MEASUREMENT SYSTEMS FOR GRAVITY CIRCUIT
PERFORMANCE: A NEW APPROACH.

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ABSTRACT:

The use of differences in specific gravity between minerals to separate them has long been utilized in the extractive industries. The environmental and cost benefits of the commercialized forms of these processes are well understood and widely used.

Gravity concentration is used inter alia in the primary beneficiation of gold, diamonds, coal, tin, ferrous metal ores and andalusite. The potential for economic loss due to poor performance of these gravity processes is significant, but diverse in manifestation and regular process monitoring can prevent or at least reduce these losses.

The measurement of performance of gravity processes has always presented a challenge, due primarily to the masses of material involved and the physical nature of the processes, generally typified by long reporting time, and hazardous materials (such as Tetrabromoethane) for float and sink type tests.

The development of density tracers has improved this situation, however recovery of these tracers from the process streams created the next set of challenges, requiring significant manpower to physically remove tracers from product dewatering screens. Additions to these tracers (magnetic or x-ray fluorescent) eased the recovery mechanism issues but made them much more expensive to produce, hence operators became concerned about losses during process testing. In addition, magnetic recovery of smaller size tracers by a magnet suspended above a loaded screen panel is still problematic.

The development of new low cost magnetic tracers has improved statistical significance of tracer tests, as the tracers themselves can be bought and used in much larger quantities, whilst still remaining economically viable. Coupled with the development of effective magnetic recovery technology, such as the Gekko MagScreen, for even fine sized tracers, on-line, continuous tracer testing is now becoming a reality.
Whilst the development of high technology radio frequency detection tracer systems continues, enabling the real time measurement of the process and interpretation of results, miniaturization and recovery of these tracers, which is critical given their costs at present, remains an issue.

Keywords: Gravity, process measurement, tracers, magnetic recovery

INTRODUCTION

DMS and Gravity Processes

The use of gravity (or differential particle settling rates in a medium) has been exploited as a means of recovering or upgrading valuable minerals for thousands of years, with the process occurring even in nature, typical examples being placer gold deposits, alluvial diamond deposits and the heavy mineral rich dunes of the KwaZulu-Natal North Coast of South Africa.

The process utilizes the density difference between two (or more) mineralogical components of an orebody and hence their different settling velocities in a medium of given density. This may be practically illustrated by considering the rate of settling of, for instance, 5mm lead beads (density 11.35) in water compared with the same size of aluminium beads (density 2.71).

The ease of separation is dictated by the degree of liberation of the minerals to be separated, (hence how close they are to their theoretical specific gravity) and how close their specific gravities are to both each other and to the medium in which they are to be separated.

This measure is defined as the concentration coefficient (cc) and for a binary mineral system is given by the following relationship:

\[
\text{Concentration coefficient (cc)} = \frac{\rho_H - \rho_M}{\rho_L - \rho_M}
\]

Where \( \rho_H \) is the specific gravity of the dense or heavy component, \( \rho_M \) is the specific gravity of the fluid medium in which the mineral mix is suspended, and \( \rho_L \) is the specific gravity of the light component.

For the case of alluvial gold recovery in a water medium, \( \rho_H \) is 19.3, \( \rho_L \) is 2.7 (for a silica sand type gangue material), and \( \rho_M \) is 1.0 for a water medium, giving a coefficient of 10.76. As the density of the media is increased, so the value of the denominator is reduced, thus increasing the concentration coefficient. Under these conditions, the ease of separation not only increases, but the sharpness of the separation is also improved.

Gravity processes are widely used due to their environmentally friendly and benign nature. In addition, they are generally significantly cheaper to install and operate than their hydro or pyrometallurgical alternatives.
Typical applications of gravity processes are as follows:

a) Coal Processing Plants:
The coal industry has long utilised many forms of gravity concentration as a means to reject low value non-combustible inorganic components (generally shales) which are co-mined with the coal and reduce the calorific and hence financial values of the resulting coal product. This industry utilises spirals and jigs (water medium) and also uses dense media extensively as a means to control product “ash” content.

b) Diamond Recovery:
The use of gravity processes is well established in the diamond industry, with dense media separation forming the main recovery mechanism to reduce non-valuable bulk to a minimum ahead of specialist low tonnage recovery processes such as grease or x-ray sorting. The use of jigs is finding more acceptance as a more economic way of reducing the bulk fed to the dense media plant with commensurate benefits in terms of both capital and operating cost.

c) Ferrous Metal Ores:
The use of dense media technology to reject light low value gangue components of the ore is common practice. This has the effect of increasing feed grade and reducing bulk to downstream smelting processes, examples of this may be found in the iron, manganese and chrome beneficiation industries.

Why measure?
In all forms of gravity concentration, the efficiency of the separation of the minerals from one another is important, but for different reasons depending on the industry. Measurement of separation efficiency is critical to diamond processors to ensure that immensely valuable diamonds are not discarded through process inefficiency. However, for coal, measurement is crucial to ensure the finished product grade and hence value is not eroded. In ferrous metal ore processing, gravity inefficiency will lead to an improved recovery of valuable minerals but at a reduced grade, thus adversely affecting either sale value or downstream processes such as smelting.

All gravity processes have an efficiency of separation (or partition), which will be examined in more detail later.

In order to effectively manage a unit process such as a gravity or dms plant, it is necessary to measure its operation and efficiency. Measurement provides feedback to process operators and managers, allowing control of the process and reaction to changes such as variations in the quality of an orebody. This process control, in turn, prevents or minimizes value losses and improves the economics of the process by finished product control or operating cost optimization.

The old adage of “If you don’t measure it, you can’t manage it” could have been written with this application in mind!

Forms of Measurement
There are two crucial measurements in the control of a gravity process, namely the separation density or cut-point, and the error of the separation or the amount of material misplaced to either the floats or sinks streams.
There are currently three main mechanisms for the determination of the efficiency of a gravity process as follows:

1) Float and Sink Analysis
Samples are taken from the floats and sinks streams from the gravity process. These samples are then immersed in a heavy liquid (normally organic) which has a density equivalent, or close to the theoretical density of separation of the process. Material above the density of the liquid in both streams will sink, while lighter material will float, by varying the density of the liquid the amounts of misplaced material in both streams may be established. This process is extremely accurate, but is time consuming, with reporting times after sampling being measured in weeks. In addition, the liquids used are generally extremely environmentally unfriendly and in some cases extremely hazardous (such as perchlorethylene (1.6 sg) and dibromomethane (2.48 sg) for coal and lead sulphamate for diamonds)

2) Fractional Density Analysis
This method of analysis will generate a partition curve for the process (from which can be derived the error and also the cut point), but is tedious, time consuming and labour intensive. It entails subjecting each of the product streams to separations at a range of different densities above and below the theoretical separation density and capturing floats and sinks at each density. This process is carried out in either a Multi-Gravity Separator or Ericsson Dense Media Cone type such as the Gekko Viking Cone (figure 1) apparatus. The floats and sinks fractions at each density are then dried and each individual particle checked for its individual density using a gravimetric flask.

3) Tracer Testing
Tracers are particles of known density, size and shape, which may be introduced into a separation process, their passage and final disposition in the process allowing calculation of both process cut point and also the error in the process (see figure 2). They can also be used to calculate the size recovery efficiency of a process for particles of a known density. This method is used in the diamond industry where tracers simulating the density of diamonds are used to assess size-by-size recovery efficiency of the process. The drawback to tracers is that their disposition needs to be measured, which is generally done by collection of the tracers from floats and sinks streams and then manual reconciliation. There have been a number of methods of tracer recovery developed, and it is the future of these systems on which this paper will focus.
Theory of Measurement
The performance of a specific gravity concentration device is measured using a Tromp or Partition curve, which depicts the percentage of product reporting to sinks at different particle densities.

The most practical application of this involves the feeding of a known quantity of tracers of known sizes, shapes and densities, and measuring the recovery of these particles to floats and sinks products.

A typical partition curve is illustrated in Fig 3. It is obvious that, for a perfect split at a given density, the cut point line should be vertical. However, production processes are not ideal and as such a measure of this imperfection is given by the EPM or $E_p$ (ecart probable moyen), which is the error or misplaced material present in each of the process streams.

The EPM is defined as half of the specific gravity difference between the 25% and 75% cut points on the partition curve, hence the lower the EPM value obtained, the closer to vertical the separation line and the more accurate the density cut.

APPLICATIONS OF MEASUREMENT SYSTEMS

Coal Industry
Coal, an organic-rich sedimentary rock, is different from most minerals, in that the valuable component occurs in large quantities (particularly when compared with hard rock mineral recovery systems). In addition the low value component (in this case the inorganic minerals) are generally widely distributed but as discrete components. This allows coal to be beneficiated at a much coarser size than most minerals and using primarily gravity processes (typically 90% of the recovery process utilises gravity) [2].

The Run-of-Mine coal is generally crushed and sized, and selected size ranges are subjected to different gravity processes such as jigs, spirals and dense media plants. Inefficient operation of these plants leads to value loss for the operating company through reduced value of the washed coal product (ash content increases due to inefficient removal of mineral impurities). Value loss also results if the coal is washed “too clean”, since saleable coal will report to the gangue/discard stream from the gravity circuit. It is thus evident that operational control and management of coal washing plants is critical.
CURRENT TESTING MECHANISMS:

The commonly accepted method for testing gravity process efficiency in the coal industry is the standard float and sink analysis, which involves taking significant quantities of representative sample from both float and sink screens (typically 500kg of each for a Wemco Drum type DMS plant) [3]. These samples are then manually subjected to a float and sink analysis using organic heavy liquids (such as tetrabromoethane diluted with benzene), modified to cut at a range of closely spaced densities. This technique measures the amount of material above and below density for a range of density fractions. The float and sink products from each range are then subjected to determination of the so-called ash content. The fractional analyses are used to calculate a reconstituted feed analysis. The percentage in each fraction reporting to the clean coal component is then expressed as a percentage of the total coal in each density fraction of the whole.[4]. Figure 4 presents a washability curve for anthracite produced from the underground orebody at Springlake Colliery in Kwa-Zulu/Natal[5]
This technique can be used for process control purposes. However, the turn-around-time for the results usually reduces its effectiveness for plant monitoring purposes, and thus is more often used as a routine check, or for specification acceptance purposes on new plants.
The results of these tests can also be entered into a simulation programme for the actual coal being washed, and the day-to-day results of the operation of the washing plant compared against the model as an empirical means of checking the process operation.
An alternative is the use of tracers as a supplement to the float and sink analysis. This has the benefit of not requiring chemical analysis to obtain results, but is still very labour intensive and time consuming.
A known quantity of tracers of a predetermined range of densities is introduced, to allow collection from the product streams and hence the construction of a partition curve based on tracer disposition. There is some debate about the number of tracers required for a significant test, however consensus is that ten to twelve density ranges is sufficient with the increment between each range being determined by the sharpness of the split [6]. The recommended number of tracers per density increment varies between 30 and 100 according to authors [4,6,7,8] to obtain a statistically meaningful result.
The tracers report to either float or sink streams and are generally collected by hand from the product flowing across the screens. This process is relatively straightforward for large
size tracers (32mm tracers are most commonly used for cobble and nut coal fractions) as the tracers float to the surface of the stream on top of the screen, allowing for easy and accurate recovery. However, for smaller fractions, recovery of the tracers becomes more difficult, as they tend to remain in the mass of the product, and also their physical size makes them more difficult to both see and recover.

Tracers have more recently been manufactured in different colours per density, both to ease recovery and also to identify density fractions. This is also useful in establishing residence time and hang-up through the process.

The recovery process for tracer testing has been the subject of much research, with development of colour sensing technology to ‘read’ tracer recovery, and also magnetic flux technology whereby a magnetic sensor registers the flux from an implant within each tracer as it passes. Any technology such as this implies that the tracers are lost, as they report to the product streams and are not recovered.

LIMITATIONS TO CURRENT TECHNOLOGY:

Float and sink analysis is a slow and laborious procedure requiring much manual labour. The results of a single analysis are often only available to plant management weeks after the initial sampling exercise was performed, as a result, its value as an ‘on-line’ process control measurement is limited.

There are also a number of hazards associated with this analysis, manhandling of large bulk samples, and, as previously mentioned, the hazardous nature of the liquids used for separation (TBE and Benzene are both known carcinogens).

Tracer testing has a quicker turnaround time than float and sink analysis, but is still labour intensive in the recovery and counting of the various tracers. In addition if tracers are not recovered as a result of being missed by the ‘collector’, the statistical accuracy of the test is compromised, and hence its absolute value is diminished.

The other systems discussed, such as magnetic flux and colour recognition have not to date been commercialised, however the technology associated with these systems will, in all likelihood, be expensive and may be impractical for the coal industry.

Diamond Industry

Diamond bearing ores are different to most other ore types in that the valuable component, namely diamonds, are generally extremely high in value and discrete in their occurrence. Diamond feeds are typically measured in carats per hundred tons (cph), for example, a typical diamond head grade of 50 cph would correspond to 10 g of diamonds per 100 tons of ore, or 0.1 ppm. [9].

Due to the high value associated with each individual diamond in an ore stream, establishing recovery efficiency is essential to maximizing revenue potential for a given deposit. Diamond ore deposits typically fall into the categories of either kimberlitic or alluvial (diamonds liberated over time from host rock and occur as discrete particles in a gravel mix), and the characteristics of either type can vary greatly within a given ore body. Variables such as grade, size and mineralogical distribution, ore hardness, and clay content can each vary greatly over the life of an ore body. The effects of these variations...
on the diamond recovery process must be well understood to ensure optimum process efficiencies.

A conventional diamond flowsheet consists of three sections: feed preparation, primary concentration, and recovery. The feed preparation stage serves several purposes; liberation of the diamonds from the gangue; crushing, screening and washing the feed product into a size range suitable for downstream primary concentration, and finally to remove screened material below the plant bottom cut size to tailings. This size has historically been 1.4mm for the diamond industry as until recently, diamonds below this size had no economic value.

After the material has been prepared, it is then fed to the primary concentration section. Gravity separation is the most commonly used method of primary concentration, with dense media separation in the form of cyclones (DMS), jigs, and diamond pans being the most common equipment types employed in diamond flowsheets.

CURRENT TESTING MECHANISMS:
Similar to the coal and iron ore industries, diamond operations use methods such as heavy liquids and tracer testing to monitor the performance of their gravity circuits. Given the significantly higher density of separation for diamonds when compared with coal, heavy liquid testing requires even more exotic and hazardous liquids, in the form of lead sulphamate.

In some cases, large bulk samples of the DMS or jig tailings streams are procured, and processed through separate DMS/Recovery Plants. While this approach does provide the extractive metallurgist with statistically meaningful data, it is costly and time consuming, meaning that audits are usually conducted on a non-routine basis.

Diamond spikes are another method used to monitor the performance of gravity circuits in the diamond industry. This method relies on the use of adding a known amount of marked, seeded diamonds to a gravity process, and recovering these diamonds in the final sorting process. The diamonds are often painted or coloured in some way, alternatively boart stones (diamonds of no commercial value) may be used. It is critical however that the marked diamonds used can be recovered and their properties match those of the normal stones. The obvious advantage of this method is that real diamonds are used during ‘feed on’ situations, the results obtained have much more credibility than tracer tests performed without feed, in order to minimise risk of losing tracers. However, downstream efficiencies must be well understood to account for potential diamond losses that could occur in these processes prior to the final diamond hand sorting process. For example, a concentration process using gravity alone could recover diamonds that due to sorthouse inefficiency are not recovered, thereby creating a ‘grey area’ as to which process did not recover the diamonds.

In recent joint trials between Gekko Systems and Namdeb Diamond Corporation, the Gekko Viking Cone was used to evaluate the performance of the In-Line Pressure Jig (IPJ). For these tests, samples of the floats and sinks products from the IPJ were procured, and analysed using the Gekko Viking Cone pictured previously in Figure 1.
The South African Institute of Mining and Metallurgy

DMS and Gravity Concentration Operations and Technology in South Africa

R A Heins, P M Grady and R L Langa

The Gekko Viking Cone, is similar to a DMS cyclone in that it uses ferrosilicon as a medium to manipulate cut-point. A variable speed pump is used to circulate the gravel / ferrosilicon medium in a closed system. Floats and sinks products are recovered in separate product baskets, sized at 2 mm. For the test work, the Viking Cone was calibrated to recover 100% of + 3.2 s.g. material to sinks. Floats and sinks samples from the IPJ were then separately processed through the Viking Cone to determine the percentage of + 3.2 s.g. material present in each fraction. Results of the test work show promise for the technology, as the Viking Cone was able to generate points for a partition curve, without the environmental drawbacks of heavy liquids. Turn around time is similar to that for heavy liquids.

EXAMPLES & TYPICAL RESULTS:

During the past year, Gekko Systems have conducted several test programs to evaluate their IPJ in various diamond applications. As is the case for any new technology, the effects of individual operating parameters must be well understood and demonstrated before acceptance can be gained within the industry. Although the main purpose of these trials was to gain a better understanding of the IPJ technology, a side benefit was the experience gained in the design and use of tracer recovery systems. For each of the trials, magnetic tracers of various sizes and densities were used to generate partition curves for the IPJ. High intensity rare earth magnets were used to recover the magnetic tracers from the concentrate and tailings streams, under feed on conditions. An example of such a system is depicted in figure 5 above. This particular installation was designed to allow for both horizontal and vertical movement of the magnet to optimize tracer reconciliation. Tracer reconciliation averaged 99% for 12 mm tracers, 95% for 8 mm tracers, and 90% for 4 mm tracers.

Tracer testing in the diamond industry generally is performed using only 4mm and 8mm tracers at sg’s ranging from 2.50 to 3.53 (diamond simulant). Sampling plants are generally tested daily due to the high profile nature of the application, however operating plants are more likely to be tested either weekly or monthly[10]. An example of the results of a tracer test from a diamond plant dense media plant audit is presented as figure 6.

Figure 5: Example of Gekko Manual Tracer Recovery Magnet
DMS and Gravity Concentration Operations and Technology in South Africa

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<table>
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<tr>
<th>Densit y g/cm³</th>
<th>Tracer Colour</th>
<th>Floats</th>
<th>Sinks</th>
<th>Cum</th>
<th>Floats</th>
<th>Sinks</th>
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Figure 6: Example of Diamond Plant Tracer Test Results

LIMITATIONS TO CURRENT METHODS

The turn around time associated with densimetric (or float/sink) type analyses remains an issue for diamond operators, particularly given the potential for loss with a non-performing plant.

The cost of diamond tracers (magnetic or x-ray fluorescent) and the resultant tendency to perform tests in ‘feed off’ environments remains the major limitation to the accuracy and value of diamond tracer testing.

Ferrous Metal Ore Industry

The run-of-mine ore in the ferrous metal industry generally contains significant proportions of non-valuable waste rock such as granites, dolomites or limestones. After crushing to obtain some degree of liberation, it is generally possible to separate much of this waste from the valuable ore components by means of gravity separation prior to downstream beneficiation.

In many cases, the next step in the process for ferrous ores is either commercial sale or pyrometallurgical processing (such as roasting or smelting). The inclusion of excess gangue material is obviously undesirable in either of these options.

Gravity processing is particularly applicable to ferrous ore beneficiation due to the density difference of the valuable mineral (in the range 4.3 to 5.1 for manganese, chrome and iron ores) against the waste (2.5-2.7 quartz/calcite/dolomite) components.

The specific processes favoured in this industry are conventional dense media separation (using cyclones and drums), spirals and jigging.
CURRENT TESTING MECHANISMS

Due to the density of separation for iron and ferrous ores (greater than for diamond processing and typically around an sg of 4.0), float/sink testing using heavy liquids is not practical. As a result, dense media separators such as the Mintek Multi Gravity Separator and Ericsson cone are required.

By changing the density of the suspension through a range of densities, the floats and sinks at each density can be established. However the final assessment of misplaced material at each density is still a manual process.

Tracers have also been used in the ferrous industry, although recovery remains manual due to the generally magnetic nature of most of the ores.

LIMITATIONS TO CURRENT METHODS

The non-availability of heavy enough liquids to perform a float/sink analysis means that synthetic suspensions must be made up generally using Ferro-silicon. It then becomes necessary to have equipment which circulates and maintains this suspension, not allowing the medium to settle and hence change the density. As a result of this, the equipment required and hence difficulty and manpower implications of performing these tests once again become restrictive.

Tracer testing has been performed and is effective in larger size fractions for the same reasons as in coal processing, however magnetic recovery of tracers is often not an option due to the magnetic properties of the ore. Thus tracer recovery remains manual.

WHAT ARE THE ALTERNATIVES?

Low Cost Tracers, Batch Systems

Tracers are generally plastic or polymeric particles with materials added to them to give them physical properties allowing them to both simulate valuable ore components and also be recovered relatively easily. These properties include density, magnetic susceptibility, fluorescence under specific X-Ray illumination and colour.

Tracers were commercialised and have been used in diamond operations since the early 1970’s, with the coal industry following in the early 1980’s [6], are currently available from 1mm to 64mm and sg’s from 1.24 to 4.50 and generally cubic in shape. Recent technology however is increasing these envelopes for size, sg and also shape at reduced costs and an example is presented in figure 7.

Tracer testing usually involves the addition of a known quantity of same sized tracers at known density intervals, with the density range centred at the estimated separation density of the unit process. According to suppliers of conventional tracers, approximately 10 density fractions containing 40-60 tracers in each
is sufficient to develop a partition curve for the process and hence establish its operational efficiency.

After the tracers are added to the process feed, it is necessary to recover the tracers. The recovery of the tracers is generally done manually from the lip of the floats and sinks screens downstream of the process being tested.

The recent addition of ferromagnetic powders to the tracer polymer mix has meant that the recovery system can be automated to some extent by the installation of a plate magnet above the floats and sinks dewatering screens. This process flow is depicted in figure 8. This has increased the complexity of production of the tracers and hence the cost. The effectiveness of this magnet at recovering tracers (particularly in the smaller size ranges) is restricted by the depth of the bed on the product screen during the test, which increases the risk of losing tracers. As a result of this and the increased cost, operators have tended to perform tracer tests, particularly for dms plants, without feed to the plant. This obviously produces a partition curve under ideal conditions, without the interparticle interferences and viscosity effects which occur under feed conditions. Thus, the value of the data generated by the test is limited.

The risk of loss of the tracers becomes even more important in the diamond industry where compounds are added to the tracers which make them fluoresce at the same frequency as diamonds under X-Ray illumination, thus allowing process efficiency measurement for sorting plants. This addition to the tracers makes them even more expensive, and operators even less willing to risk losing them.

**Low Cost Tracers, Continuous Systems**
The development of extremely low cost magnetically susceptible tracers has opened up the potential for real time statistically significant plant process control.
The process flow is depicted in figure 9.

A hopper containing a known mix of size and density tracers sits above the process feed bin, and on a preset cycle batches these tracers into the process feed. Due to the low cost of these tracers when compared with conventional hand cut tracers, the number per test will be of the order of hundreds or thousands per density fraction. These tracers will travel through the process and will report to either floats (lights) or sinks (heavies) dependant on their density and the process efficiency. The floats and sinks streams containing the tracers will feed over a drum magnet ahead of the product dewatering screen. The drum contains an alternating pole tapered high strength Neodymium Iron Boron rare earth magnet configured to extract even the smallest tracers from the stream, and then discharge them into a separate tracer collection bin.

Once the tracers have been recovered from the process stream, they need to be counted and their size/density recorded prior to recombination ahead of recycle to the tracer feed bin. The technology to identify the tracers reporting to each stream still needs to be commercialised for full continuous on line measurement, but could use a combination of physical sizing and optical methods (such as small optical sorters etc). These techniques would allow instant assessment of the process partition and feedback to the process control system, whereby action could be taken in real time to rectify process inefficiencies.

The technology is currently available to recover large quantities of low cost tracers in the form of the Gekko MagScreen (figure 10). This will produce two separate hoppers of tracers, one originating from the floats stream and one from the sinks stream. The tracers will still need to be reconciled and counted manually and an assessment of process efficiency made from this exercise, however the risk in terms of poor manual tracer recovery and the statistical accuracy of the test are both addressed.
The continuous tracer system has a number of benefits, specifically in terms of the number of tracers which are used, the fact that minimal labour is required and thus tests are easier and hence more likely to be routinely performed.

As the tracers are low cost, large numbers of tracers are used, as a result of which losses due to hangup or non recovery become statistically much less significant, for instance if 2 tracers from 2000 are lost, this is much less significant than losing 2 from 50. A potential disadvantage is the cost of the system, particularly around the fully automated tracer identification systems, however this cost needs to be viewed over the whole life of the plant and offset against the potential for losses by running an out of specification process for two or three weeks whilst waiting for a float and sink analysis – or worse still never doing meaningful process checks.

**Radio Frequency Tracers, Continuous Systems**

The CSIR in South Africa is currently in the process of negotiating to commercialise a system of radio frequency identification (RFID or Supertracers) tracer technology.

This involves implanting a transponder chip into each individual tracer without affecting either its size or density, this transponder is tagged with the data specific to each tracer such as its size, density and any other information relevant to the process.

These tracers are introduced into the process, and an antenna is placed either around product discharge pipes or above product screens, the emission from the antenna powers the transponder as it passes, causing it to transmit its unique identification and data to the receiver. This collates the information relating to which tracers have passed which antenna (floats or sinks) and passes it to a computer which interprets the information, deriving a partition curve in real time. Thus process control of the gravity process can finally be automated based on real measurements of process performance.

Currently these tracers are recovered manually, they are not disposable due to the cost of the chip and manufacturing process, and cannot be made to utilise existing recovery systems as magnetic or x-ray fluorescent additives interfere with the radio transmission. Once commercialised the intention is that the tracer is cheap enough to not need to be recovered from the process.
The process flowsheet for this measurement system is presented as figure 12.

Currently RF tracers are only available as a 23mm diameter sphere, this is dictated by the size of the transponder, however miniaturisation is being investigated, which will allow the tracers to be made in smaller sizes.

Due to the addition of the chip, the sg is currently also limited to 4.0, which is still enough for both the coal and diamond recovery industries.

Pilot testwork on the use of RF tracers has allowed calibration of 23mm tracers against a float/sink analysis as reported by de Korte [4]. It should be noted that the test results shown below were obtained using a limited number of tracers in a limited number of density fractions. Larger quantities of tracers and more density increments would have improved the correlation between the two results presented in figure 13.
A further potential benefit in the use of RF tracers if recovery technology can be developed is the removal of the statistical limitation of the tests by using the tracers in closed circuit. The testing is thus performed continuously. This would also allow a batch of tracers to be made up to simulate the density distribution of the feed ore and a direct reading of process efficiency would be obtained.

There are a few limitations to the technology as it currently stands, being primarily the sizes which can be achieved and that the tracers are still relatively expensive, and as such single pass testing with disposable tracers is not feasible. Current investigation into interference if more than one tracer passes the antenna simultaneously is also being carried out [11].

The benefits of this technology are apparent in that real time, immediate process control is possible, in addition, the opportunity to add a number of different size and density tracers simultaneously is also a benefit as the test mechanism thus starts to simulate the actual process being measured.

The fact that the detection of the tracers is electromagnetic also means that the reading cannot be masked by material depth on product screens and reduces the potential for inaccurate results.
CONCLUSIONS
Gravity processes are utilised extensively in most sectors of the extractive industry and measurement of the efficiency of separation and operation of these processes has long been under investigation.

Current processes are generally costly, resource hungry and unable to produce accurate results in real time, with the turnaround time for some tests such as Float/Sink analyses being in weeks.

The development of tracer technology has improved the situation, however tests are still time consuming and labour intensive, the introduction of recoverable components into these tracers such as magnetic compounds and X-ray fluorescent materials has allowed some automation of the recovery process. However these same developments have complicated the manufacturing process and hence increased the cost of the tracers to the point that the risk of losing tracers by failure to recover has caused operators to conduct tests without “feed on” to the plant to ensure recovery.

This step has obviously limited the usefulness and validity of the data generated.

More recently the development of significantly lower cost magnetically recoverable tracers is about to open a whole plethora of new opportunities for process operators. These include the potential to perform statistically meaningful tests on a routine (per shift or per day) basis and reliably recover the tracers in order to measure and record process efficiency, and take action as required to maintain optimum process efficiency.

The next step in using these low cost tracers, is the installation of automated magnetic recovery and tracer identification systems which will allow real time process measurement and control down to very fine sizes of tracer, typically 1mm. The possibility further exists to close the circuit and then recycle these tracers back into the process in order to obtain continuous real-time monitoring.

Radio frequency tracers provide the ultimate measurement technique and whilst still not commercialised, present the potential for a completely computerised and automatic measurement and control system in real time, the cost and physical size issues of the tracers need to be resolved and the practical implications addressed.

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DMS CYCLONE SIZE VS. CYCLONE EFFICIENCY: THE DE BEERS PERSPECTIVE

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ABSTRACT

With the decline in fine diamond production from the Argyle mine in Australia, there is a greater emphasis on efficiently treating the finer size fractions through a DMS circuit. Although it is generally well understood that smaller diameter cyclones are more appropriate for this application, practical results do not necessarily meet this expectation.

In this paper the operational performance of particular sized cyclones throughout the group was compared. Based on the results there is evidence that under certain practical operating conditions, small cyclones are not necessarily best for fine size particle treatment, particularly given the production pressures faced by all mines. However, there seems to be considerable merit in using larger sized cyclones, which tend to exhibit less performance variability, irrespective of operation conditions.

1. INTRODUCTION

The efficient treatment of diamondiferous ore by dense medium separation has been standard practice in De Beers for many decades. With the decline in fine diamond production from the Argyle mine in Australia, there is a greater emphasis on efficiently treating the finer size fractions such that the supply gap can be addressed. DMS certainly has a role to play in fine diamond production and it is generally well understood that smaller diameter cyclones are more appropriate for the application.

However, while the theory is well entrenched, the practical results do not necessarily meet expectations. This paper discusses the issue of recovery performance for particular sized cyclones and highlights that size is not a silver bullet when considering recovery efficiency for a particular sized material. There are many other setup and operational aspects that can completely overwhelm the basic function of the cyclone, which seems to have led to a wide variability in performance throughout the group. This is despite the generally consistent approach to adhering to best practice standards.

This paper presents details on the performance of particular sized cyclones throughout the group and highlights the basic operational conditions that can detract from this performance. Moreover, there is evidence that given practical operating conditions, small cyclones are not necessarily best for fine size particle treatment, particularly given the production pressures faced by all mines.

2. SUPPLIER CYCLONE SELECTION CRITERIA