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Intensive cyanidation: onsite application of the InLine Leach Reactor to gravity gold concentrates [☆]

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Abstract

Gekko Systems have advanced the science of intensive leaching by developing an innovative alternative to the traditional intensive leach systems of agitated tank and vat leaching. As leaders in the field, Gekko present mine site results and operational data for Australian and overseas mines. The Batch Inline Leach Reactor maintains the critical technical advantages of a rolling drum and reliable solution clarification while simplifying the equipment to a rolling drum, two tanks and a single pump.

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1. Introduction

The last two decades has seen resurgence in the recovery of gold using gravity—often in conjunction with a conventional carbon-in-pulp (CIP) or carbon-in-leach (CIL) circuit. Generally the gravity gold concentrates are high-grade with gold grades of 20,000 ppm and with relatively low mass at 0.03% of the plant feed. Bowl centrifugal concentrators (BCC's) such as the inline spinner, falcon and Knelson concentrators invariably produce the gravity gold concentrates, Gray and Katsikaros, 1999, although flotation may also be utilised. The new technology exhibited by the BCC's has injected new life into what was regarded as 'old technology'.

Treatment of these high-grade gold concentrates has usually been through amalgamation with mercury (a process route that has now become very minimal due to environmental and safety concerns) or by a second stage of gravity treatment commonly utilising tabling or a related process. In particular the tabling of gravity concentrates was proven to offer very low recoveries, Longley et al., 2002—often between 30% and 60%,

much lower than expected by the mine sites operating these devices. An example of the tabling performance of a Western Australian mine site is shown in Fig. 1.

The research indicated that tabling was clearly a "below optimum" process. It was regarded as inefficient to achieve high recoveries in a high "g" force unit like a BCC only to lose it in the next metallurgical process. Research also showed that the tabling of concentrates in a number of circuits resulted directly in instantaneously high cyclone overflow grades when the table tails are returned to the milling circuit and subsequent losses from the leach circuit to tails. This behaviour is illustrated in Fig. 2 from a Western Australian mine site, Grigg, 2002. Due to the classification, Wills, 1979, characteristics of a hydrocyclone, misplacement of coarse gold particles to the overflow will occur. Particles that may not be dissolved prior to discharge to tails resulting in reduced recoveries.

Intensive cyanidation is proven technology that gives high recoveries from gravity gold concentrates—this was achieved by either a high-speed agitator in a tank or by vat leaching. Both methods had their problems due either to excessive wear and high energy requirement for the agitated systems or channelling of solution and loss of fine gold in the vat type systems giving poor recoveries.

In 1997 Gekko Systems Pty Ltd introduced the In-Line Leach Reactor (ILR)—the first were continuous units and treated the gravity concentrates from either batch type concentrators or continuous concentrators

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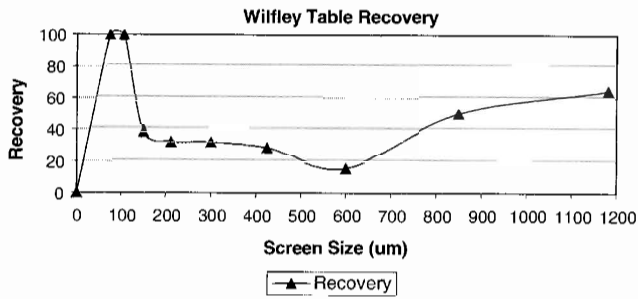


Fig. 1. Gold ore—table recovery curve.

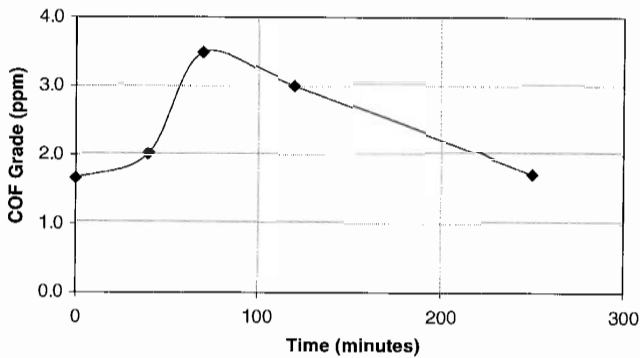


Fig. 2. Cyclone overflow grades during tabling.

such as jigs or flotation. An important breakthrough for the InLine Leach Reactor came with the introduction of the technology into the African market where the security issue created a compelling event. Ashanti Goldfields introduced the technology across all their mining operations (six units now installed).

The Batch Inline Leach Reactor was subsequently developed to treat smaller masses of gravity concentrates than are treated in the continuous system. The batch units will treat up to 8400 kg/cycle (commonly 24 h), whilst the continuous units treat from 150 kg/h up to 7000 kg/h.

2. Why intensive cyanidation?

Why invest in intensive cyanidation? Each mine site and organisation is attracted to this technology for different reasons. However, the key factors include:

- significant gravity recovery improvements
- proven chemistry
- security
- safety benefits
- major capital cost reductions for increased leach throughput

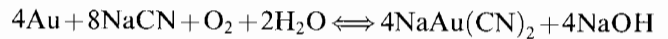
There are over fifteen mines worldwide using InLine Leach Reactors for intensive cyanidation of gravity gold concentrates. These include both batch and continuous units. While Batch Inline Leach Reactors are cost effective for small concentrate masses, higher feed rates require a continuous reactor.

Significant gravity recovery improvements

For this process to be viable it is necessary to reliably obtain high recoveries from the gravity concentrate—in excess of 97%. The only proven technology giving high gold recoveries from gravity concentrates is intensive cyanidation coupled with either direct electrowinning or carbon absorption.

Proven chemistry

The chemistry of cyanidation is proven and well known with the majority of gold operations in Australia using the process. Cyanidation as a process had been used for the extraction of gold since 1890. The reaction for the leaching of gold is known as Elsner’s equation, Lenahan et al., 1986:



Oxygen is an indispensable reagent in the reaction and is provided either from atmospheric oxygen, hydrogen peroxide or a production oxygen facility, McQuiston, 1985. The level of oxygen addition required is determined from the initial test work and/or during plant commissioning. Fig. 3 shows leach profiles for both oxygen and peroxide.

Intensive cyanidation, typically using cyanide levels of 2%, requires no exotic chemicals or materials and uses standard process operations. At these levels of cyanide the safety procedures currently used around a CIP/CIL gold room are readily applicable with only minor modifications.

The harsh chemical conditions exhibited by the intensive cyanidation process are necessary due to the high gold tenors within the gravity gold concentrates. Table 1 shows the relative comparison between the conditions in a CIP/CIL circuit and a Batch Inline Leach Reactor.

Security

With no requirement for manual handling of the gravity gold concentrates and the harsh leach conditions, coupled with the enclosed drum design a high level of security is obtained. Commonly the units are fenced off separately from the rest of the plant.

Safety benefits

Negation of the need for manual handling reduces the occurrence of strains and sprains. Also the generation of toxic fumes during the calcining and smelting process is minimised. Since there is no contact with what are commonly high sulphide materials the incidence of skin problems is also negated.

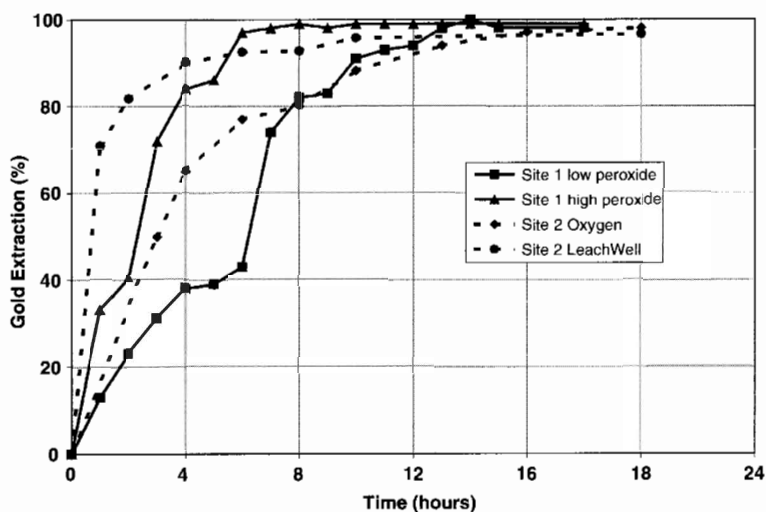


Fig. 3. ILR leach kinetics utilising oxygen or peroxide.

Table 1
Comparative leach conditions

	CIP/CIL	ILR-B	Factor
Au, g/t	2.0	20,000	10,000
CN, ppm	500	20,000	40
O ₂ , ppm	8	15	2
Au dissolution rate, g/h/t	0.1	1000	10,000

Table 2
Models available

Model	Maximum dry capacity
ILR100B	1140 kg
ILR1000B	3000 kg
ILR2000B	5700 kg
ILR3000B	8400 kg

Major capital cost reductions for increased leach throughput

The opportunity exists to recover 70–80% of the total plant gold production from the gravity circuit. Significantly reducing the requirement for carbon handling etc. In retro-fit installations where a plant throughput increase is planned, the addition of intensive cyanidation may reduce the requirement for any leach and CIP/CIL upgrade.

3. Batch InLine Leach Reactor design features

The batch models of the InLine Leach Reactor have been developed to treat high-grade, low volume gold bearing concentrates. The Batch InLine Leach Reactor is available in four sizes as shown in Table 2—each model is available in either manual or automatic modes.

3.1. Well mixed reaction zone

The ILR operates on a semi-submerged bed principle. A partially closed medium aspect ratio drum is filled with concentrate to the overflow level and rotated. The rolling drum technology closely resembles common bottle roll technology but with added features. The solution carrying all reagents is cycled through the drum at

relatively high flow rate to ensure a constant supply of cyanide and oxygen.

The action of the drum ensures a high level of solution shear at the particle surface, which removes chemical passivating products that may form at the particle surface. This also guarantees that there are no “Dead Spots” in the solution/solid interface and the solid particles see fresh solution continuously.

3.2. Flexible reagent regime

Due to this relatively high shear, intense reagent environment, exceptionally rapid reaction kinetics is seen. Oxygen utilisation is maximised and surface passivation is minimised. The effective mixing allows a wide variety of oxidants to be used to maximise recovery and minimise operating costs.

3.3. Good electrowinning performance

Pregnant solution is well suited to recovery by electrowinning. LeachAid or similar addition is not generally required so electrowinning performance is not compromised. Where required, trace metals such as mercury and arsenic can be precipitated in the reactor drum and removed during clarification. Fig. 4 shows typical site performance of electrowinning circuit on a pregnant intensive cyanidation solution.

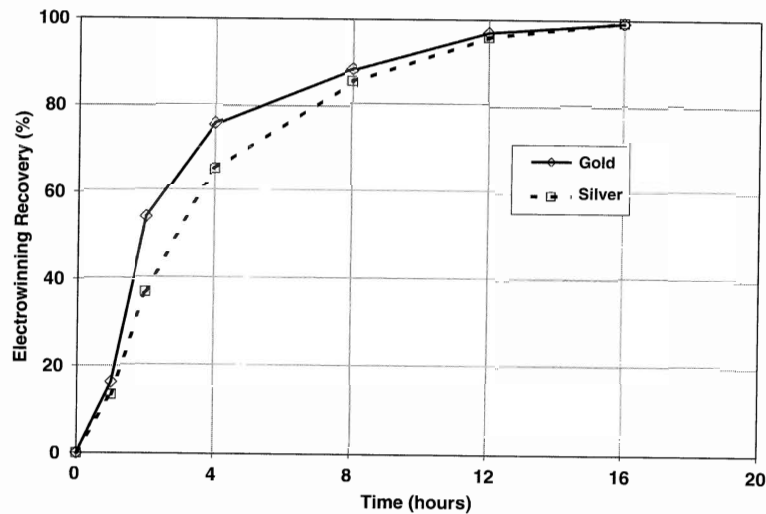


Fig. 4. Typical electrowinning kinetics.

3.4. Coarse and fine gold leaching

Both coarse and fine gold are targeted with no physical losses to tails of fines through short circuiting or clarification. During drum loading all solids are retained within the leaching system. Any fines that overflow the drum, including hydrophobic gold fines, are retained in the solution storage cone and form part of the leaching solution. This solution is recirculated through the drum during leaching. In this way all solids are contacted with leach solution and all gold is leached.

3.5. Clarification step

A separate step is used to clarify the pregnant solution prior to transferring to electrowinning. This process gives good control of clarification. The solids are returned to the drum and flocculant addition is used as required. This means all types of concentrates can be treated. This includes concentrates where slimy precipitates are formed as part of the leaching process.

3.6. Batch InLine Leach Reactor operation

The concentrates from the primary recovery device report to the feed cone for de-watering, with the water overflowing and returning to the mill circuit. Solids are stored in the feed cone until the beginning of each leach cycle. Figs. 5 and 6 show a Batch Inline Leach Reactor.

The Batch Inline Leach Reactor works on the principal of the laboratory bottle roll to keep the solids in contact with the liquor. A horizontal drum rotating at low speed with a set of specially designed baffles and aeration system for maximum leach performance. Residence time is predicted in the laboratory and controlled by leach cycle time. During leaching solution is continually recirculated through the solids from the solution

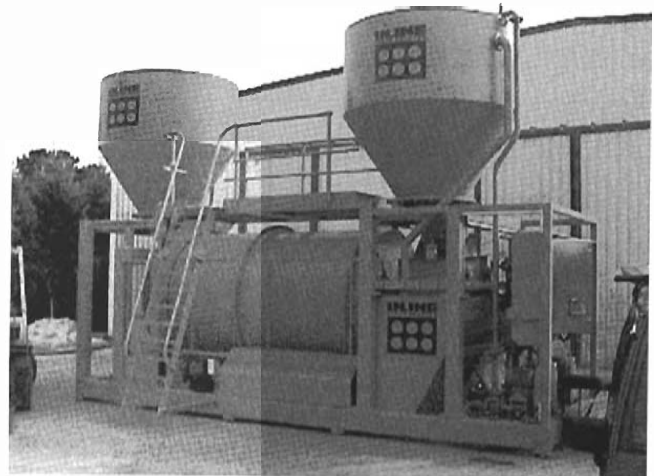


Fig. 5. InLine Leach Reactor.

storage tank to ensure a fresh supply of reagents, including oxygen, is always available for leaching.

At the completion of the leach cycle the pregnant solution is clarified then pumped to the electrowinning circuit. Barren solids are emptied by reversing the drum rotation and pumped to the mill circuit. Pregnant liquor is pumped to the electrowinning circuit where it can be recovered in a dedicated electrowinning cell or mixed with the main elution solution. The barren solution from electrowinning is then pumped to the CIL/CIP circuit (optionally to the ILR) to reuse the residual cyanide. Fig. 7 depicts the flow sheet for a '000 series reactor.

During the leaching step solution is recirculated from the solution storage tank to the reactor feed and overflows to the sump before being returned to the solution storage tank. The recirculation rate is controlled via a restriction orifice in the line to the reactor drum. By recirculating a relatively large volume of solution through the solids the equivalent of a low leach density is

fresh solution is mixed through the solid. The action of the rotating drum also draws air into the slurry, which ensures no portion of the solids can become oxygen depleted, therefore re-precipitation of gold onto steel particles does not occur.

At the completion of the leach cycle the drum is stopped and the solution in the drum is drained into the sump and pumped to the solution storage tank. Some fine particles are carried through the drum and are re-circulated with the solution. The solution is clarified by allowing it to stand then periodically draining solution from the bottom of the tanks conical base. Flocculent is added to improve clarification performance as required.

Wash water is added to the drum and used to wash entrained pregnant solution from the solids.

Wash water is drained from the reactor drum and clarified. Steps 6 and 7 can be repeated as often as required.

The leached washed solids are emptied from the reactor drum by reversing the rotation of the drum. A scoop inside the drum empties the solids into the sump while water is added continuously to pump back to the mill circuit.

The pregnant solution can be transferred to the electrowinning section at this stage. The solution can be transferred into a dedicated electrowinning tank and cell for recovery or the solution can be added directly into the elution circuit for recovery in the main plant electrowinning cells. The ILR is now ready to start at step 1 with concentrate collected during the last cycle of steps.

4. Installation results

The process and design flexibility of the ILR has resulted in over 20 installations world wide, with the majority in Australia or in Africa.

The following examples illustrate the very good results the batch units have had at several mine sites.

4.1. Indonesia

Site results are shown from a gold mine in Indonesia showing the leaching/electrowinning performance of a Batch Inline Leach Reactor. The mine operates five Knelson concentrators producing approximately 2500 kg's of concentrate per day. Previously the concentrate was treated over a two stage tabling process over two tables. The gravity concentrate was first screened over a 1 mm screen, then the minus and plus size fractions tabled separately. First over a large table as a rougher and the concentrate then cleaned over the second table. The table tails were returned to the grinding circuit. The process was very labour intensive with two or three qualified metallurgical personnel required every second day to process the concentrate. There were additional personnel required as security during the tabling process.

A sample of gravity concentrate was forwarded to Gekko Systems Pty Ltd for laboratory scale high intensity cyanide leaching and associated electrowinning test work on the leach solutions generated. The test work determined the leach kinetics, reagent regime and electrowinning capacity required.

The concentrate is treated in an ILR2000 Batch-Automatic (ILR2000BA) operating on a 24 h cycle. The clarified solution is transferred to the gold room for electrowinning using two Alglass electrowinning cells in series. Since the unit is fully automated there is only intermittent operator involvement required during the process. Fig. 8 shows the leach and electrowinning performance of the unit.

The ILR2000BA utilises oxygen, which is sparged into the leach solution. DO levels of 10 ppm are main-

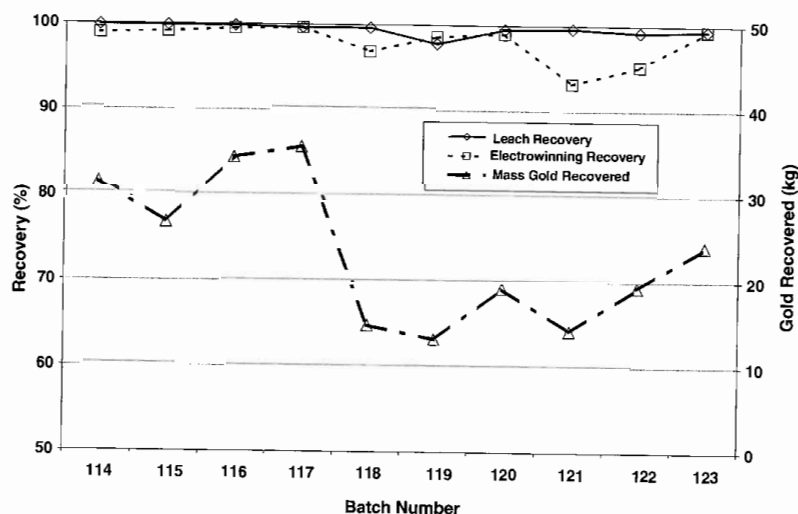


Fig. 8. Leach and electrowinning results for Indonesian ILR2000BA.

Table 3
ILR2000BA performance in Indonesia

Batch no.	Concentrate mass (tonnes)	Leached		Residue grade		Leach recovery		E'Win recovery	
		Au (gr)	Ag (gr)	Au (ppm)	Ag (ppm)	Au (%)	Ag (%)	Au (%)	Ag (%)
114	2.20	31,465	7356	15.87	13.00	99.9	98.2	98.9	99.3
115	2.05	26,788	7915	17.14	5.60	99.9	99.3	99.1	98.4
116	2.46	34,401	6985	22.10	3.40	99.8	99.5	99.5	99.1
117	2.03	35,694	7006	57.90	4.10	99.7	99.5	99.6	99.7
118	2.60	14,824	4628	18.90	2.64	99.7	99.5	96.9	99.3
119	2.56	13,201	4493	114.00	3.21	97.8	99.4	98.6	95.0
120	2.58	19,201	6079	34.00	3.75	99.5	99.4	99.0	96.1
121	2.50	14,231	4093	21.00	11.00	99.6	97.4	93.2	98.0
122	2.76	19,333	4980	56.00	8.00	99.2	98.5	95.2	98.5
123	2.67	24,062	6061	54.00	28.00	99.4	95.9	99.4	99.3
Average	2.44	23,320	5959	41.09	8.27	99.5	98.7	98.0	98.3
Maximum	2.76	35,694	7915	114.00	28.00	99.9	99.5	99.6	99.7
Minimum	2.03	13,201	4093	15.87	2.64	97.8	95.9	93.2	95.0

tained on the drum discharge (the requirement for oxygen addition was determined at the laboratory testwork stage). The results show very good recoveries with an average of 99.5% gold dissolution in the gravity concentrate. Gold electrowinning recoveries averaged 98% on the leach solutions, Gray, 2002. From gold feed grades of approximately 10,000 g/t, residue grades of 50 g/t are regularly obtained. Table 3 shows the detailed performance of the unit. The silver recoveries are also high—only 1% below the level attained for gold. Along with associated high silver electrowinning recoveries.

4.2. Western Australia

Results from a recent trial at a mine site located in the Yilgarn region of Western Australia using an ILR100 Batch-Manual to treat gold room wheel tailings from Knelson gravity concentrates are detailed below and in Table 4. This sulphide gravity concentrate containing high levels of pyrrhotite was known to be extremely oxygen consuming and difficult to leach. The addition of either hydrogen peroxide or Proleach™ was found to provide leaching conditions that enabled excellent results to be obtained.

With the addition of either hydrogen peroxide or Proleach™ leaching kinetics were such that final recoveries were achieved after 20–22 h of leaching, achieving 98.2% using hydrogen peroxide addition and 98.5% using Proleach™. Overall gravity concentrate recoveries increased from an average 63% using a gold wheel and ranging from 28% to 85% alone to an average 98.4% ranging between 97.2% and 99.3% using the ILR and gold wheel. Similar recoveries are expected for full gravity concentrate leaching in the ILR, a single leach was conducted using the full gravity concentrate with 97% recovery achieved after 19 h of leaching and 94.3% final recovery after 49 h of leaching using hydrogen peroxide.

This shows that the use of the ILR increased the recovery of gold from the gravity concentrate from a volatile average of 63.1% to a more consistent average of 98.4% overall recovery. An additional advantage for the site was the possibility to increase the number of Knelson dump cycles and therefore further increase the overall gravity gold recovery, which was previously limited by the time required to treat the Knelson concentrate being produced using the wheel.

Table 4
Western Australian minesite trial data

Feed	Reagent	ILR feed mass (kg)	Initial Au grade (g/t)	Residual Au grade (g/t)	ILR Au recovery	Wheel Au recovery	Total Au recovery
Wheel tails	Peroxide	680	1203	21	98.2%	62.5%	99.3%
Wheel tails	Peroxide	295	1247	68	94.5%	85.4%	99.2%
Wheel tails	Peroxide	295	1419	98	93.1%	73.7%	98.2%
Wheel tails	Peroxide	295	2589	104	96.0%	46.9%	97.9%
Wheel tails	Peroxide	460	928	176	81.1%	85.2%	97.2%
Wheel tails	Peroxide	680	699	75	89.3%	81.8%	98.0%
Full conc.	Peroxide	460	2947	169	94.3%	47.3%	97.0%
Wheel tails	Proleach	960	2619	50	98.1%	59.1%	99.2%
Wheel tails	Proleach	560	1500	23	98.5%	73.5%	99.6%
Wheel tails	Proleach	680	3923	96	97.6%	50.9%	98.8%
Wheel tails	Proleach	680	5169	152	97.1%	28.2%	97.9%

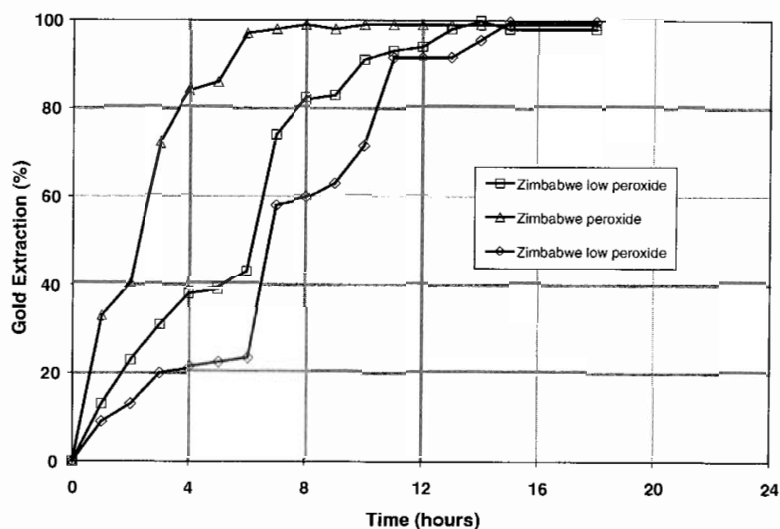


Fig. 9. Leach results for Zimbabwe ILR1000BM.

4.3. Zimbabwe

Site results from a gold mine in Zimbabwe in Fig. 9 show the leaching performance of a Batch Inline Leach Reactor. The mine operates Knelson concentrators producing approximately 1000 kg's of concentrate per day. The concentrate is treated in an ILR1000 Batch-Manual (ILR1000BM) operating on a 24 h cycle. The clarified solution is transferred to the gold room for electrowinning.

The ILR1000BM utilises hydrogen peroxide, which is dosed into the leach solution. Hydrogen peroxide is used since the site is very remote and does not have a ready source of plant oxygen. Cyanide levels of up to 4% in conjunction with DO levels of approximately 20 ppm results in high leach recoveries with in 8 h, Mooney, 2002. The mineralogy on the site requires a pH of less than 12.4 to be maintained during the leach. At pH levels greater the 12.4 the gold dissolution rate falls almost to zero—believed to be due to the presence of antimony. The gold leach recoveries attained are high—

over 99%. From concentrate feed grades of 4000 g/t tails residues of less than 40 g/t result.

The ILR1000BM was assembled and fully commissioned at Gekko Systems premises in Ballarat prior to shipment (refer Fig. 10). The unit was broken down into standard shipping containers for shipment to Zimbabwe. Commissioning on site was completed within two weeks with one experienced metallurgist from Gekko Systems working with the plant personnel.

5. Conclusions

The Batch Inline Leach Reactor enables gold operations to significantly increase the amount of gold recovered from gravity. Product from InLine Spinner, Falcon and Knelson Concentrators can now be effectively and efficiently treated. It brings substantial advantages by increasing recovery, improving security, reducing labour requirements, reducing capital costs and improving safety.

Routine recoveries of above 98% are obtained using proven chemistry without the requirement for exotic chemicals—using reagents that site operations are already confident and experienced in their use.

The use of BCC's in conjunction with a Batch Inline Leach Reactor allows for greater flexibility in the leach and CIP/CIL circuit, minimising the effects of grade fluctuations and throughput variations.

The Batch Inline Leach Reactor is a proven, reliable and simple addition to gravity gold circuits generating high gold recoveries.

Advantages of the InLine Leach Reactor

- Increased gravity gold recoveries.
- Improved security by eliminating manual concentrate handling.



Fig. 10. ILR1000BM for Zimbabwe.

- Eliminates smelting of metal sulphide concentrates and resultant toxic fumes.
- High shear agitation gives thorough mixing and increases reagent utilisation.
- Treats entire concentrate without removing gold bearing fines prior to leaching.
- Flexible, up-gradable capacity (batch to continuous; expandable drum).
- Fully integrated automation system with alarm, diagnostic and DCS capability.
- Low installed power and low power consumption.
- Space efficient design.
- Captures and leaches fine and coarse gold.
- Engineered to prevent gold precipitation on steel scats.
- Simple system with low component count; one drum; one pump; one sump; two tanks.
- Low operating costs with no requirement for expensive chemical leach agents.
- Low installed power of less than 10 kW.
- Dedicated clarification step reliably produces clear electrowinning solutions.
- Pregnant solution is highly suitable for recovery by electrowinning.

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