FEED PREPARATION FOR GRAVITY SEPARATION IN GRINDING CIRCUITS

A.H. (Sandy) Gray
321 Learmonth Rd, Ballarat, Victoria, 3350
Phone: +61 3 53395859; Fax: +61 3 53395803
Website: www.gekkos.com Email: gekkos@gekkos.com

Introduction

One of the most difficult areas of engineering in a modern gold plant is the feed preparation and flows surrounding the gravity circuit. The greatest reason for gravity circuits failing to deliver, in both a metallurgical and maintenance sense, is due to inadequate installation. This paper covers the preparation of feed to be presented to any gravity concentrator in a grinding circuit although for the purpose of the exercise I will use gold gravity circuits as the basis.

Gravity in Grinding Circuits

Most grinding circuits, regardless of mineral type, have similar characteristics with regards to their physical layout, stream densities and size distributions. Other issues such as heavy loadings of magnetics and high viscosity can all affect the efficiency of the gravity separation device. How and where to install the gravity circuit will never be completely agreed but some helpful indicators will be pointed out in this paper. The debate over cyclone feed versus cyclone underflow versus cyclone overflow will rage forever but there are certain issues that should be considered in the decision making process. Also the choice of screen type is contentious and requires some clarification.

Dilution plays a key role in the grinding circuit and can be very limiting as far as an advanced gravity circuit is concerned. The amount of material that can be effectively treated in the cyclone underflow or overflow stream is limited by the amount of water that can be added through the gravity separator without disturbing the water balance in the mill. Grinding efficiency is severely affected if grinding density is low. Water can become problematic not just due to addition through the gravity separator but through addition into pipes and feed boxes in order to keep high density, coarse slurries flowing. A major contributor to water addition and dilution is often the pre-screen in front of the concentrator.

Magnetics are another issue in the grinding circuit. Many mills have very high levels of magnetics in the circulating load and removal of these magnetics can significantly increase grinding capacity as well as have a positive effect on the gravity concentrator. The heavy magnetics increase the burden on the concentrator. In the case of the InLine Pressure Jig, magnetics artificially increase the ragging density and report to the concentrate. Magnetics also build up in the bed of a centrifugal concentrator and force reduced cycle times. The magnetics also report to downstream processes where they must be removed prior to concentrate cleaning and smelting.

Figure 1.

Figure 1. shows an IPJ and Spinner installation at Kundana. Cyclone underflow reports directly to the IPJ. Pre-screened and sized product from the IPJ concentrate reporting to Spinners for further upgrade.

Measurement is extremely important if an efficient system is to be maintained. In order to run at the highest possible efficiency it is important to be able to accurately sample and measure the flows in all streams. It is essential to be able to measure the operation of your units on a size-by-size basis. Maximising recovery is done by targeting recovery in a certain size fraction or fractions with the highest value mineral loading. Without accurate sampling it is not possible to measure the size-by-size performance and therefore it is not possible to target increased recovery in those size ranges where maximum gains are available.

Figure 2.

Figure 2. shows a picture of IPJ and Knelson in the mill circuit at Bibiani. The IPJ receives feed directly from the cyclone underflow whilst the Knelson feed is pre-screened at 2 mm.

Gravity - Where and Why?

Where am I going to install my gravity device? How do I decide whether to take mill discharge, cyclone underflow or cyclone overflow?

It is first necessary to decide

- **What** you are trying to achieve with your gravity circuit.
    - o Maximum recovery
    - o Fines Recovery
    - o Coarse recovery
    - o Sulphide recovery

- **Material** type and viscosity
- **Optimum** feed density to concentrator.
- **Feed size** required.

Gravity Circuit Feed Decision Matrix

Feed Type	Dilution	Feed Size	Recovery Size	Grade	Volume	Screening	Viscosity	Recirculation	Total
CUF	3	5	8	10	8	4	10	10	58
C Feed	8	5	6	7	3	6	5	8	48
COF	8	8	3	3	5	10	3	0	40

Table 1.

The above matrix will help in the decision making process and where you place the maximum emphasis for your installation. Different applications have different requirements and the key drivers appear to be variable depending on the mill layout and ore body. Adjusting the above matrix to your own situation will help resolve key design issues as well as keep the decision making process transparent to others in the design group. Healthy debate surrounds this type of decision and the weighting placed on each box can be manipulated according to the decision makers' preference.

Cyclone Underflow

Historically the most popular feed stream for batch centrifugal concentrators, such as the Falcon, has been the cyclone underflow. The reasoning has been both metallurgical and physical as the cyclone underflow has the highest grade and is on first impression the simplest stream to utilise. The test work probably started on this stream due to access, high grade and the low velocity at which it exits the circuit. The key benefit is the highest available stream grade particularly if fine screening of this stream is possible. The finer the fraction targeted in the cyclone underflow stream the higher the grade in almost every case.

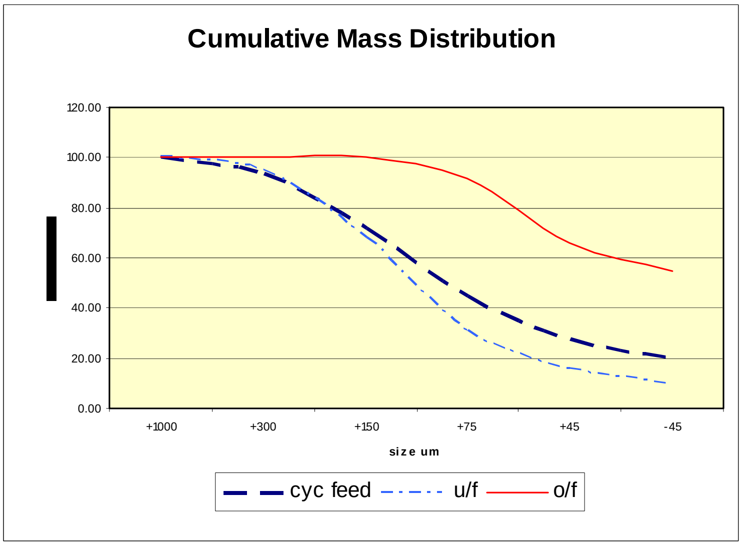

Figure 3.

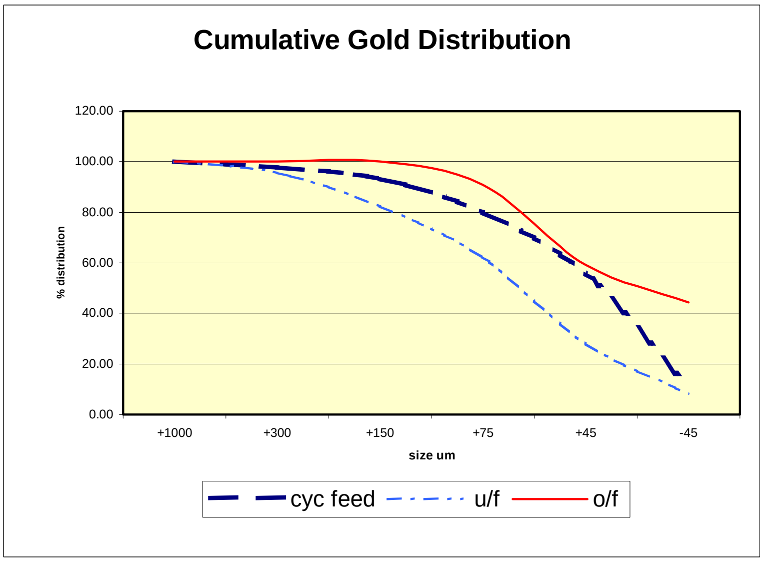

Figure 4.

Fine screening can increase feed grade considerably and is an ideal way in which to increase the utilisation of any concentrator. The higher the feed grade to the concentrator the more likely it is that the gold is free and the higher the gold mass recovery per hour. In other words the more gold fed at a given tonnage the more gold is recovered.

The cyclone underflow stream is arguably the simplest to split from the circuit as it has had its energy dissipated and is sitting at the highest point in the plant. This gives the impression that it is the easiest stream to handle. It can however be far more difficult to handle than first impressions would suggest. The very high density of this stream can be problematic when it comes to screening and flow of this coarse high density product. It requires relatively small apertures to restrict the flow in the case of small circuits, which can easily lead to blocking. Also this stream is lower in total gold mass than the cyclone feed. It can be very limiting in the overall design of a plant as the head height, engineering loadings and floor space required for a good gravity circuit layout is not insignificant. This can drive the engineering in the front end mill structure design. Cyclone efficiency plays a key role in this decision as a well run, highly efficient cyclone will hold back the gold far better than a cyclone being run for a coarse size distribution with no pre-leach thickener. Coarse grinds lead to poor cyclone efficiency and poor gravity recovery in the grinding circuit.

Figure 5.

Figure 5. shows cyclone underflow reporting to IPJ feed. Underflow launder designed to allow excess feed to overflow and report to pipe on left of picture which returns feed directly to the mill feed chute.

Cyclone Feed

The cyclone feed stream is a very versatile stream as it can be split separately from the mill discharge with its own pump from the mill discharge hopper or from the cyclone distributor at the top of the circuit. This is a far more friendly slurry to manipulate as it has a lower density and retains the slimes fraction that can help in the pumping. However it has a lower grade and the slimes / viscosity can be a negative in some slurries as it reduces the settling rates of the fine flat particles. It is far friendlier for screening in most cases due to the higher water content. This stream is the most easily engineered and allows for the greatest flexibility in design of the plant.

In the case of Beaconsfield in Tasmania the InLine Pressure Jig feed is pumped from the feed side of the mill discharge hopper and the tail returns to the cyclone pump suction to ensure no short circuiting. This has been very effective and allows the gravity circuit to be positioned well away from the immediate mill area in a separate building. The complete primary gravity circuit runs with only one pump.

Jubilee Gold Mine in Western Australia runs InLine Pressure Jig feed from the cyclone distributor with a Clarkson muscle valve at one of the discharge points on the distributor to control flow. The IPJ tail flows through a variable orifice valve to maintain pressure in the IPJ and then gravitates to the mill feed. See figure 6.

Both of these installations are relatively simple to operate and require low maintenance.

Figure 6.

Cyclone Overflow

The cyclone overflow or screen underflow depending on the type of classification in the grinding circuit is a far poorer circuit in which to operate from a grade and a recirculation point of view as it allows only a single pass recovery, i.e. The gravity tail does not recirculate for a "second bite at the cherry". All gravity only circuits such as tin/tantalum circuits operate on a coarse primary grind and then re-grind basis which in effect sets up a similar regime to a gravity device operating in the recirculating load of a mill with cyclone classification. The cyclone overflow stream in a typical gold circuit will have a size distribution of 80% passing 75um but in fact the typical gold size distribution will be far lower at around 40um and the grade will be only that of head grade, or lower if a gravity circuit is operating ahead of the cyclones. In terms of gravity gold recovery this stream is a far poorer target than the other cyclone streams.

However it has several major factors in its favour and there are two main reasons that keep people coming back to investigate it: the size distribution which makes it an ideal feed for units such as the Falcon continuous centrifugal concentrator and the Kelsey Jig and the relatively low tonnage and low density when compared to the other cyclone products.

Screening

The screening options are many and varied; the major options are covered in Table 2. It is ***not a pre-requisite to achieve high efficiency at this screen,*** as some bypass of fines back to the circuit will not affect performance as long as the gravity unit sees the required amount of feed. Screening is used as a preventative measure to protect the gravity separator from mechanical damage as a result of oversize material reporting to the unit. Oversize material will cause, in the mildest form, abnormal wear on the units and in the extreme can cause catastrophic failure. Another major issue is blocking of process ports such as in the Falcon "C" and plugging of screens in the Kelsey Jig. Coarse material can have an adverse outcome on the separation efficiency of many units as the feed size distribution becomes so wide as to limit the recovery of fines in the presence of the coarse material which preferentially reports to the heavies fraction.

Screening is a major consideration in most fine mineral recovery circuits due to the parameters listed in Table 2. The decision is complicated and requires careful thought. The more effort put into classification of products the better the outcome.

Screen Type Decision Matrix													
Type	Efficiency	tons per metre squ	mass	dilution water	head height	maintenance	cost	vibration	installation	power	upgrade	fines	total
weighting	10	8	10	10	10	10	10	10	5	5	10	10	108
Flat Deck	8	5	3	4	6	7	4	3	3	2	0	5	50
DSM	6	7	8	8	4	8	7	10	7	5	0	5	75
Declined	7	6	6	6	4	7	6	5	3	2	0	5	57
Trommell	7	3	5	7	8	4	4	10	2	3	0	5	58
IPJ	5	7	4	8	5	7	10	8	4	4	5	1	68

Table 2.

Flat Deck Linear Vibrating Screens

Many installations today utilise flat deck screens ahead of concentrators due to the perceived low head and low maintenance. The flat deck screen consists of a flat frame that supports a polyurethane screen panel system. A pair of eccentric vibrating motors running at 45degrees through their own centrelines creates a linear action that can be increased or decreased in "throw". The oversize material is transported across the screen panels to the discharge by means of the linear throw, which lifts and throws forward in each cycle. They are however large consumers of water, have a high mass, low tons per metre square treated, high power consumption and are expensive to install. The mass of the support frame can be extreme as these units generally reside high in the mill cyclone tower and require heavy structure to support the sanded weight and the vibration of the unit.

One of the critical issues overlooked by many engineers is the density of the feed required to achieve efficient (or in fact any) classification. The volume of water required for screen feed dilution can be significant and is often overlooked in the mill water balance. In order to get efficient classification on one of these units it is necessary to dilute the feed down from the cyclone underflow density of as high as 85% to an optimum of 40% solids by weight.

If feed is presented to a flat deck screen at high density it will act as a dewatering screen and material will flow to the discharge without classification (noted on many occasions). See Figure 7. The flat deck screen in another slightly different configuration is in fact a "dewatering screen". The feed is presented to the deck from a cyclone underflow and the material "balls up" on the screen and dewaters.

Figure 7. shows material flowing to discharge without screening due to very high density feed.

Figure 8.

Figure 8. shows the water addition required to dilute 1 ton of cyclone underflow stream from 80% solids down to various dilutions in order to achieve efficient screening.

When it is necessary to treat high percentages of a recirculating load in the gravity circuit it is impossible to achieve efficient screening with the high levels of dilution required.

Many installations have been seen with extra water addition in the form of spray bars (see Figure 9.) and feed dilution valves retrofitted ahead of the screen feed to achieve reliable classification.

Figure 9.

In order to reduce the maintenance on vibrating screens many sites have polyurethane screen decks fitted. These decks consist of panels of various sizes and the panels tend to have very low open area. The panel open area is one of the key factors in the capacity of the screen, which is a function of tons treated per square metre of screen area. Typically the open area of such poly panels is as low as 20%. This ultimately means larger and larger screen areas for lower throughputs. The choice of panel types is also critical as the highly wear resistant panels also tend to be the least flexible and are prone to high rates of blinding. Many non blinding panels are available today but they tend to have a lower wear life and due to their configuration are less selective for particle shape.

DSM Screen

A well-manufactured DSM (Dutch State Mines) screen with auto screen rotation solves many of the above issues. DSM screens tend to be of relatively light construction with virtually no moving parts. The only critical wear part is the screen panel itself. This panel is generally a fabricated curved section of wedgewire screen fitted into a static screen frame. The feed is distributed evenly onto the screen at relatively high velocity with the sharp edge of the wedgewire cutting the fines from the stream. The carry over of fines to the discharge assists with the removal of coarse oversize product from the surface of the screen deck. The screen panel is rotated every 6 to 12 hours for high efficiency of cut as the leading edge becomes dull and the cut is reduced. The screen classification efficiency is not as high as other screens with a proportion of the fines reporting to the discharge. However, as previously stated, ***high efficiency is not a pre-requisite for this design***.

Figure 10.

Gekko DSM with integral magnetic separator to be fitted.

Figure 11.

Gekko Low Head Scatex combined DSM and magnetic separator for gravity feed preparation.

The DSM screen appears to have high headroom requirement although when compared to a fully installed flat deck screen there is very little difference. The capacity of these units is very high on a ton per square metre of screen area. It is possible to achieve up to ten times the throughput of conventional vibrating screens for the same floor area. Therefore they are simple to install with very little support structure required and no vibration. The maintenance can be higher although at Kundana Mine in Western Australia a DSM operated efficiently with very little maintenance over many years.

The use of DSM type screens is probably limited most by the fact that very little information is available on the sizing and operation of these units. There are also very few manufacturers of quality DSM screens. Automation of the screen rotation makes the unit operate in a maintenance free fashion, relieving the operator from more than cursory inspection on a daily basis. It is also possible that a few poorly installed screens may have destroyed the reputation of the DSM and pushed people to the flat deck type screen.

Other Screens

Other screen types can be investigated but have been mostly overlooked by industry due to inherent deficiencies. The Table 2. lists several other types of screen but it is not proposed to go into detail regarding them in this paper.

InLine Pressure Jig

The only other type of classifier I would like to mention is the InLine Pressure Jig (IPJ). The IPJ can and is being used ahead of other jigs, centrifugal and spiral concentrators in a dual role of concentrator but also to ensure the feed is prepared for the downstream process. The IPJ at several Australian and overseas gold mines is fed coarse mill discharge product direct from the cyclone feed hopper with a P80 of approx 3 mm and max particle size of 16 mm. In one particular case the IPJ upgrades the feed and removes the coarse product to produce a feed to a Spinner at a P80 of 300 um, a max particle size of 3 mm and an increased grade of approx 10 to 20 times. This is a very efficient screening and feed preparation unit ahead of a centrifugal concentrator. The dilution water required is limited and installation is not more difficult than a screen.

Screening Upgrades Feed

As previously mentioned screening the feed will in fact not only upgrade the feed but will also help in the separation efficiency of the concentrator. The major downside of this is the small but important coarser fraction of gold that will potentially be lost if this fraction is screened out. It is important to ensure that the gold size distribution is well understood before the decision is made on one concentrator or another. The use of several technologies in the same circuit has delivered great benefit in some mines with two separate size distributions being targeted. The combination of say the InLine Pressure Jig and the Falcon Super Bowl can be a powerful team for a broad range of gold size distribution.

MAGNETIC SEPARATION

Magnetic separation, as a feed preparation tool ahead of primary gravity separation has been slow to be adopted in Australia with very few installations utilising this technology. However the benefits are many and the full value of removing the magnetics loading from a milling circuit has not been fully explored. In the case of gravity separation the magnetics stream is made up of relatively high density material such as steel with a specific gravity of around seven. This material generally spans a wide size distribution range and inevitably ends up in the gravity concentrate, which in turn, at some point requires removal. To date this removal has been achieved in the cleanup area when the final upgrade is carried out on a gold concentrate.

In South Africa it has been seen that magnetic separation is beneficial ahead of the primary recovery device. The key issues being the load that the magnetics put on the bed of the centrifugal concentrators which reduces the cycle times and recovery as well as the negative effects the magnetics have on downstream concentrate handling. The new mines in South

Africa such as Target Gold Mine and South Deeps have installed magnets ahead of the primary concentrators.

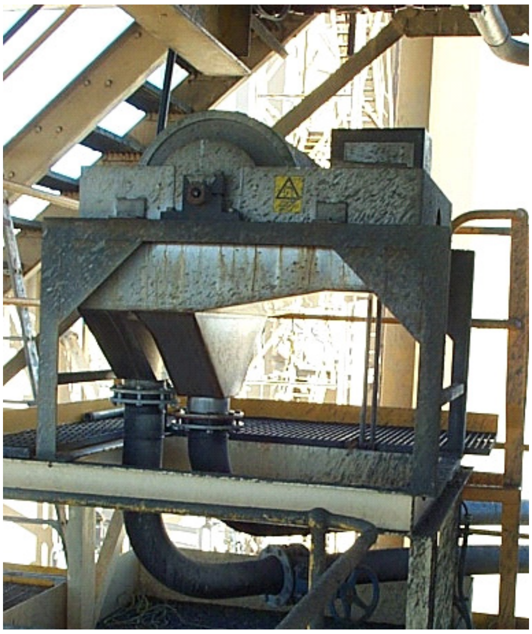

Figure 12.
St. Ives trial circuit with magnetic separation ahead of IPJ

Magnetic separation ahead of the InLine Pressure Jig can significantly increase overall recovery by maintaining a constant density in the bed. If the magnetics are left to build up in the bed they continually change the bed density and therefore the operation of the unit. StIves Gold Mine in Western Australia has just trialled a magnetic separator in front of the InLine Pressure Jig and will install them in the new circuit.

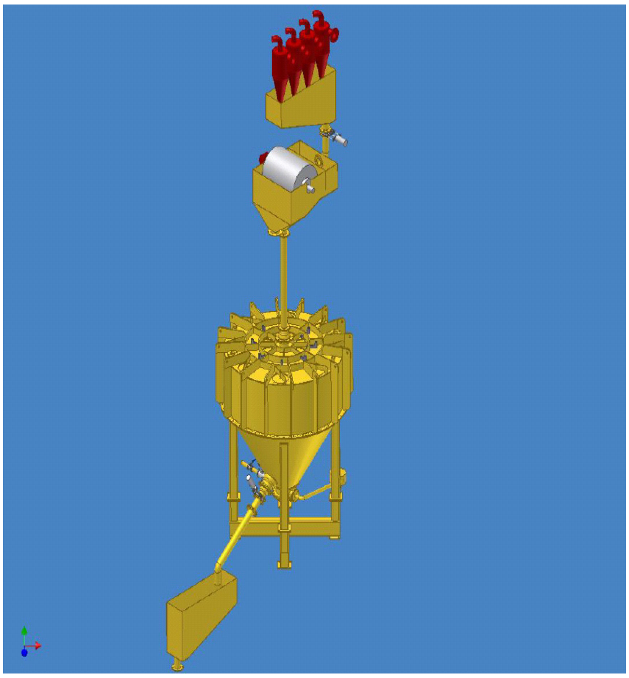

Figure 13.
Proposed St Ives Installation

Trials were also run at Bibiani in Ghana with the results shown below. Size by size recovery was significantly affected when the bed density was kept low with the magnetics removed.

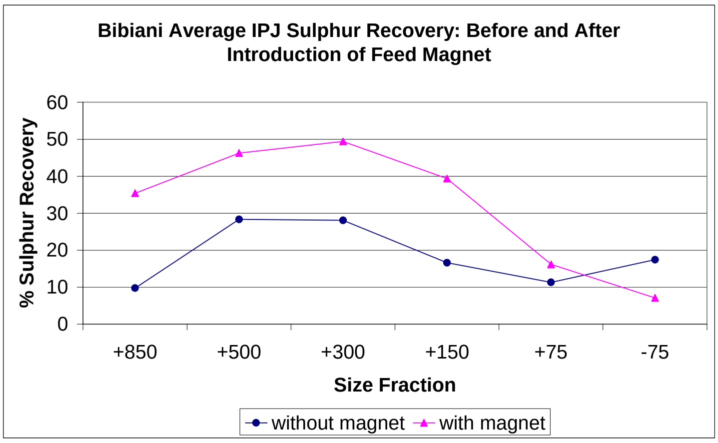

Figure 14.

Sulphur recovery with an InLine Pressure Jig showing increased performance without magnetics in the feed stream.

A modified wet drum type magnet seems to be the best suited to this application as the slurry stream targeted tends to be coarse and is fed to the unit at high density. It is important to leave enough clearance in the unit to allow the odd very coarse particle to pass while at the same time keeping the gap small enough to ensure maximum magnetic force at the bottom of the launder. Another key issue is the highly magnetic nature of the target material, which once recovered to the magnet drum face is not so keen to let go. If highly magnetic material sits at the discharge point of a standard wet drum magnet the high power used to recover the magnetics from the slurry becomes detrimental and tends to make discharge difficult. The result can be very high wear on the face of the magnetic drum. Gekko have developed a counter rotating drum magnet with a reducing field which incorporates a highly magnetic zone for recovery then a wash zone for cleaning in which the field is switched to force the magnetics to "flick" on the drum surface and remove the entrapped non magnetic stream. The magnetic force is then gradually dissipated to allow ease of removal from the drum face.

Figure 15.

Typical steel mill scats recovered from a grinding circuit. Mostly they are broken mill balls.

Sampling

An area not yet touched on but as important as all the previous areas discussed is that of sampling. Many (almost all) gravity circuits installed and operational today have little or no built in ability for automated sampling or in fact for manual sampling. This in fact is an indication of the attitude towards the gravity circuit in most cases. Regular sampling and efficiency testing is not carried out and good data is almost impossible to come by. If asked people will discuss the benefits of the gravity circuit but will not have data to back it up. If a process is beneficial to the well being of the whole plant then why would you not monitor its health in the same way as you monitor the health of the rest of the plant?

It is critical that sampling is addressed at the design stage. This is often overlooked due to the difficulty perceived in the sampling of such coarse, high grade streams. It can be an added cost but can also be as simple as making access to the necessary streams.

Provision should be made to “hand sample” all streams without risk to life and limb. There are only a few necessary samples to be taken in most cases but they are critical to optimising the operation of a gravity circuit.

Summary

The development of hands free, low maintenance feed preparation systems will reduce the difficulties in the engineering and installation of gravity circuits and also reduce the perception of mystique around them, resulting in greater utilisation and reliance on the gravity circuit from a recovery perspective. The gravity separation devices themselves are inherently simple but the surrounding engineering can have a high level of complication. In order to optimise the outcomes of high efficiency, robust operation and low maintenance it is essential to continue to develop the support structures and devices surrounding these circuits. Collecting information from all operating gravity circuits and further developing “best practice” from this experience is crucial to the further development of gravity recovery.

The use of magnetic separation, DSM type screening and more flexible feed systems in grinding circuits will become widespread as the uses of gravity separation are broadened.