of ore, the mine was forced to close in 1914.

Re-development of the Beaconsfield gold mine

Re-development of the mine began in the 1980s, and extensive exploration has identified a resource of 1.5 million tonnes within a 450 vertical metre zone beneath the old workings, which extended more than 450 metres below the surface. Installation of a pump station with a capacity of 800 *l*/s at 180 metres below the surface has been critical in overcoming the flooding problems experienced during previous operations at the turn of the previous century.

The Beaconsfield gold mine is one of only a few new Australian gold projects to come into operation in the current climate of low gold prices. Up to 200 000 tonnes per annum of ore will be mined and processed over a minimum period of eight years, to a depth of 900 m. The Tasmania Reef is a gold-bearing quartz-carbonate-sulphide vein occupying an old fault structure which transgresses a series of sedimentary beds. The sulphides are predominantly pyrite with lesser arsenopyrite, and also minor copper as chalcopyrite. Drilling to date below this level clearly indicates that the high-grade orebody is open at depth and that the mine life should be extended significantly over time.

Sulphide treatment plant

A multi-stage development programme, designed to bring the mine into full production, and incorporating the construction of an on-site sulphide treatment plant incorporating bacterial oxidation, has been completed. Prior to execution of a detailed engineering design of the Mintek-BacTech bacterial-oxidation process, a programme of bacterial-oxidation test work was completed to provide a basis for establishing the process design criteria.

A simplified flow diagram of the Beaconsfield sulphide treatment plant is shown in Figure 1. The process plant comprises the following unit operations:

- Feeding of run-of-mine (ROM) ore from the ROM stockpile to the crushing circuit
- Two-stage crushing and screening with a product size of 100 per cent passing 12 mm
- Primary ball milling to a size of 80 per cent passing 75 µm
- Gravity concentration within the grinding circuit

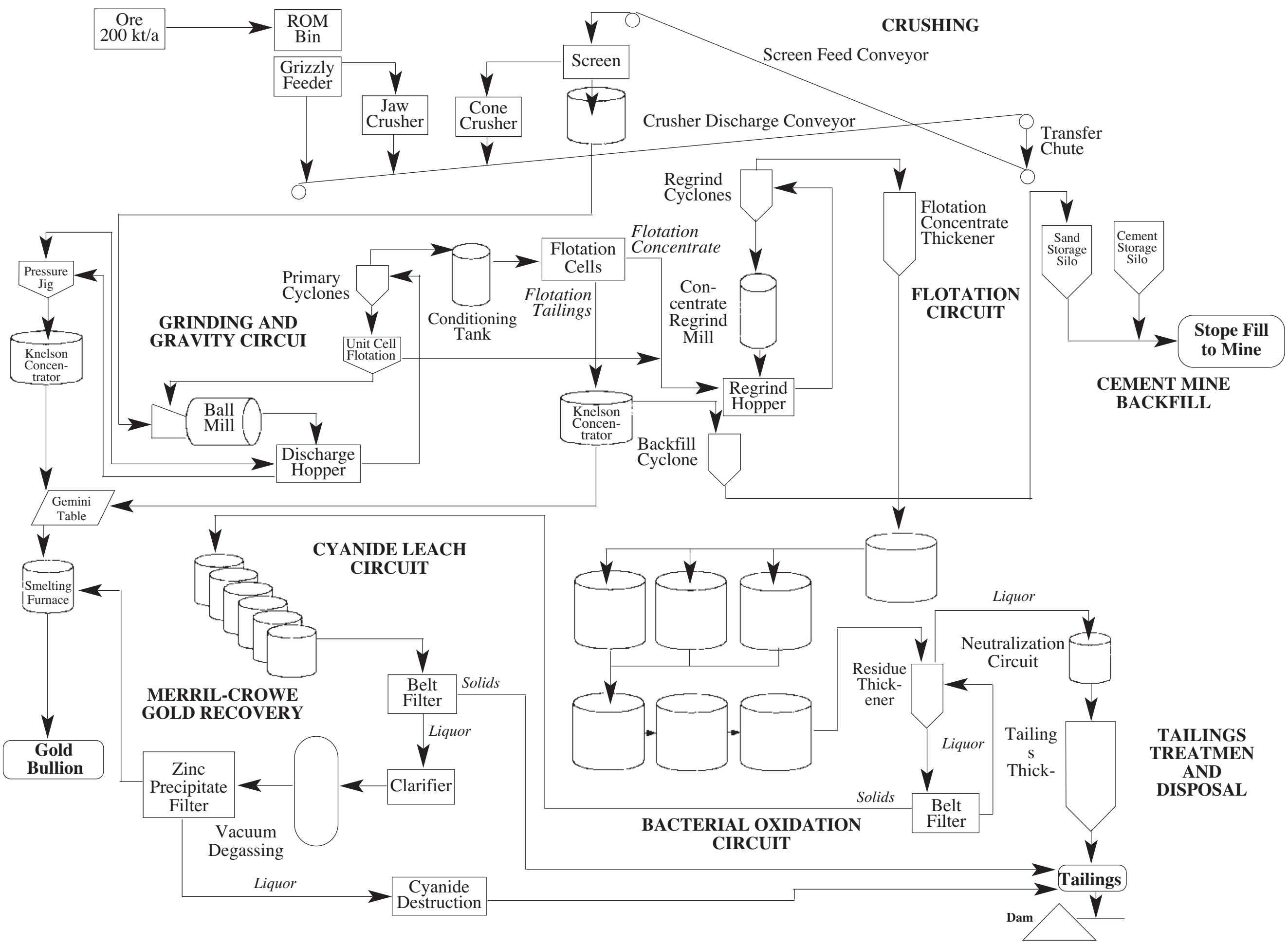

Figure 1—Beaconsfield gold mine sulphide treatment plant

(approximately 40 per cent of the total gold recovery)

- Froth flotation to produce a clean sulphide concentrate containing approximately 58 per cent of the ROM ore gold content, and a flotation tailing of sufficiently low gold grade for disposal
- Bacterial pre-oxidation of the sulphide concentrate using the Mintek-BacTech technology
- Cyanide leaching of the bacterial-oxidation residue
- Recovery of the soluble gold using the Merrill-Crowe process, incorporating solid-liquid separation, clarification, deaeration, zinc dust cementation, and filtration
- Cyanide detoxification of the leached solids using the Caro's acid process, prior to disposal in a dedicated storage facility
- Cleaning of the gravity concentrate to produce a direct smelt product for smelting with the addition of fluxes to produce bullion
- Bullion production from filtered Merrill-Crowe precipitate by calcining and the addition of fluxes prior to smelting
- Size separation of flotation tailings, with the fine fraction being stored in a dedicated tailings dam and the coarse fraction being utilized for underground fill as required.

The Mintek-BacTech technology was chosen for the pre-oxidation step, as it was considered the best available for the treatment of the Beaconsfield concentrate. Factors that were considered are:

- The absence of the need for pH control, which minimizes iron and arsenic precipitation in the leach and which, in turn, maximizes the solids mass loss over the bacterial-oxidation process
- Minimizing precipitation further reduces the chances of gold losses due to encapsulation in iron-arsenic precipitates
- The mass loss results in a substantial upgrading of gold in the oxidized residue
- This in turn results in a higher gold tenor in the cyanide-leach circuit, minimizing the size of this circuit.

The Beaconsfield gold mine is situated in an environmentally sensitive region of northern Tasmania, and this impacted on the design of the sulphide treatment plant. For example, detoxification of all cyanide species prior to disposal was a requirement. This in turn impacted on the selection of the gold-recovery process. As a result, the Beaconsfield plant is unusual in that it employs the Merrill-Crowe process for the recovery of gold, whereas most new gold plants these days elect to use a carbon absorption process. The rationale for this choice—made by the client and the contracting engineer—was that the high soluble gold tenor, combined with the low solution volumes after filtration of the leached slurry, significantly reduced the volume of solution requiring cyanide detoxification. This meant that a small Caro's acid plant could be used for cyanide destruction, with capital and operating cost advantages.

Bacterial oxidation process design

Metallurgical test work programme

Throughout the metallurgical test work programme, only very limited quantities of concentrate were available, and as a result the bacterial-oxidation test work was limited to batch laboratory-scale testing. Continuous piloting was only possible once the flotation plant was commissioned and concentrate was being produced on site at the mine. The engineering contractor completed thickening, filtration, neutralization, cyanide leaching, zinc precipitation, and cyanide destruction test work, using pulp samples obtained from the limited bacterial-oxidation test work.

Feed concentrate characterization

The range of the major chemical and mineralogical components of the Beaconsfield concentrate used as the basis for the design of the plant is summarized in Table I. The ratio of the sulphide components to carbonate (which occurs at Beaconsfield as ankerite, $CaCO_3.FeCO_3$) indicates that the bacterial oxidation process should be net acid producing. Further, the ratio of iron to arsenic was sufficiently high to ensure that a stable iron- and arsenic-bearing precipitate would be produced in the liquor neutralization process. Other components of significance that could occur in the concentrate in varying amounts are copper (as chalcopyrite) and graphitic carbon.

Batch test work

Choice of bacterial culture

Two bacterial cultures were considered for pre-oxidation of the Beaconsfield concentrate. The first was a mesophilic iron- and sulphur-oxidizing culture, with an optimum temperature range 37 to 43°C, that has been maintained at Mintek over a twenty-year period[7], and exhibits a high activity for the oxidation of pyrite and pyrite-arsenopyrite concentrates. The second was a moderately thermophilic iron- and sulphur-oxidizing culture, with an optimum temperature range 45 to 50°C, that has been maintained by BacTech over a fifteen-year period, and was previously used in the Youanmi commercial bacterial-oxidation plant in Western Australia.

Both cultures were shown to be able to oxidize Beaconsfield sulphide concentrate successfully in laboratory test work. A key factor in the previous decision to use the moderately thermophilic culture in the Youanmi plant was the lower cost for cooling of the process resulting from the higher process operating temperature. The mesophilic bacterial culture was chosen for use in the Beaconsfield plant, primarily because of its proven track record for operation at a low pH level and in the presence of a high iron concentration[7], which was an important design requirement for the Beaconsfield plant.

Table I

Range of chemical analyses of the Beaconsfield flotation concentrate

Sulphide, %	27.0	34.0
Sulphidic iron, %	24.8	31.8
Arsenic, %	3.2	5.6
Pyrite, %	48.2	59.3
Arsenopyrite, %	6.9	12.1
Ankerite, %	8.4	6.9

Sulphide oxidation and gold recovery

A range of laboratory-scale batch tests was carried out using a variety of concentrate samples derived from the Beaconsfield ore. The concentrates were generally within the range of chemical and mineralogical compositions shown in Table I, but also with some parameters lying outside this range. These were notably a High Arsenic Concentrate (with an arsenic grade of 13.3 per cent), and a High Sulphide Concentrate (with a sulphide grade of 35.9 per cent). The concentrates also contained small quantities of chalcopyrite. The High Sulphide Concentrate had the highest copper content, assaying 2.69 per cent copper.

The relationship between the level of sulphide oxidation and gold recovery by cyanide leaching for the range of concentrate samples tested is illustrated in Figure 2. These data indicated that the bacterial-oxidation plant would need to be designed to achieve greater than 90 per cent oxidation of combined pyrite- and arsenopyrite-sulphide in order to maximize gold recovery. The cyanide leach results also indicated that any graphitic carbon present would not be preg-robbing.

Process design criteria

Because of the variable nature of the ore at Beaconsfield, the bacterial-oxidation plant was designed to treat a range of concentrates. Two sets of design criteria were established, covering a range of concentrate grades, as summarized in Table II. Equipment was then sized to cater for the worst case. For example, the agitators, the blowers, and the cooling circuit were sized according to the requirements of the 34 per cent sulphide concentrate, but the downstream thickener and filter were sized to cater for the 27 per cent sulphide concentrate (because the mass loss for the lower-grade material is less).

Pre-commissioning activities

The major pre-commissioning activity was the staged build up in volume of the bacterial inoculum. The first stage involved the preparation of 200 *l* of bacterial pulp at Mintek using a sample of Beaconsfield concentrate. This was then air-freighted from South Africa to Tasmania, which took a period of three weeks. On site, this pulp was used to inoculate a 5 m^3 inoculum preparation tank. This, is turn, was used to inoculate one of the 35 m^3 neutralization tanks specifically adapted for this purpose. The pulp from this stage was then used to inoculate one of the 385 m^3 primary bioleach reactors, which in turn was used to inoculate the entire circuit. Each stage of inoculum build-up took approximately two to three weeks to complete. The bacteria exhibited excellent resilience and no problems were encountered at any of these stages.

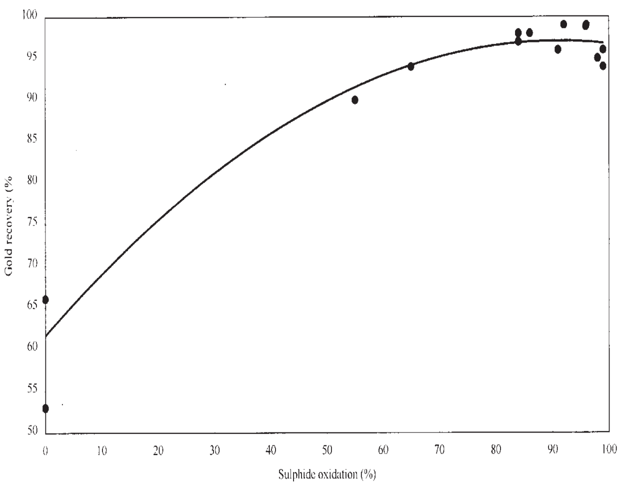

Figure 2—Relationship between sulphide oxidation and gold recovery

Plant operation

Confirmatory piloting test work

Once a concentrate sample could be obtained from the Beaconsfield plant, a small-scale pilot plant trial was commenced at Mintek. The data in Table III summarize the oxidation performance obtained from this trial. As far as possible, the operating conditions employed on the Beaconsfield plant were adopted in a scaled-down form in the pilot plant trial. Some differences were that the concentrate sample was washed and dried prior to use, the small pilot plant was operated in a slightly different configuration (three primary reactors in parallel and only two secondary reactors in series), and the air supply was supplemented with carbon dioxide gas. The site nutrient mix was employed at the rate of addition as on site.

While the overall sulphide oxidation level achieved was in excess of 98 per cent, analysis of the data indicated that it would be possible to achieve the design level of 95 per cent sulphide oxidation at an overall residence time of around four days. This result confirmed the relatively conservative assumptions that were used to specify the plant design criteria. The results also clearly demonstrated the ability of the Mintek mesophilic bacterial culture to tolerate low pH

Table II

Process design criteria for the bacterial-oxidation plant

Concentrate throughput	2.84	2.44	t/h
Overall FeS_2/FeAsS-sulphide oxidized	95	95	%
Feed-solids concentration	14.2	11.7	% (m/m)
Maximum soluble iron concentration	40.0	40.0	g/*l*
Maximum soluble arsenic concentration	5.0	5.0	g/*l*
Grind size (P_{80})	38	38	µm
Overall residence time	5.1	4.8	d
Number of primary oxidation reactors in parallel	3	3	
Number of secondary oxidation reactors in series	3	3	
Design reactor volume	385	385	m^3
Operating temperature	40	40	°C
Operating pH range	1.0–1.4	1.0–1.4	
Mass loss	53.9	69.1	%
Design heat load	5309	kW	
Design air flow rate	18383	Nm^3/h	
Design cooling-water flow rate	411	m^3/h	
<u>Nutrients:</u>			
Di-ammonium phosphate	1.86	kg/t	
Potassium sulphate	0.89	kg/t	
Ammonium sulphate	1.55	kg/t	

Table III

Results of confirmatory pilot plant test work

Operating Conditions	
Feed-solids concentration	14.2% (m/m)
Residence time	5.1 d
Temperature	40 ± 0.4°C
Steady-state Plant Performance	
Soluble Fe	40 to 48 g/*l*
Soluble As	11 to 14 g/*l*
pH level	0.5 to 1.1
Eh level	640 to 700 mV (Ag/AgCl)
Dissolved oxygen concentration	2.0 to 5.5 ppm
Residue solids concentration	3.4 % (m/m)
Mass loss over bacterial oxidation	76%
Total FeS_2/FeAsS-sulphide oxidized	98.5%

levels, and its ability to maintain high levels of oxidation even under these relatively extreme conditions. This was also demonstrated by the ability to maintain a high redox potential across all the oxidation reactors. As a result of the low pH level, virtually all of the iron and arsenic remained soluble, and as a result an overall mass loss of over 75 per cent was achieved. Under these conditions it was only possible to oxidize around 20 per cent of the chalcopyrite, with the soluble copper concentration reaching approximately 1 g/*l*.

Operation of several small pilot plants at Mintek has continued over the past few months. The objective has been to provide ongoing back up over the initial operational period, using the plant feed material, to ensure that steady and optimum performance is achieved with respect to critical parameters such as carbon dioxide supply, nutrient supply, and the possible ingress of reagent or other inhibitors into the bacterial oxidation circuit. For example, these ongoing trials have successfully demonstrated that, even in excess of the design levels, the flotation reagents being used at Beaconsfield do not affect the performance of the bacteria. Further test work is being conducted to evaluate the effect of the flocculant being used at Beaconsfield, and to optimize the rate of nutrient addition.

Current Beaconsfield bacterial oxidation plant performance

The data in Table IV summarise the current (early June 2000) operating conditions and performance data from the Beaconsfield bacterial-oxidation plant.

The current plant throughput is 2.1 t/h of concentrate, compared with the design range of 2.44 to 2.84 t/h. The reduced throughput has been caused by mechanical failures which have been experienced on the agitation units in the primary bacterial-oxidation reactors. At present, one of the primary reactors is not operational while repairs are being made. Upgrading of the agitation units will continue for the next few months. There is every expectation that the plant will readily achieve the design throughput when all reactors are fully operational.

Obtaining reliable estimates of the level of sulphide oxidation and the mass loss has been difficult, owing to the mechanical failures which have interrupted the steady operation of the plant. However, based on the results of the small-scale pilot plant test conducted at Mintek, it is anticipated that the design sulphide oxidation level (and mass loss) will be realised or surpassed once all of the primary reactors are in operation, and a period of steady operation is achieved.

Other specific issues that have influenced plant operation are discussed below.

Water quality and bacterial inhibition

The various reagents used throughout the plant have the potential to inhibit the oxidative activities of the bacterial culture. Of major concern is the extreme toxicity of cyanide and thiocyanate to the bacteria, even at very low concentrations. It has therefore been extremely important to ensure that liquors that could potentially contain these substances are not allowed to contaminate the water in the feed to the bacterial-oxidation plant. As far as possible, fresh water is used for feed dilution. As already noted, an ongoing programme of toxicity monitoring has been undertaken at Mintek to detect any inhibitors that may reduce bacterial activity, and has shown that, under normal operating conditions, the reagents in use at Beaconsfield are not toxic to the bacterial culture. Chemical analyses have confirmed that the levels of free cyanide and thiocyanate in the bacterial oxidation feed water are both below 0.5 ppm.

Monitoring of the leach liquors from the bacterial-oxidation reactors indicates that a high level of arsenic oxidation occurs, but that the concentration of the relatively more toxic As^{3+} is always very low.

Feed variation

Some variations in the feed concentrate have been experienced as a result of changes in the ore being mined or changes made to the flotation circuit. In the last three months, the feed arsenic grade has varied between 4.3 and 9.2 per cent. This has impacted on the soluble arsenic concentration, which has been as high as 20.8 g/*l*, compared with a design value of just 5 g/*l*. The concentrate sulphide grade has varied between 22.2 and 30.6 per cent, which is generally within the range specified in the design criteria,

Table IV

Current operating conditions in and performance of the Beaconsfield bacterial-oxidation plant

Operating Conditions	
Feed-solids concentration	14.2% (m/m)
Residence time	6.0 d
Temperature	37 to 40°C
Steady-state Plant Performance	
Soluble Fe	42 to 48 g/*l*
Soluble As	8 to 10 g/l
pH level	1.0 to 1.4
Eh level	600 to 700 mV (Ag/AgCl)
Dissolved oxygen concentration	2.5 to 5.0 ppm
Residue solids concentration	6.6% (m/m)
Mass loss over bacterial oxidation	52%
Total FeS_2/FeAsS-sulphide oxidized	91.8%

and is easily controlled in the flotation circuit. The feed iron grade has varied between 24.8 and 32.1 per cent. Generally, it has been within the design limits, although soluble iron concentrations of up to 53.1 g/*l* have been measured, compared with a design value of 40 g/*l*.

In the same period of time, the carbonate grade of the feed concentrate has varied widely, between 0.8 and 7.2 per cent. The combined effect of high arsenic and carbonate feed grades has been that the pH levels in the circuit have been higher than anticipated. Furthermore, the fluctuations in the feed grades of arsenic, sulphide, and carbonate resulted in significant swings in the pH levels in the reactors. Provision was made in the design for acid addition to the feed to cope with high carbonate grades, but there were occasions when acid was not available for short periods of time, resulting in the pH swings.

Recently, this problem has been overcome to a large extent by improving the acid addition system to cater for acid addition to the individual primary reactors, and by ensuring that acid is always available. This, coupled with more stable iron, arsenic, sulphur, and carbonate grades in the concentrate, has considerably reduced process fluctuations.

Nevertheless, the mesophilic bacterial culture withstood the wide variations that were experienced in the process conditions well.

Nutrient supply

During the first few months of operation of the plant, it became apparent that insoluble solids associated with the nutrients were settling out in the nutrient supply line. Improvements were made to the nutrient dosing system to improve the reliability of supply of nutrients to the reactors, and included the installation of a strainer to remove insoluble solids, and replacement of the nutrient pump. The improved system has now operated trouble-free for a continuous period of eight weeks.

Oxygen and carbon dioxide supply

A critical consideration in the design of bacterial-oxidation processes is to ensure that the supplies of oxygen and carbon dioxide are adequate to meet the maximum rate of sulphide oxidation attainable. In both cases this is achieved by gas-liquid mass transfer from the gas phase supplied to the reactors. In the case of oxygen, a key design requirement is that the rate of supply of oxygen must be sufficient to maintain the dissolved oxygen above the critical concentration (1.5 to 2.0 ppm) at all times in all parts of the reactor[7]. A similar critical requirement exists for the supply of carbon dioxide. While oxygen is required as the oxidant for the sulphide and iron oxidation reactions catalysed by the bacterial cells, carbon dioxide is required as the carbon substrate for the biosynthesis of new cell mass (bacterial growth). There is a predictable stoichiometric relationship between the consumption of oxygen and carbon dioxide. Depending on the bacterial-oxidation system and the conditions employed, a ratio of around 20 kg O_2/kg CO_2 is generally used for design purposes.

In the case of Beaconsfield concentrate, it was clear that carbon dioxide supplied in the air to the primary reactors would be insufficient to meet the requirements of the bacterial oxidation and growth rates specified. This shortfall would need to be made up by supplemental carbon dioxide made available from the dissolution of carbonates occurring with the feed concentrate. It was estimated that a minimum carbonate grade of approximately 4 per cent in the feed concentrate would be required for this purpose.

On initial plant start-up, the bacterial-oxidation feed distribution system allowed for the three primary reactors to be fed sequentially, each for a period of nine minutes. Each primary reactor would then not receive feed pulp for the subsequent 18 minutes while feed was directed to the other two reactors in sequence. A bacterial-oxidation process modelling and simulation package was used to assess the implications of this feeding schedule on carbon dioxide availability in the primary reactors. The results indicated that the carbon dioxide supply rate to the primary reactors would fall below the consumption rate for approximately 50 per cent of the time. The primary reason for this was the unexpectedly rapid rate of dissolution of the ankerite. The small pilot plant test work showed that complete dissolution of the ankerite (and hence complete evolution of contained carbon dioxide) occurred within 7.5 minutes of the feed being switched off. This can be compared with dissolution times of the order of days that are experienced with other sulphide concentrate feeds to bacterial oxidation, in which the carbonate minerals were present as calcite or dolomite. On the Beaconsfield plant this issue was easily addressed by decreasing the sequential cycle time of the feed system.

Gold recovery performance

The oxidized residue is thickened, and then filtered and washed on a three-stage counter-current belt filter, ahead of gold leaching in conventional cyanide-leach tanks. The cyanide leach residue is filtered and washed on a four-stage counter-current belt filter. Cyanide-leach residues currently contain about 16 to 20 g/t gold, and the belt filter wash efficiency is about 95 per cent.

The solution chemistry arising from leaching oxidized residues, partially oxidized residues and occasionally unoxidized concentrate (necessary to obviate the mechanical failures) has proven to be extremely complex, often leading to poor control through the zinc cementation process. However, efficiency levels have improved along with the level of oxidation. Varying levels of sulphide ions and copper in solution have contributed to zinc cementation difficulties, with copper levels often exceeding 2000 ppm in pregnant liquor. The high copper content of the pregnant liquor and the concomitant cyanide required in solution places a high load on the Caro's acid cyanide detoxification circuit, which has had to undergo some re-design.

Conclusions—beyond Beaconsfield

The Beaconsfield bacterial-oxidation plant is now operating at a sulphide oxidation performance level close to that specified in the design criteria. Although plant operation has been affected by tank outages caused by mechanical failures, the Mintek-BacTech bacterial-oxidation process has shown itself to be robust and able to withstand the process perturbations that persisted through the commissioning period and beyond. In addition, the bacterial culture has performed well under the relatively extreme conditions of low pH and high iron and arsenic concentrations that have been observed.

Future projects

A commercial bacterial-oxidation plant using Mintek-BacTech technology will be constructed and commissioned at the Laizhou Gold Metallurgy Plant, Shandong Province, People's Republic of China, by early 2001. Laizhou Gold plans to establish a custom treatment plant with an initial capacity of 65 000 oz (about 2 000 kg) of gold per annum, and anticipates an expansion in the future to handle multiple identified sources of refractory gold in the general region. Construction of the facility will begin shortly, and production is scheduled to commence early in 2001. The first stage of bacterial inoculum preparation was recently started at BacTech's premises in Perth, Western Australia.

A further two refractory gold projects are currently under investigation. For the first of these, BacTech is currently conducting test work on a refractory gold concentrate from a European refractory gold project. The project has to date identified an indicated resource of over one million ounces (more than 33 000 kg) of gold, and exploration drilling is continuing.

For the second project, Mintek has been conducting an extensive programme of laboratory-scale test work on a range of samples from two deposits in Tajikistan, central Asia. One of the deposits is a refractory gold deposit, but also contains a significant quantity of copper, while the second is a refractory gold deposit. A pre-feasibility study has been conducted for the recovery of gold and copper from the first deposit, and a similar study is being finalized for the recovery of gold from the second deposit. During 2000, Mintek will conduct pilot-scale bacterial-oxidation tests on samples from both of these deposits, leading to the completion of a full feasibility study in 2001. Various options for the recovery of both gold and copper are being considered for this project.

The Beaconsfield project has firmly established Mintek and BacTech as suppliers of bacterial-oxidation technology for the treatment of refractory gold concentrates. Commercial implementation of the Laizhou project has now begun, and further commercial successes are anticipated.

Acknowledgement

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