Successful Applications Of The InLine Pressure Jig With Particular Reference To The Recovery Of Gold and Diamonds

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Abstract

The Gekko Systems InLine Pressure Jig is a unique and efficient gravity separation device, which has found a wide variety of applications within the mining industry. The unit was originally developed in Australia for recovery of placer gold. The IPJ very quickly moved into the recovery of gold in grinding circuits given the unit's low water consumption and capital cost benefits. In the late 1990's research into the use of the IPJ in diamonds was commenced envisaging a number of potential benefits including security, low cost performance and simplicity of operation. Some of the advantages and applications of the IPJ in the recovery of diamonds including actual operating plant experience are covered in this paper. Other potential applications and the use of the IPJ for environmental rehabilitation are also discussed.

Introduction

The InLine Pressure Jig (IPJ) is an effective and efficient gravity separation device that has found application in the processing of a wide variety of minerals. While based on the same principles as traditional jigs, its pressurised design and advanced control system give it many advantages including high recovery, high unit throughput, low water use, close control of operating conditions, low installation cost, low operating costs and high security. The IPJ can be used either in placer deposits as the primary concentrator or in hard rock circuits to treat all or part of the cyclone underflow or mill discharge. As a result of the large range of jig parameters and ragging types possible, the IPJ has successfully been used for a range of minerals, including gold, sulphides, silver, native copper, tantalum, garnet and diamonds.

The IPJ is a compact, low cost continuous process that requires minimal infrastructure or logistical support. In addition to its low capital cost, it has very low operating costs per volume treated, and very low power requirements. Hutch water can be supplied from the ocean, rivers, boreholes, thickener overflow or slimes dam return. Trials using de-sliming cyclone overflow as hutch water have been conducted without any noticeable adverse effect on jig performance up to 5-6% solids w/w. The IPJ requires as little as 10% of the water consumption of traditional jigs.
There are currently over 100 IPJ's in operation around the World, many in Africa treating a variety of minerals, including 13 currently used in diamond applications.

Theory of Operation

The IPJ is unique in its design and use of jigging concepts. The unit is fully encapsulated and pressurised, and combines a circular bed with a moveable sieve action. The encapsulation allows the IPJ to be completely filled with slurry and water. As a result, slurry velocity is slowed and water surface tension eliminated improving recovery potential. The screen is pulsed vertically by a hydraulically driven shaft. Length of stroke and speed of up and down stroke can be varied to suit the application. Screen aperture, ragging dimension and ragging material can also be altered for the application. An overview is shown in Figure 1 below.

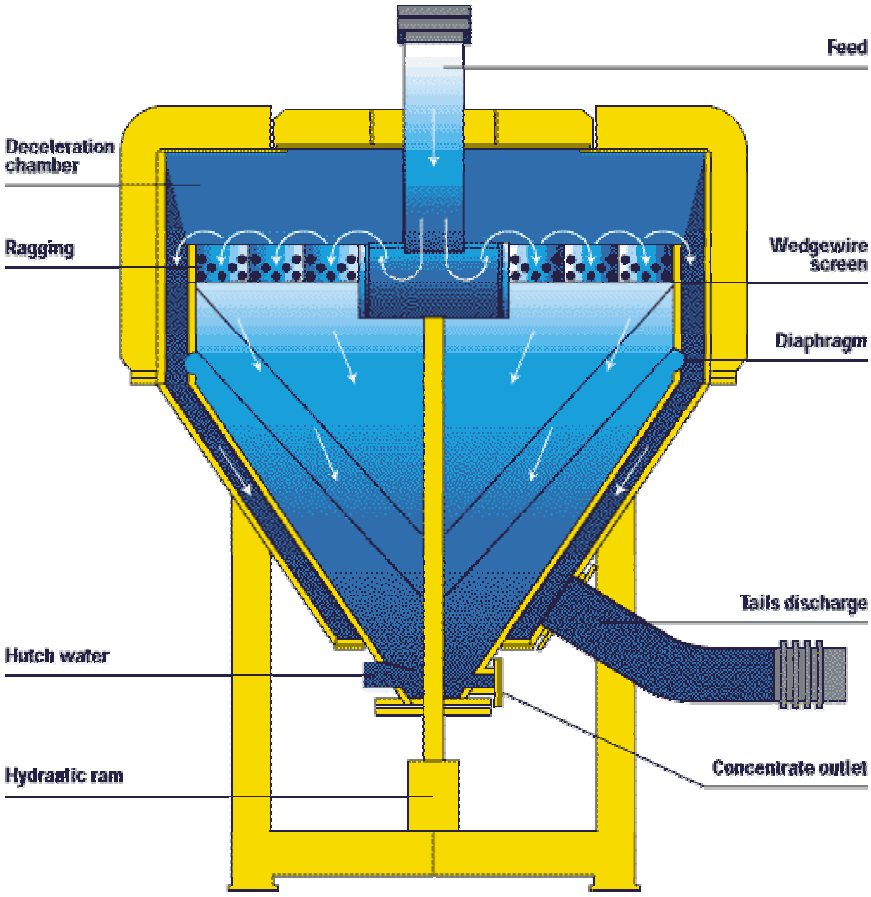

Figure 1: Cross sectional view showing overview of an IPJ

Separation of values from gangue particles occurs based on relative density as well as particle size and shape. High specific gravity particles are drawn into the concentrate hutch during the suction stroke of the bed and are continuously discharged. The lighter gangue is discharged over the tailboard to the outer cone. Both concentrates and tailings are discharged under pressure.

Advantages

Low water consumption: The IPJ's low impact on water balance allows grinding circuit operators to treat the full recirculating load and maximise the gravity recovery of minerals, gems or waste materials. In arid areas the availability of water can severely limit the use of gravity treatment options.

High yield, high recovery: As a continuous concentrate discharge unit, the IPJ offers a high degree of flexibility. Mass pull to concentrate can be varied from 0.5% up to 30% to optimise performance for a particular application.

Minimise grinding requirements: By recovering minerals or gems at their coarsest fraction the potential to recover by gravity is improved and over grinding of minerals is minimised.

Wide feed and particle size recovery: Feed sizing of up to 30mm is acceptable. In many circumstances this may eliminate the requirement for an additional screening step.

Easy retrofit: Given the pressurised nature of the IPJ, the unit can be easily retrofitted at ground level if desired. Tailings will return to mill discharge without the need for additional pumping.

Cost savings: The design of the IPJ is very efficient for the volume treated. As a result, capital and operating cost savings can be significant.

Gold Recovery by Gravity and the South African Mining sector

The introduction of gravity concentration systems into South African mineral processing plants has tended to lag behind the trend in the world's other major gold producing nations. This factor reflects both the engineering complexity issues in South African circuits as well as a concern over the security issues associated with the concentration of coarse free gold.

Areas in which the engineering characteristics of the South African industry vary from their foreign counterparts include the incidence of multiple smaller mills with associated screening, significantly higher levels of foreign material including steel and wire, single large diameter cyclones and high scat levels. As a general rule the South African gold mines run cyclones at low solids densities which diminishes the likelihood of coarse gold particles reporting to cyclone overflow

A number of factors have encouraged the local industry to move towards the installation of gravity circuits including the success of similar circuits worldwide and the introduction of intensive leach technology (which both enhances gravity circuit performance and eliminates security issues associated with hands on tabling processes).

Given the unique design issues for the local plants it has become evident that the design and engineering of the gravity circuit is of utmost importance to achieve full potential for these installations. As a result, Gekko Systems has developed, through collaboration and onsite trials, a comprehensive optimisation package. An outline of a number of recommended engineering solutions are discussed later in this paper.

Figure 2: IPJ Installation at Beaconsfield, Australia

Application of the InLine Pressure Jig (IPJ) to free and complex gold ores

The IPJ has achieved strong recoveries across a range of gold installations. The use of the IPJ to recover free gold has been driven by unit features such as low water consumption, capacity to use poor quality water and low maintenance.

Increasingly the industry has recognised the very strong benefits of the IPJ in the treatment of complex gold ores. The IPJ operation differs from batch centrifugal concentrators (such as the Knelson and Falcon SuperBowl) in that it produces a continuous concentrate discharge. This allows the IPJ to recover a high proportion of the feed to concentrate and to optimise the total recovery achievable by gravity.

Witswatersrand Ores – greater potential with gravity in the long term.
Gekko has undertaken test work on a number of different Witswatersrand orebodies and created grade recovery curves to identify the full potential of gravity for this particular mineral deposit.

The results are exciting and underscore the potential of reviewing gravity in a wider application than purely the recovery of a low mass pull, high grade concentrate.

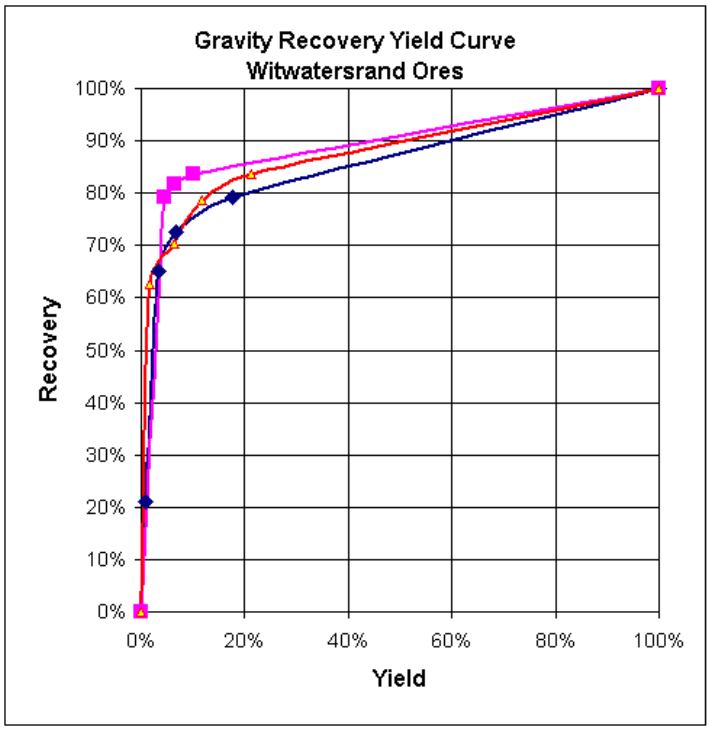

Figure 3: Gravity Yield Curve on Various Witswatersrand Ores

The above chart shows the amenability of several Wits type ores to gravity separation. The separations are carried out on a small Wilfley style table and represent the increased gold recovery possible with increased yield. This testwork is representative of the potential performance of the IPJ and indicates that as a higher mass is recovered to the concentrate the overall recovery of gold increases. Accordingly the concentrate grade drops.

The chart shows that high potential recoveries (greater than 80%) with mass pulls of less than 10% of the feed mass are possible from some Wits ores. The gold recovery increases over and above that normally seen in Wits gravity circuits as the sulphide associated gold component of the ore is recovered. Because the InLine Pressure Jig is a continuous recovery device it recovers the gold bearing sulphide component as well as the free gold component and hence increases overall gravity gold recovery.

The potential benefit of maximising gravity recovery

By increasing recovery by gravity, costs are reduced, chemical usage is reduced, low cost plant throughput upgrades can be achieved, security is improved and complex difficult to treat mineral components can be intensively treated to minimise gold losses to tails.

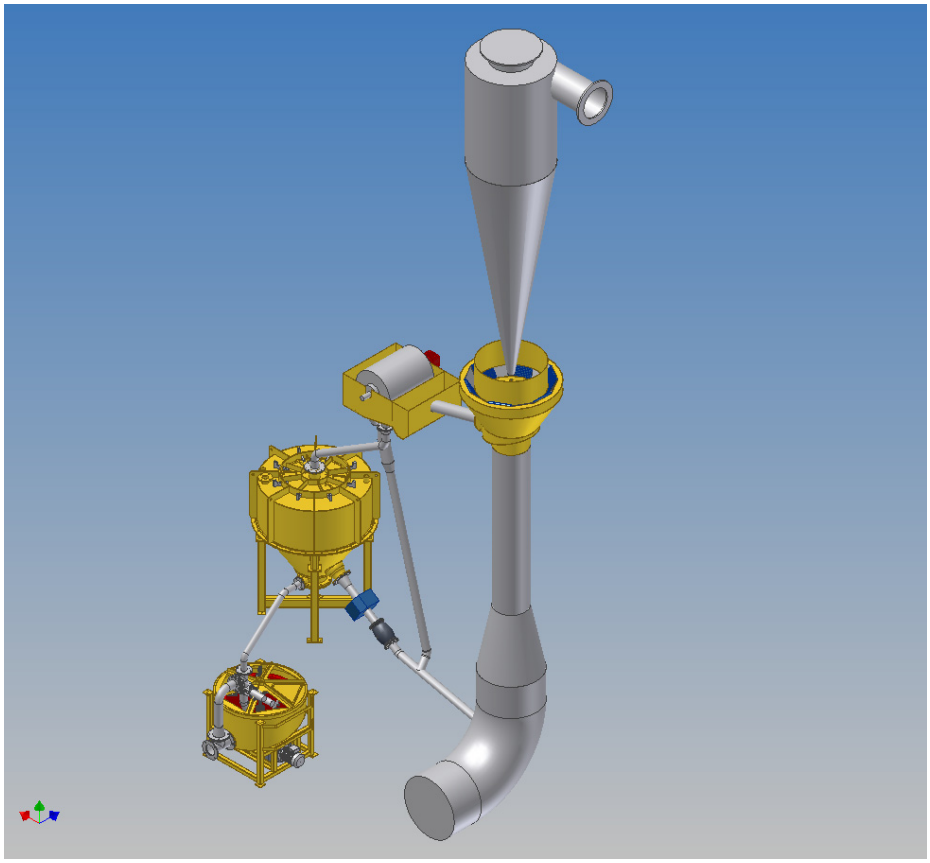

Figure 4: General Arrangement of Gravity Circuit designed for South African Conditions

Gekko have designed the circuit illustrated above for recovery of free gold from Witswatersrand ore. The features of the flowsheet are low water consumption, the use of poor quality water, , a purpose designed feed splitter for taking a portion of feed from the cyclone to the gravity circuit, a purpose designed magnetic separator for removal of scats followed by a primary jig and a secondary spinner concentrator

It is expected that following installation of the first of these free gold recovery gravity circuits that further testing would follow rapidly to verify the potential of the high mass pull circuit indicated by the testwork.

Summary of Key Engineering Issues for RSA Gold Plants

- Managing water consumption associated with the larger numbers of smaller mills, screening units and hence gravity devices required.
- Difficulties in maintaining flows from split lines from larger single cyclones and representivity of the split.
- Magnetic separation is highly recommended prior to the treatment of slurries by gravity given the high tramp and scat levels which are typical of SA circuits. Intensive Leach of Concentrates - using the Gekko InLine Leach Reactor is highly recommended for the ease, recovery and security of handling concentrates produced.

Gold Concentrate Handling – InLine Leach Reactor

Until the advent of intensive cyanidation, gold gravity concentrates were generally treated by tabling, with the table concentrates being smelted while table middlings and tailings were recycled to the milling circuit for further grinding and subsequent leaching in the CIP/CIL circuit. Gold recovery on production tables is relatively low, often only 30 percent, and rarely above 60 percent. Significant factors in tabling performance are mineralogy and the operator's experience and ability. Units have been developed by Gekko to treat both batch and continuous gold concentrates. Unit sizes are determined by leach kinetics and required residence time of the concentrate in the unit.

The commercialisation of intensive leaching of gravity gold concentrates was commenced by Gekko in 1997 with the first commercial prototype of the InLine Leach Reactor (ILR). Nearly 20 units are now installed worldwide with over half that number on the African continent. South African mines, South Deeps (Placer Dome WAJV) and Target (AvGold) have both installed InLine Leach Reactors. Ashanti Goldfields have placed the ILR on their standard equipment list and have six units in total. AngloGold installed one of the first ILR production units at Morila in Mali.

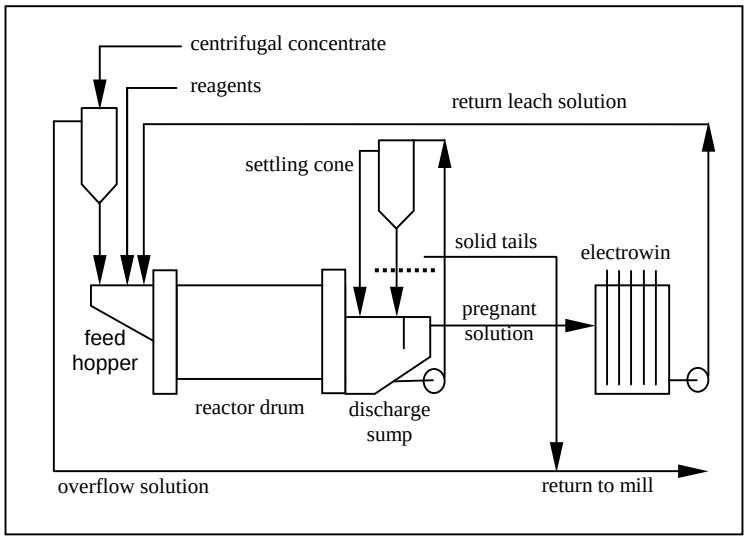

Figure 5: Schematic Flowsheet

For further information on the inline Leach Reactor visit website www.gekkos.com

Figure 6: Target Smelthouse Staff with the ILR

Please refer to the www.gekkos.com site for more information on the InLine Leach Reactor

Application of the IPJ to Diamond Processing

The InLine Pressure Jig was the basis on which Gekko Systems was formed in 1996. Shortly thereafter research into the use of the IPJ for diamond recovery was started, due to a number of potential benefits including high security, low cost performance and simplicity of operation.

Advantages also include mobility, high efficiency, low installation and operating cost, low water consumption, and low power consumption.

The adoption of some minor design changes to the standard IPJ has resulted in new “diamond” jig specifications. Synthetic ragging of uniform size and controlled specific gravity has also been developed by Gekko Systems to further improve the performance and operation of the IPJ. An example of the diamond screen with synthetic ragging is shown in Figure 7.

Figure 7: IPJ diamond screen and synthetic ragging

The performance of the IPJ is enhanced by the use of a sealed lid, which apart from process performance advantages does not require a stable platform for optimum performance.

This has resulted in successful trials and the installation of equipment in various diamond applications, which include:

- Marine
- Alluvial
- Tailings
- Hard rock treatment plants
- Exploration

Potential areas of flowsheet application specific to diamonds include:

- Upgrading Dense Media Separation (DMS) feed by removal of waste
- Upgrading diamond pan concentrate
- Scavenging diamond pan tails
- Continuous treatment of DMS tailings to monitor plant performance
- Plant upgrades where DMS capacity is limited

- A higher security alternative to Pleitz Jigs
- Volume reduction in operations where transport costs are high

Marine

It is a known fact that in all coastal applications including surf-zone and beach deposits, media losses can be significant. The IPJ is successfully employed ahead of DMS treatment for pre-concentration of gravel which results in improved performance and a reduction in operating costs. Gekko Systems supply IPJ units specifically rated for coastal conditions, designed to ensure the unhindered passage of diamonds through the unit.

Alluvial

Typically operators of small-scale mines work in remote regions often situated on riverbanks. Equipment is required to be mobile and simple to operate. Diamond pan plants are often employed for primary gravity separation. Fear of diamond loss results in an abnormally high ratio of concentrate to waste, which hinders the diamond sorting process further downstream. Operators have to maintain the "puddle" density unlike the IPJ, which uses the density of the ragging to control the split density. The IPJ is capable of producing a low mass pull to concentrate without diamond loss, which results in more efficient final diamond sorting. The equipment is compact using less water than conventional gravity separation devices with the added advantage of a sealed lid for security.

Tailings

Tailings from conventional hard rock diamond recovery plants and alluvial gravels are often found to have a higher diamond content than expected. This is due to process plant inefficiency, which is attributed to poor process control with earlier treatment processes often employing diamond pans. The re treatment of tailings is economically justified when large volumes of tailings can be efficiently processed resulting in a diamond-rich concentrate of low mass which is then sent to DMS or the diamond sorting process. Recent tests have proved a 100% recovery of diamond tracers, which reported to a concentrate comprising only 10% of the total mass fed to the IPJ.

Hard Rock Treatment Plants

Conventional diamond recovery plants include crushers, screens and scrubbers for pre-treatment ahead of DMS. The DMS plant design is often limited by volume resulting in the discard of –2 mm diamondiferous material ahead of DMS. The use of IPJ's ahead of the DMS would result in a pre concentrate relieving DMS capacity and reducing ferrosilicon consumption. Existing treatment plants would therefore benefit from increased throughput with a reduction in operating costs.

Exploration

Diamond exploration requires the use of cost effective mobile equipment for ease of transport and installation. Water conservation is important since this is not always readily available. Typically a rotating trommel and vibrating screen are used ahead of a pilot 5 t/h DMS plant with a bottom cut size of 1.5mm for DMS feed. The IPJ would be employed ahead of DMS or X-ray sorting devices to prepare a low volume/diamond rich concentrate feed. Gekko Systems have designed and supplied skid-

mounted mobile plants for exploration purposes where primary and secondary stage IPJ's are utilised. The primary stage IPJ acts as a pre-concentrator, delivering to the 'cleaner' secondary stage IPJ for production of a concentrate suitable for the X-Ray sorting process.

Boungou River Project - Central Africa Republic

The Boungou River Project is an alluvial diamond deposit that is situated in south-eastern Central Africa Republic (CAR), some 80 kilometres north of the town of Bria, one of the country's largest diamond centres. The region reportedly accounts for some 25% of the CAR's total annual diamond production of approximately 450,000 carats. Gekko Systems has supplied a complete modular plant including power, water and ancillary modules. The processing module comprises a two stage "through the bed jigging" plant with a capacity of 50 tph and is pictured in Figure 8. Manufacturing and dry commissioning was completed at the Gekko factory in Ballarat, prior to containerising and shipping

Figure 8: Boungou alluvial diamond plant during dry commissioning at Gekko Systems prior to dispatch

Williamson Diamond Mine – Tanzania

Figure 9: Williamson Diamond Mine Processing Plant - Tanzania

Tanzania has one operating diamond mine at Mwadui, south east of Mwanza. The Williamson diamond mine (Figure 9 above) is operated and owned by De Beers (70%) and the Tanzanian government. The Mwadui kimberlite deposit was one of the world's largest producing kimberlite pipes. The mine has been in operation since 1940 and has produced around 2Mct. Production has dropped significantly, due to flooding of the mine coupled with decreasing ore reserves. The mine produced 320,000 carats in 2000 and 190,000 in 2001 with the recovered diamond grade also reducing. Williamson are currently processing the extensive diamond rich tailings and as a result, production is set to increase to over 30,000ct/month.

A low capital cost solution was required to increase diamond production that would not significantly increase the current operating costs. A conventional diamond treatment plant was considered to retreat the old DMS tailings but proved too costly. Williamson were aware that Debtech and Gekko Systems had been successfully performing trials to remove shell from marine gravels using the IPJ, and saw an opportunity to also test the application of the IPJ on their old DMS kimberlite tailings.

A test jig (IPJ 1500) was installed in July 2001 at Williamson and testwork conducted on the feasibility of recovering diamonds from the old DMS tailings (Figure 10). Initial testwork conducted using tracer diamond simulants showed 100% recoveries using 25, 16, 12, 8 and 6mm tracers and 98% recoveries of 4mm tracers.

Figure 10: Trial IPJ 1500 onsite at Williamson Diamond Mine - Tanzania

Following the success of this initial testwork a bulk sample program was conducted and the first diamonds were produced. Numerous diamonds were recovered including fine and flat diamonds, which are the main revenue target of the tailings retreatment. The IPJ was found to be capable of concentrating the diamonds into 10 - 15% of the initial mass, at an operating cost of less than US$0.02 per tonne treated compared to US$0.25 per tonne treated using DMS.

A plant was then designed to treat 4.2 Mtpa of old DMS tailings, with 600 tph of feed between 1.5 and 25 mm being treated using six IPJ 2400's. The IPJ's have reduced the overall treatment cost per ton with a low associated capital cost. Reductions have also been made in the power consumed per tonne treated and in water consumption. Further investigations are also being made into using the IPJ's in the treatment of normal run of mine ore in the main treatment plant.

A complete conceptual and detailed design of the plant was performed on site with significant input from Nigel Grigg, Gekko Systems and the De Beers research unit, Debtech in South Africa, with the whole project completed within one year.

Figure 11: Installed IPJ's and newly constructed tailings treatment plant

Kimberley Diamond Company Ellendale Diamond Project – Australia

Located in the West Kimberley region of Western Australia this project has successfully trialled and then incorporated the IPJ into their stage one processing plant. This has allowed the operation to increase planned stage one throughput from an expected 500,000 tpa to 715,000 tpa at no additional capital cost.

Initial testwork was conducted using an IPJ 1500 onsite to remove organic material and possibly pre concentrate lamproite to the DMS plant. Following the success of this testwork to remove organic material, further diamond tracer testwork was conducted. This testwork indicated that at a 30% mass yield the IPJ was capable of recovering +98% of the feed diamonds. Further reductions in the mass yield while maintaining diamond recovery could be possible.

Based on the trial results an IPJ 2400 was incorporated into the production plant at Ellendale and has the potential to more than double the initial expected feed rate of the existing production plant.

Application to Other Minerals

The IPJ has been used extensively in the gold extraction industry in Australasia to recover gravity gold from the milling circuits, and has also been applied to native copper, lead/zinc, tin, tantalum, garnet and native silver processing.

A number of further applications exist, including the coal, iron ore, beach sands, platinum and ferrous metals industries to name a few which are currently under investigation.

A particularly exciting aspect of the IPJ's application is in environmental clean-up, a major area of focus in the industry currently. Gekko are currently looking with potential customers into the retreatment of previously non-viable ferrous ore dumps and also coal discard dumps.

Conclusion

The IPJ has the potential to be successfully applied to a number of different applications both within the gold and diamond industry and in many other sectors. As with the application of any technology, testwork and trialling are paramount in the successful implementation to a particular application.

There is significant interest in the gold processing industry in Africa generally for the application of IPJ technology for the recovery of gravity gold.
Gekko Systems are currently investigating installations for retrofit into existing gold operations and as the dedicated gravity circuit in a number of new plant designs. This interest spreads from North Africa to South Africa and encompasses most of the major goldfields in between.

The IPJ has also been shown to be successful in the preconcentration of gravels in marine diamond applications and in reducing feed mass in ROM and tailings re treatment ahead of DMS while maintaining diamond recovery. Many other areas of mineral recovery exist where the IPJ can be successfully employed. Low initial capital cost and ongoing operating costs, when compared to other processes, have the potential to increase investor return and significantly reduce operating costs whilst

increasing security and maintaining recovery, thereby making previously sterile resources viable. All these areas are paramount to the success of an operation in an increasingly competitive industry.

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