Reduction of Free Gold Losses in the Cleaner Circuit with the Installation of a Gravity Circuit at the Kemess Mine

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ABSTRACT

The Kemess mining and milling complex is operated by Northgate Minerals Corporation and is located in the mountains of north-central British Columbia, 430 kilometers northwest of Prince George. The complex consists of the Kemess South open pit mine and a 52,000 tonnes per day mill. Hypogene, supergene and leach cap ores are processed using conventional crushing, grinding, and flotation techniques to produce gold-copper concentrates with minor by-product silver value.

The rougher flotation concentrate is re-ground in closed circuit before being cleaned to final concentrate grade. Historically, gold losses in the cleaner tailings were primarily associated with pyrite, with only minor amounts of free gold. More recently, with the processing of high pyrite ores, the major losses were found to be free gold less than 10 microns in size. The fine grind required for the high pyrite ores resulted in over-grinding of the free gold particles in the regrind circuit, contributing to poor flotation characteristics. It was thought that if this free gold could be recovered by gravity at coarser size in the regrind circulating load, the free gold losses in the cleaner tailings could be reduced.

Preliminary test work carried out by Knelson Gravity Solutions indicated the potential for free gold recovery in the regrind circuit. A Knelson XD-30 Concentrator was installed with variable speed capability, and a series of optimization tests were carried out. In addition, cleaner tailings were characterized with gravity operating and with gravity not operating to determine the overall gold recovery benefit. The single Knelson XD-30 installation recovers ~10% of the total gold in the regrind circuit and increases overall recovery by 3% when high pyrite ores are processed.

INTRODUCTION

Among Northgate's principal assets are the 300,000 ounce per year Kemess South operation and the adjacent Kemess North property, which contains proven and probable reserves of 4.1 million ounces of gold.

Processing 52,000 tpd, the Kemess concentrator consists of a primary gyratory crusher feeding two identical standard SAG / Ball mill circuits in parallel. Rougher flotation consists of four parallel rows, each with eight tank cells. Rougher concentrate (2% Cu, 6 g/t Au) is pumped to a Metso regrind mill to produce a regrind circuit product of 80% passing 40 microns. This product is fed to a cleaner flotation circuit consisting of two stages. The first cleaner stage takes place in two parallel rows of conventional Denver cells. The first cleaner concentrate is further upgraded in two column flotation cells in series, designed and constructed by Kemess to produce a 22% copper concentrate grade. Cleaner flotation middlings are returned to the regrind mill. Figure 1 shows a simplified flotation circuit flowsheet.

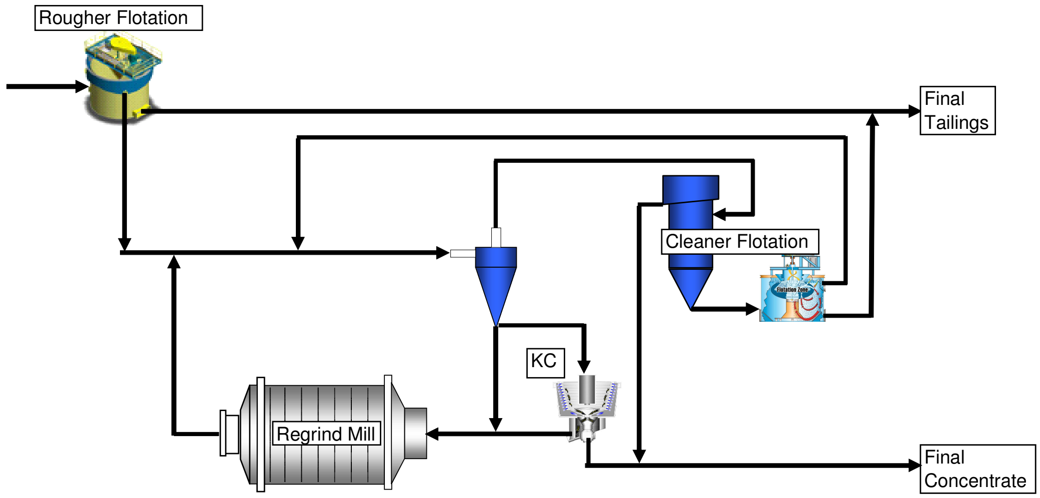

Figure 1: Simplified Flotation Circuit at Kemess

This paper focuses on the Knelson Concentrator recently installed in the regrind circuit. This is a unique application for a Knelson Concentrator, due to the fine gold particle sizes being targeted in this circuit. A cooperative effort between Kemess and Knelson Gravity Solutions resulted in a greater understanding of the gravity concentration of fine particles on a production scale. Preliminary testwork, optimization, and evaluation of benefits to date are discussed, as well as the concentrator's importance in the future success of the Kemess operation.

MINERALOGY / PROBLEM STATEMENT

The Kemess South deposit is a large gold-copper porphyry containing proven reserves of 87 million tonnes. The deposit contains three principal types of ore: a primary sulphide hypogene ore; a copper-enriched secondary sulphide ore; and an oxidized supergene leach cap ore. The hypogene ore makes up approximately 85% of the ore body.

During the first quarter of 2005, an ore uncharacteristic of the main Kemess south ore body was milled. This ore was atypically high in pyrite and low in pay metal content, with an intimate association of pyrite with fine-grained chalcopyrite. In order to achieve a concentrate of acceptable quality, very fine regrinding was required. This was at the risk of cleaner circuit recovery losses with increasing feed fineness. Hence, regrind fineness was increased gradually. Ultimately, a regrind circuit product size in the range of 80% passing 20 microns was realized.

As expected, with increasing fineness of regrind, a notable loss of cleaner flotation performance occurred, due to hydrodynamic factors. Attempts were made to optimize the cleaner flotation circuit to target fine particle recovery, with limited success. Gold deportment analysis on cleaner flotation tailings samples during this fine regrind period revealed that the majority (over 70%) of the cleaner circuit gold losses occurred as minus 10 micron free gold.

In light of the Kemess North proposed expansion, concerns arose that there would be similar cleaner flotation circuit gold losses during the processing of Kemess North ore. While the average pyrite to chalcopyrite ratio (Py:Cpy) of the Kemess North ore is expected to be considerably lower than the ore milled in the first quarter of 2005, it will nonetheless be considerably higher than that of the typical Kemess South ore.

Copper and gold grades as well as pyrite and chalcopyrite contents expressed as a ratio of pyrite to chalcopyrite for each of the Kemess South, Kemess North, and Q1 2005 ores are displayed in the table below.

Table 1 – Comparison of Kemess North and South Ores

Ore	% Cu	Au (gpt)	Py:Cpy
North	0.20	0.40	4.7
South	0.22	0.75	1.5
Milled Q1 2005	0.20	0.62	7.0

Amtel's mineralogical assessment of gold deportment in the high pyrite material found the gold to be generally fine-grained. Gold occurs principally in two forms: native and electrum in a ratio of approximately 10:1. Free / liberated gold grains are typically small, with 83% contributed by particles finer than 20 µm in size, as depicted in Figure 2.

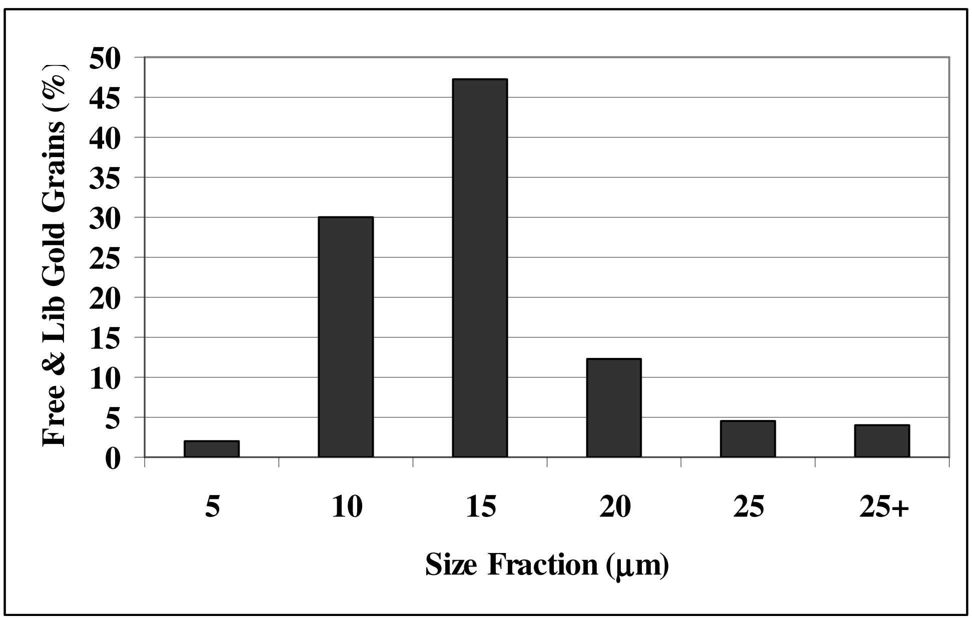

Figure 2 - Free & Liberated Gold Grains in High Pyrite Feed Material

In previous years very little of this high pyrite ore had been milled, due to unfavourable market economics. As such, the operation's experience with it was limited. Previous in-house and external testwork (including locked cycle tests) was reviewed and the recommended operating strategy of high rougher mass pull and reagent dosage combined with aggressive regrinding (p80 of 20 microns) was implemented. Unfortunately, plant results did not meet metallurgical performance expectations.

From comparison to various sampling campaigns and process observations it quickly became clear that regrinding to this fineness resulted in excessive gold losses in the cleaner circuit. Amtel was employed to further investigate the nature of the gold losses and through various studies confirmed that rougher flotation was being performed adequately, but significant losses were evident throughout the various stages of the cleaner circuit in the form of free, flat, flaky particles. The majority (72%) of the cleaner circuit gold losses to tailings, however (displayed in detail in Figure 3 below), occurred as free gold in the slimes fraction (minus 10 microns). This was attributed to recirculating free gold particles in the cleaner and regrind circuits that were eventually ground to an unfloatable size.

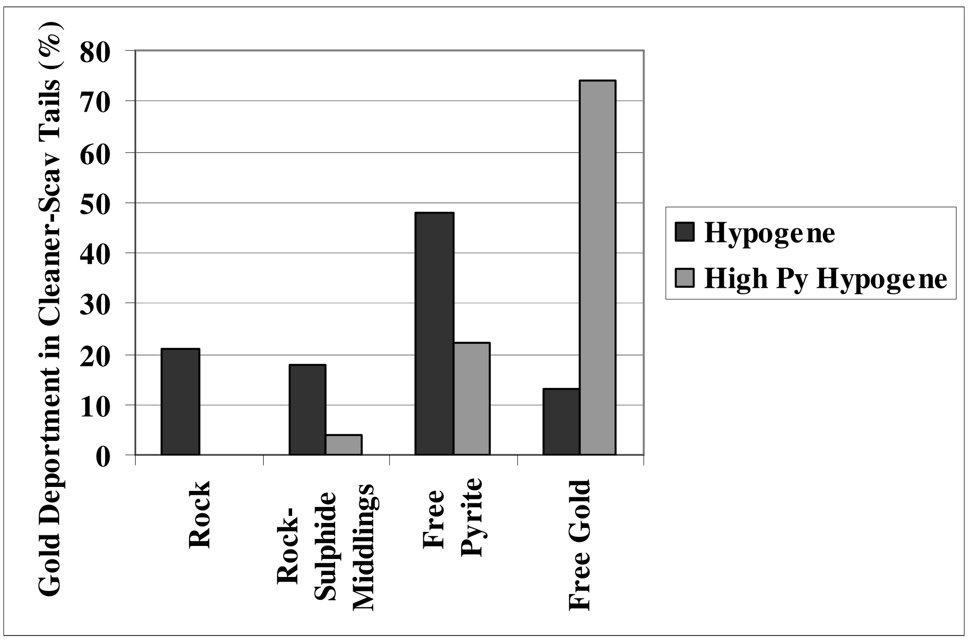

Figure 3 - Gold Deportment of Cleaner Scavenger Tailings With Py:Cpy of 14:1

Due to the continued cleaner flotation gold losses in spite of significant circuit changes aimed at recovering fine gold particles by flotation, a different approach was required. The question that then arose - “Can the free gold be removed prior to the cleaner circuit?” -initiated the idea of gravity concentration in the regrind circuit, and a new investigation began.

BENCH SCALE GRAVITY TESTING

To determine whether gravity recovery might be practical for a given application, bench scale testing and mathematical modelling is used. Knelson uses a proprietary modelling program developed in-house, called KC MOD*Pro. Predicting gravity recovery at full scale requires data on the following to be known or inferred:

- The Gravity Recoverable Gold (GRG) of the feed to the circuit
- The GRG partition curve of the cyclone
- The GRG unit recovery of the primary recovery device

For typical gravity circuits, where Knelson Concentrators are installed in primary grinding circuits, as opposed to regrinds circuits, there is a large database of GRG partition curves and GRG unit recoveries of the Knelson Concentrator. For regrind circuits, there was no existing data to use as a guide. Thus, in addition to characterizing the feed to the circuit (in this case the rougher concentrate), samples around the regrind cyclones were characterized to develop the data with which to predict potential gravity recovery. As there was no full scale data on Knelson unit recovery, several ranges of possible recovery were used for modelling purposes.

Gravity Recoverable Gold Testing of the Rougher Concentrate

To determine whether gravity recovery might be possible, a sample of rougher concentrate was sent to Knelson Gravity Solutions for Gravity Recoverable Gold (GRG) determination. Normally, to determine the GRG value of an "ore", a one to three stage grind/gravity recovery test is carried out (Woodcock, 1993). In this case the "ore" was rougher concentrate and a two pass test was carried out. The first pass processed the sample through the Knelson MD-3 laboratory Concentrator as it was received. The tailings from the first test were then ground to a p80 of 38 microns, and the sample was processed once again through the Knelson MD-3. Higher g forces were used due to the fine nature of the gold. The two concentrates were sized and assayed to extinction, and representative samples of each stage's tailings were sized and assayed. The entire test was balanced, with results presented graphically in Figure 4.

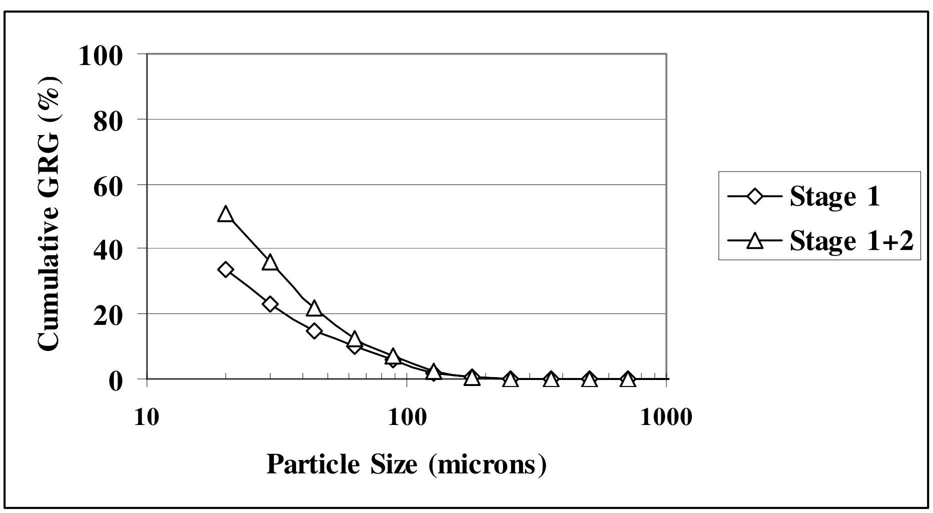

Figure 4- Cumulative GRG Content of the Kemess Rougher Concentrate (Knelson)

A rougher concentrate sample was also sent to Dr. Andre Laplante of McGill University for third party verification. The results shown in Figure 5 (Laplante, 2005) were similar to the Knelson results. Both tests showed the potential for gravity recovery in the regrind circuit. However, it was exciting to realize that the results were very encouraging in a size range where gravity recovery historically was problematic.

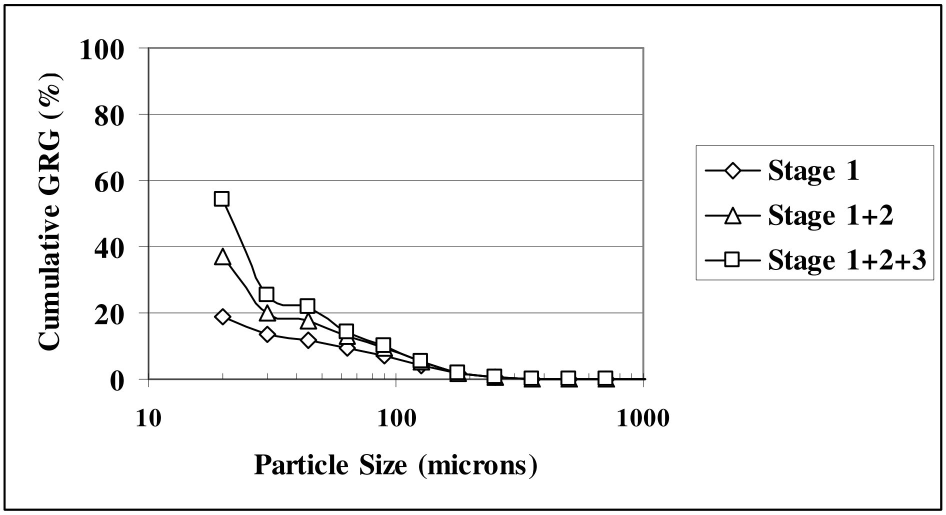

Figure 5- Cumulative GRG Content of the Kemess Rougher Concentrate (McGill)

Gravity Recoverable Gold Content of the Cyclone Samples

Samples of regrind cyclone feed, underflow, and overflow were received by Knelson and characterized for Gravity Recoverable Gold. The results were balanced and a GRG partition curve for the cyclone developed. This GRG partition curve, along with the GRG of the rougher concentrate and some assumed Knelson GRG unit recovery data, allowed for a preliminary determination of expected gravity recovery.

PRELIMINARY MODELLING OF THE KEMESS REGRIND CIRCUIT

The following data was used to model the regrind circuit at Kemess.

- Feed rate: 206 tph rougher concentrate to regrind circuit
- GRG of the rougher concentrate: 50.9% as determined by the Knelson GRG test
- Feed rate to Knelson XD-30: underflow from one cyclone, 41 tph feed rate based on 79% circulating load
- Knelson unit recovery: three assumptions used - optimistic, moderate, and conservative
- Cyclone GRG recovery: as determined by cyclone GRG balance

The best location for a Knelson Concentrator in the circuit was in regrind cyclone underflow, taking approximately 25% of the flow as feed. Sufficient height was available to feed the Knelson tailings directly back to the regrind mill feed, with no short circuiting. No sizing screen was required in this application, due to the narrow size range of the Knelson feed.

The choice of installing a Knelson in cyclone feed or cyclone underflow was another consideration. Modelling an installation of the Knelson treating cyclone feed instead of cyclone underflow reduced predicted gravity recovery quite significantly, up to 30% less. Generally in a primary circuit there is little between one versus the other. In this case, due to the very low circulating load, cyclone underflow was a much smaller stream, so a larger portion of the underflow could be treated with a given concentrator size.

It was estimated that gravity recovery of between 7% and 13% might be achieved with the installation of a single Knelson XD-30. The wide range of expected results was due to uncertainties in Knelson unit GRG recoveries on a plant scale installed in a regrind circuit.

PILOT OR FULL SCALE?

To generate data on Knelson Concentrator unit GRG recovery in a regrind circuit, pilot scale testing could have been carried out. The alternative was to install a Knelson Concentrator on a trial basis and measure full scale performance. The low installation costs of this option as well as the opportunity to characterize the benefit to overall gold recovery made this option much more attractive. The decision to trial a Knelson XD-30 Concentrator was made in May 2005.

FULL SCALE INSTALLATION

A structural platform was designed and installed to support the XD-30 installation. The Concentrator was ordered with variable gravity (VG) configuration, which allows operation up to 200 g to target fine GRG. It was also thought that very short concentrating cycle time might be of benefit in this application, and thus the Concentrator also was supplied with a dynamic brake. This made the total off-line time less than one minute per cycle for flushing the concentrate. The unit was commissioned in August 2005. Total installed cost was in the order of $150,000, not including rental of the unit.

By comparison, modelling carried out by Knelson in 2003 for gravity recovery in the primary circuit suggested that the installation of three Knelson XD-48 Concentrators, processing 1200 tph of primary circulating load, would have only recovered about 6% of the total gold after tabling losses were accounted for. This is due to the relatively fine grained nature of the gold in the Kemess mill feed in general. It is estimated that the capital and installation costs of a large primary gravity circuit (including screening and pumping requirements) would have been approximately an order of magnitude higher than a regrind gravity circuit installation. Clearly, being able to predict outcomes by modelling in advance is of high benefit and is very cost effective.

OPTIMIZATION TRIALS

Operating Parameters

The preliminary modelling indicated that actual gravity recovery would be more sensitive to the unit GRG recovery of the XD-30 in this application than in a primary circuit. This is because a greater portion of the gold particles are expected to report to the cyclone overflow after one pass through the mill. It was decided to run a large matrix of optimization tests to maximize recovery with a single concentrator. Varied optimization parameters were as follows:

- Feed slurry density
- Cycle time
- Feed rate, from 38 to 134 tph
- G force, from 60 to 150 g
- Fluidisation water flow, from low setting to high setting for each cone type

Concentrating Cone Design

The standard Knelson Concentrating cone for the last decade has been the Generation 5 (G5) Cone. This cone has both fluidised and unfluidised recovery "rings" where gold is recovered and retained. This was the cone supplied with the XD-30. Knelson has been carrying out significant research on cone design over the last few years and has determined that many applications can be optimized with respect to one specific type of cone. For example, the Generation 6 (G6) cone design was developed after trials at a site in Australia indicated more gold was recovered per cycle with the G6 than with the G5 cone. Knelson's FLEX*Flo field configurable cones allow testing of several cone designs in short order, by changing fluidisation profiles while on site. In total, six cone designs were tested at Kemess.

OPTIMIZATION RESULTS

Overall, 31 optimization tests (including repeats) were carried out. For each test, a representative sample of Knelson tailings was taken and the full flush of the Knelson XD-30 collected. The tails and concentrate were then characterized for GRG on a size-by-size basis and the entire test balanced.

The results show an unusual shape to the GRG recovery curve (example, Figure 6). Typically, Knelson GRG unit recovery starts out high at coarse particle size, decreasing to lower values at finer sizes. This curve shows a trend of higher recovery at ultra fine sizes, with the low at intermediate sizes, and increasing again towards the coarser size fractions. This has been observed at several sites (Laplante, 2003; Yeomans, Fullam, and Duncan, 2004; Laplante, 2004) but no explanation has been confirmed. It is suspected that a "particle interaction / transport phenomenon" is responsible as the gold particles in the middle size range are competing with gangue of similar size and thus have difficulty migrating to the concentrating rings (Laplante, 2005). The benefit of this phenomena is that fine gold recovery under these conditions is actually enhanced.

Concentrating Cone Design

The most dominant factor in unit GRG recovery was found to be cone design, in particular a newly developed cone called the Generation 7 (G7). The G7 is a low water use cone, which produces higher mass yield and is specifically configured for fine GRG recovery. The G7 cone has been benchmarked against a G5 cone in a primary gravity circuit, with no benefit found. This suggests that the cone works best in fine or high specific gravity feed applications such as regrind circuits.

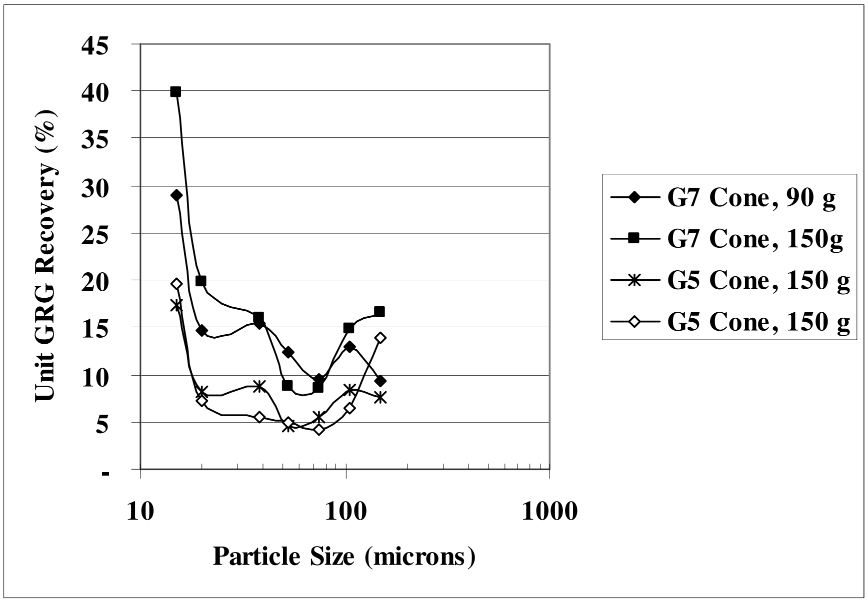

Figure 6 – Unit GRG Recovery of the Knelson XD-30 as a Function of Particle Size with Different Cone Types and Operating G Force

The results of Figure 6 show the unit GRG recovery of the G7 cone compared to several G5 cone tests. All of the tests used 10 minute concentrating cycle times.

Effect of Feed Pulp Density

Since the Knelson XD-30 feed was undiluted cyclone underflow with no preparation screen, feed pulp densities could be as high as 80% solids. More typically, due to the spray water added for scalping screens, feed pulp density to Knelson Concentrators is usually in the 55-65% range. The unit GRG recovery of the high pulp density test was low in comparison to all the lower density tests, and this was found to be one of the dominant operating variables. Dilution water is now added continuously to the Knelson feed to lower the feed density to the 55-65% range.

Concentrating Cycle Time

In general, for Knelson application in a secondary circuit or in other circuits with high levels of pyrite in the ore, a phenomena known as "concentrate bed erosion" can occur, whereby gold already recovered on the surface of the concentrating ring is removed due to the effect of high specific gravity particles such as pyrite. As such, short concentrating cycle times are generally of benefit. The test work carried out proved this to be the case in this application.

As the Knelson concentrate is added to the final copper concentrate, additional freight, treatment and refining costs are incurred as the copper concentrate is diluted. Initially, 15 minute cycles were used, but the results suggested shorter cycles would be of benefit without causing significant dilution of the final copper concentrate. Thus 5 minute cycles were adopted. Figure 7 shows the differences in unit GRG recovery between the 5 and 10 minute concentrating times.

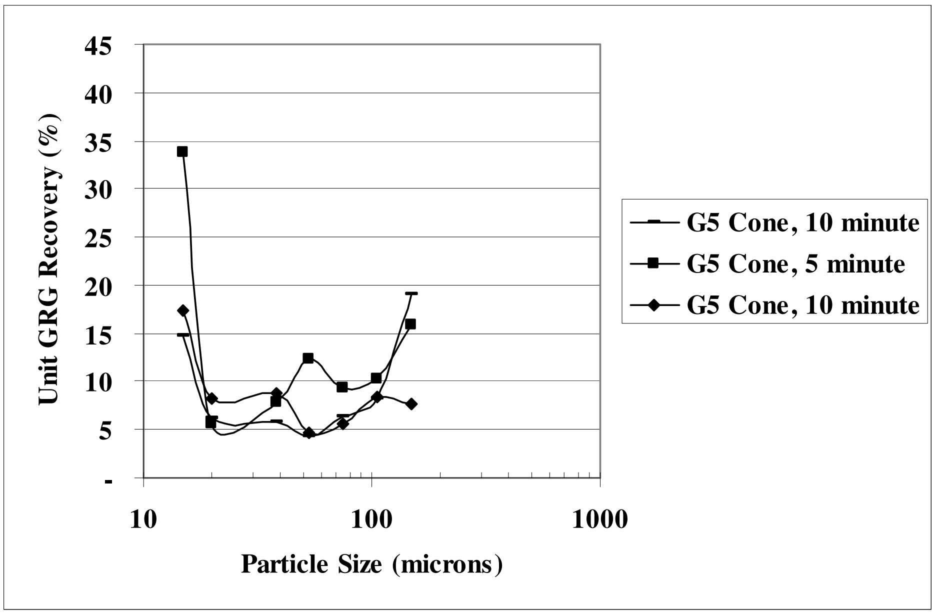

Figure 7 – Unit GRG Recovery of the Knelson XD-30 as a Function of Particle Size at Different Cycle Times

Feed Rate

The feed to the Knelson was via a separate launder that accepted the flow from one or two cyclone underflows. If fine tuning of the feed rate from a single cyclone was required, the opening in the feed line was partially covered, forcing some of the cyclone underflow back to the underflow tub. Feed rates from 38-134 tph were tested.

As is typical, unit GRG recovery was found to decrease as feed rate increased. The increased feed rate, however, allows a larger portion of the circulating load to be treated, so often global gravity recovery is higher at high feed rates even though unit recovery is lower. Modelling can help determine the optimum balance.

G Force

Increased g force was found to be beneficial for recovery, but was not found to be a dominant operating variable, at least with the G5 cone. Figure 8 shows the effect of g force on Knelson GRG unit recovery.

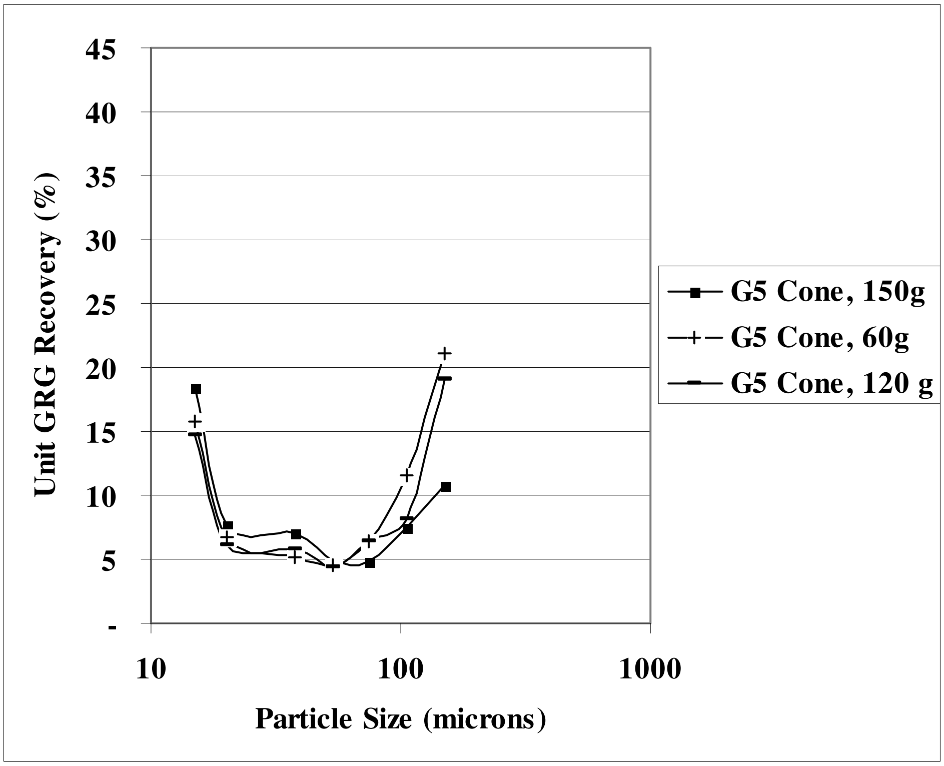

Figure 8 – Unit GRG Recovery of the Knelson XD-30 as a Function of Particle Size at Different Operating G Force

Fluidisation Water Flow

Fluidisation water flow was found to be the least important operating variable within the low flow range. However, as fluidisation water flows are increased beyond this range, a loss of recovery of fine GRG is incurred.

CALIBRATED MODELLING OF THE KEMESS REGRIND CIRCUIT

With unit GRG recovery data for the XD-30 available, the full scale circuit recovery could be modeled with the various operating parameters and cone designs (Grewal and Fullam, 2004). The results could be checked against plant figures, and gravity recovery of more or larger Knelsons could be simulated.

Modeled gravity recovery outcomes for five different combinations of three variables are shown in Table 2. Treating one cyclone (of four) equates to approximately 41 tph feed rate to the

Knelson XD-30. Treating two cyclones doubles this to 82 tph. A base case for the gravity recovery model, treating 25% of the cyclone underflow with an un-optimized G5 cone, returned gravity recovery of 7% of gold in the regrind circuit feed. Increasing the feed rate by directing two cyclones to the XD-30 produced only a marginal increase to 8%; however, treating only one cyclone but using an optimised G7 cone yielded gravity recovery of 11%. Adding a second XD-30 (using a G7 cone) treating two cyclones (one for each Knelson) would increase gravity recovery from 11% to 17%, but adding a second Knelson using an un-optimized G5 cone only increased gravity recovery from 7 to 11%. The values were slightly different but followed the same trend when the McGill GRG values were entered into the model, as shown in Table 3.

Table 2 – Modeled Gravity Recovery Using Knelson GRG Test Results

XD-30 Concentrating Cone	Number of XD-30	Feed Rate to Each Knelson XD-30 (tph)	Cyclone Underflow Teated (%)	Gravity Recovery (%)
G5	1	41	25	7
G5	2	41	50	11
G5	1	82	50	8
G7	1	41	25	11
G7	2	41	50	17

Table 3 – Modeled Gravity Recovery Using McGill GRG Test Results

XD-30 Concentrating Cone	Number of XD-30	Feed Rate to Each Knelson XD-30 (tph)	Cyclone Underflow Teated (%)	Gravity Recovery (%)
G5	1	41	25	6
G5	2	41	50	10
G5	1	82	50	7
G7	1	41	25	10
G7	2	41	50	16

The vast majority of Knelson installations are not fully optimized, and the machine is simply turned on and left to recover gold at initial settings. For many primary gravity circuits, this is not optimal but also not critical, as optimizing the Knelson parameters may not be as important for gravity recovery as ensuring that the unit is receiving the required feed rate or is achieving high availability (Laplante, 2000). For a regrind circuit where the GRG is fine, optimization can yield reasonable benefits to overall gravity recovery.

KNELSON ON/OFF TRIALS

As the primary goal of the gravity installation was to reduce the free gold losses of the cleaner tailings, two on/off trials were carried out. Samples of rougher concentrate and cleaner tailings were collected over a 12 hour (dayshift) period with the Knelson operating, and then the unit was turned off (nightshift). After a further 12 hours (to allow the circulating load of GRG to stabilize) another set of samples was collected. This was repeated several times for each set of trials. The average pyrite to chalcopyrite ratio during the first trial was 2.8 and during the second trial was 8.7. This represents two different ore types: standard hypogene (SHO) and high pyrite hypogene (HPHO).

Rougher concentrate samples were bulk assayed. Larger samples of both rougher concentrate and cleaner tailings were also collected and processed in the laboratory scale Knelson (MD-3) for removal of coarser (>~15 micron) GRG. The MD-3 tailings of the cleaner tailings contained free gold finer than 15 microns, which may have entered the regrind circuit as coarser free gold before being over-ground. As some of this gold was recovered before over-grinding when the Knelson was operating, it was important to measure any difference in the very fine free gold in the MD-3 tailings of the cleaner tailings between on and off samples. These were sent to AMTEL for gold deportment analysis.

Mill Results

The actual mill results are shown in Table 4 below for the two sets of on/off trials – the first set was during the processing of standard hypogene ore and the second was during the processing of high pyrite hypogene ore - representing a total of approximately 50 shifts.

Table 4 – Mill Results for Knelson On/Knelson Off Trials

ORE	Head Grade Au (gpt)		Py:Cpy		Rougher Con Au (gpt)		Cleaner Tailings Au (gpt)		Cleaner Circuit Recovery (%)		Cu Con Grade (%)	
	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off
SHO	0.88	0.88	2.7	2.8	15.5	12.0	0.60	0.90	96.0	95.1	20.5	21.0
HPHO	0.38	0.40	8.8	8.4	2.8	2.8	0.38	0.52	86.4*	82.0	19.0*	20.0

*These figures have been adjusted to allow for a valid comparison in terms of the grade/recovery relationships (based on previous testing on similar ore). Actual raw results showed a higher recovery and lower grade.

Results suggest a benefit of about 0.9% to cleaner circuit recovery when standard hypogene ore is processed. This equates to about 0.7% overall increase in gold recovery. The circulating load of gold in the regrind circuit was considerably less with the concentrator in operation, at 430%, compared to a circulating load of 550% with the unit off. This was using a G5 cone. Using a G7 cone, the recovery benefit would likely have been about 25% higher. The final copper concentrate was diluted somewhat by the addition of the Knelson concentrate, resulting in a 0.5% decrease in copper grade of the final concentrate.

When high pyrite hypogene ore is processed, the benefit to cleaner circuit recovery increases. This is not surprising given predominance of free gold in the cleaner tailings measured previously when this type of ore was processed. The cleaner circuit gold recovery benefit was found to be 4.5%, or 3% overall. The final copper concentrate was diluted somewhat by the addition of Knelson concentrate, resulting in a 1.0% decrease in copper grade of the copper concentrate.

Knelson MD-3 Results

Two larger samples each of rougher concentrate and cleaner tailings were collected from the HPHO on/off trial and processed using the Knelson MD-3. The goal was to use the MD-3 to remove and account for GRG separately and then to back calculate the grades of these streams using large samples for accurate results. The circuit balance was then performed to determine overall cleaner circuit recovery. The results are shown in Table 5.

Table 5 – Grades of the Rougher Concentrate and Cleaner Tailings Determined by the Knelson MD-3

	Knelson Off	Knelson On
Rougher Concentrate Grade (gpt)	2.58	2.73
Cleaner-Scavenger Tails Grade (gpt)	0.48	0.37
Cleaner Circuit Recovery (%)	82.9	87.6
Recovery Difference (%)		4.7

The results show a benefit to cleaner circuit recovery of 4.7%, or approximately 3.3% overall. This compares well with the mill results for the HPHO in Table 4.

Mineralogy Results

In the absence of gravity concentration, much of the GRG originally present in the rougher concentrate was likely converted to non-GRG in the regrind circuit. To characterize whether the GRG recovered by gravity had an effect on the free gold losses in the cleaner tailings, mineralogy was carried out. The MD-3 tailings of the cleaner tailings samples for both Knelson on and Knelson off conditions were sent to AMTEL (Amtel, 2006) for characterization of gold deportment. Both free gold and pyrite associated gold losses were characterized. This data was then mathematically combined with the free gold recovered in the MD-3. Figure 9 shows the contribution to overall tailings of each gold association.

The MD-3 and gold deportment work showed the following with the Knelson XD-30 operating:

- Overall cleaner tailings gold grade was reduced by 27%
- Losses of GRG in the cleaner tails were reduced by 27%
- Losses of free gold in the cleaner tailings was reduced 50%
- Losses of pyrite associated gold in the cleaner tailings was reduced by 26%
- There was no change in gold associated with binaries and rock

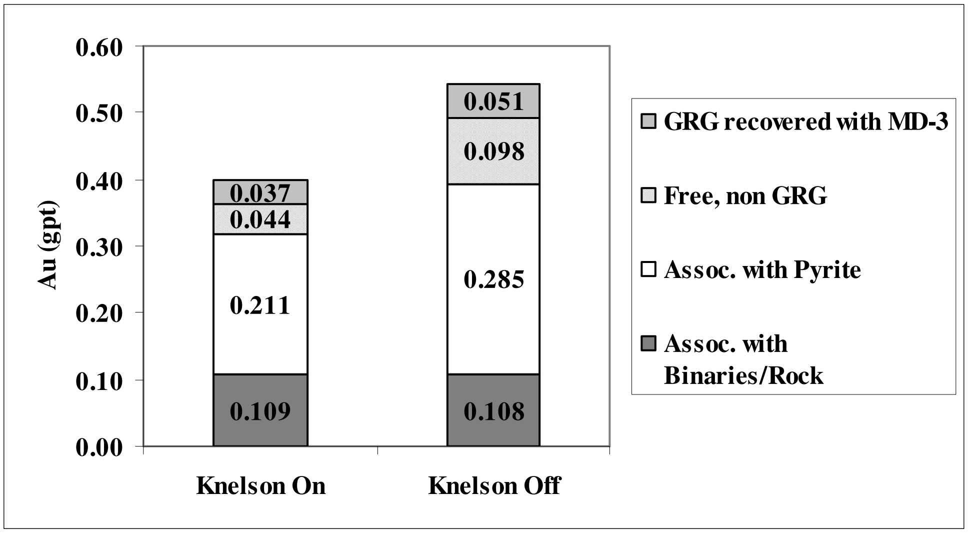

Figure 9 – Deportment of Gold by Grade in the Cleaner Scavenger Tailings

The fact that there was a 26% reduction in losses of gold associated with pyrite strongly suggests that the Knelson XD-30 is not only recovering a free gold component but also semi-liberated gold-pyrite particles that would normally have not reported to final concentrate. Considering the very short concentrating cycle times, this is entirely possible.

Results from both the MD-3 concentrate and the MD-3 tailings (which were analyzed by mineralogy) are combined and shown in Table 6.

Table 6 –Cleaner Circuit Recovery Based on Gold Deportment

	Knelson Off	Knelson On	Difference
Cleaner Circuit Recovery (%)	84.7	90.2	5.5

The HPHO cleaner circuit gold recovery benefit suggested by the combined MD-3 processing and mineralogical analysis is 5.5%, or 3.9% overall. This compares reasonably well with the results on the same HPHO ore presented in Tables 4 and 5.

Gold Particle Shape

The Amtel analysis also measured particle shape. Free gold not recovered in grinding by gravity has a higher probability of being flattened, with a much higher chance of being rejected to the cleaner tailings, as noted in the Amtel work referenced earlier. The free gold particle shape of the MD-3 tailings of the cleaner tailings is shown in Figures 10 and 11. The distribution of flaky particles was much lower with the Knelson operating.

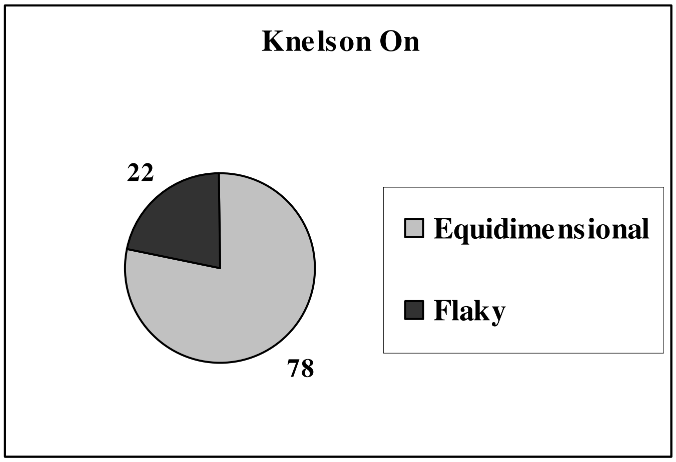

Figure 10 – MD-3 Tailings of the Cleaner Tailings Free Gold Particle Shape – Knelson On

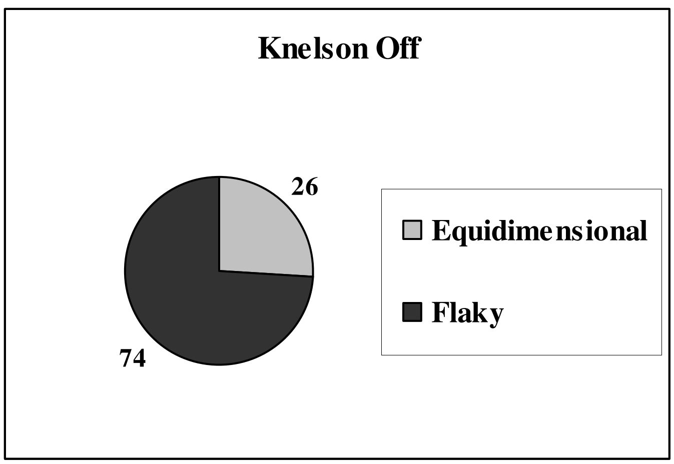

Figure 11 – MD-3 Tailings of the Cleaner Tailings Free Gold Particle Shape – Knelson Off

OVERALL RECOVERY BENEFIT

Based on the results, a gold recovery benefit of 1% overall is expected when standard low pyrite hypogene ore is processed, with an associated reduction in copper grade of the final concentrate of 0.5%. This increases to 3% overall during periods when high pyrite hypogene is processed, with an associated reduction in copper grade of the final concentrate of 1.0%. Actual mill performance compared with the Kemess hypogene recovery model has shown an improvement of slightly less than 1% to date with the G5 cone in operation. Future Kemess gold recovery targets have been increased accordingly, based on the success of this project.

The gold recovered in the Knelson Concentrator is very fine. In fact, approximately 95% of the gold in the Knelson concentrate is contained in the finest 50% of the size distribution, with a concentrate d50 of approximately 75 microns. This presents an opportunity to incorporate a simple screening system to remove the majority of the coarse gangue but very little of the gold, thereby reducing the shipping and treatment costs by half. This is currently under investigation.

As a consequence of the positive impact of the Knelson concentrator, the Kemess operating strategy for high pyrite ores continues to be an aggressive rougher float combined with very fine regrinding. Results to date have been encouraging, and the implications on the future processing of the Kemess North ore are substantial.

SUMMARY

In 2005, the Kemess mill processed a large quantity of ore that was unusually high in pyrite content. Very fine regrinding was required to achieve acceptable final concentrate copper grades. Excessive gold in the form of minus 10 micron free particles was lost to cleaner flotation tailings. This gold was found to have originated from the over-grinding of a large circulating stream of gold particles in the regrind circuit.

Centrifugal gravity concentration was determined to be a viable option for removal of gold in the regrind circuit. A cooperative effort was initiated between Kemess and Knelson Gravity Concentrators. Due to a lack of data on Knelson concentrator performance in regrind circuits, considerable effort was put into batch testing, modeling, and mill optimization.

Batch testing of rougher concentrate samples verified the presence of gravity recoverable gold in the regrind circuit and hence the suitability of gravity concentration via a Knelson Concentrator. Further modeling of the regrind circuit by Knelson estimated a potential gravity recovery of between 7% and 13%.

A Knelson XD-30 was installed and optimized in late 2005. Two different sets of on/off trials were conducted: one on standard hypogene and the other on high pyrite hypogene. Mill data and circuit sample analysis indicated considerable benefits to cleaner and hence overall gold recovery, albeit at a reduction in final concentrate copper grade. These benefits were attributed to the combined effects of removing the gold prior to over-grinding and the removal of flaky gold of floatable size. Overall gold recovery improved by 1% and 3% in standard and high pyrite hypogene, respectively. The associated losses in final concentrate copper grade were 0.5% and 1.0%, respectively. Methods to decrease the final concentrate dilution are currently under investigation, including the possibility of removal of the coarse fraction, which contains relatively little gold value.

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