STARK RESOURCES

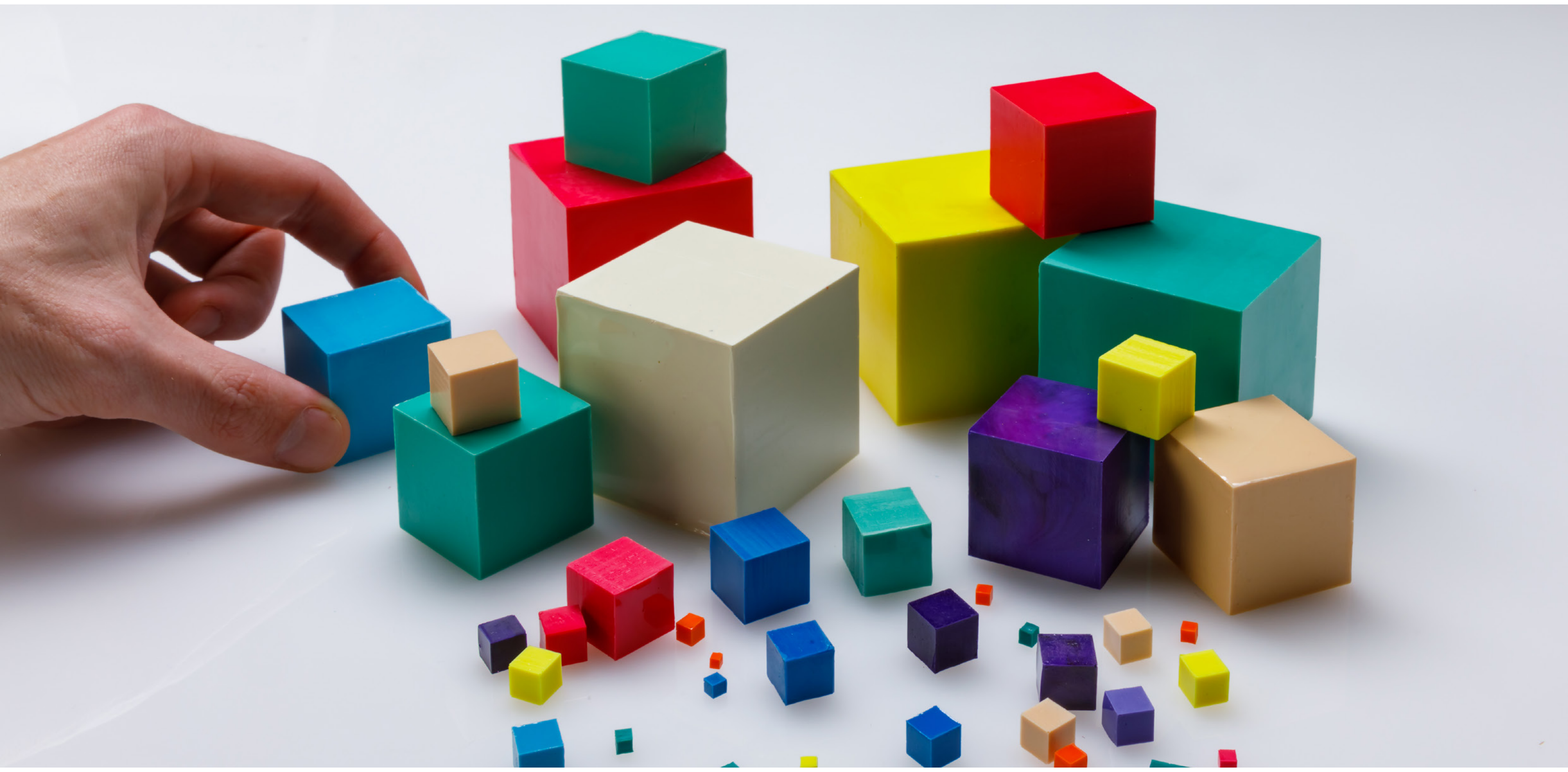
PROCESS INNOVATION INSIGHTS

DMS auditing and optimisation

Streamlining Dense Medium Separation (DMS) Processes with RFID Tracers: Real-Time Data Collection and Visualisation for Improved Efficiency and Decision-Making.

by Jean-Pierre Smith
jp@stark-resources.com

by Rynard Brits
rynard@stark-resources.com



Executive summary

This executive summary discusses the increasing interest and practical application of RFID technology in various sectors, including the mining industry. RFID technology is used to identify, categorise and track data using radio waves between a reader and a movable item. This paper focuses on how Stark Technologies has developed a unique solution for material processing plants on mines using RFID technology, allowing operations to obtain greater visibility into the actual performance of the plant. The paper provides an overview of RFID technology, including the components of an RFID system, the wireless communication between the tag and the reader, and the different frequencies used in RFID systems.

Stark Technologies is a company that uses RFID technology to assess complexities in any system, thereby providing valuable parameters in optimising a process. The company has a holistic approach; to create long-term value, it examines the entire project ecosystem, from resource to end-user, throughout the life of the project. In mineral processing, Stark Technologies uses RFID specific density tracers to audit mineral processing equipment. These range from sensor-based sorters to DM plants, and from diamond verification tracers to audits. The company has developed its own high-efficiency smart antennas that are compatible with Stark Technologies' RFID Inventory and People Management systems. The RFID density tracers are embedded with unique RFID tags to provide online and accurate results for Dense Medium Beneficiation processes. Stark Technologies has developed an online DMS auditing system that provides businesses with an online QA/QC solution to assess, optimise, and ensure optimal performance in order to maximise the ROI and bottom-line profit of a company.

This white paper discusses the efficiency of coal processing plants and equipment, particularly the ability to separate coal and non-coal particles based on the difference in their relative densities.

The most common parameters used to define efficiency are mean error, organic efficiency, and misplaced material. However, even efficient equipment may not perform at the expected level due to blockages, wear, or other factors; this will lead to lost saleable coal or yield. Fluctuations in the control of medium density too can cause yield loss, resulting in coal being produced at a higher quality than required. Additionally, producing coal of a better quality than required can result in yield loss, as it may incur penalties or rejection of a shipment. Therefore, it is important to monitor equipment and control systems to ensure efficient operation and avoid unnecessary loss.

Table of contents

Image: *Specific density tracers*

1. Introduction

Since the early 1970s, RFID technology (Radio-Frequency Identification) has attracted the attention of the scientific community. This rising interest can be seen in various special issues on the topic in academic journals such as the International Journal of Production Economics, Production and Operations Management, IEEE Transactions on Automation Science and Engineering, the International Journal of Electronic Business and Journal of Theoretical and Applied Electronic Commerce Research. However, it is the practical application of RFID technology in various sectors that has elevated this technology to a higher platform. Increasingly, industries are integrating RFID technology into their operational activities in order to ensure continual improvement.

The mining sector is one of the most dangerous industries to work in. Workers face many hazards daily, including exposure to toxic chemicals, heavy machinery, and falling debris. In recent years, the industry has been looking for ways to improve safety for workers. One way that mining companies are doing this is by implementing RFID technology.

RFID is being implemented in mining more often, not only to improve the safety of employees but also to measure and optimise the various processes and sub-processes of a mine. Such processes include:

+ Controlling access to mine sites
+ Logistic distribution of supplies
+ Tracking of personnel
+ Evacuation and rescue
+ Managing explosives
+ Detection areas
+ Material tracking

This paper will address how Stark Technologies has taken RFID technology and developed a unique solution for material processing plants on mines that will enable an operation to obtain greater visibility in the actual performance of the plant.

2. RFID Technology

2.1 RFID Description

RFID is an Automatic Data Collection (ADC) technology that uses radio waves to transfer data between a reader and a movable item to identify, categorize, and track data. Automatic Identification and Data Capture (AIDC) is the generic term of identification systems including barcodes and RFID. Various RFID technologies are available. These include Very Short Range Passive RFID, Short Range Passive RFID, and Active Beacon, Two-way Active and Real-time Locating Systems (RTLS). (Curtin et al, 2007).

RFID is a way to automatically identify objects with radio waves, like a barcode that uses radio waves instead of light. An RFID system consists of two components: the RFID tag, which is attached to the objects to be identified, and the reading and writing unit that carries out the data transmission process. RFID tags are able to store data right at the object and to assume individual shapes and sizes. Moreover, the RFID technology is able to provide RFID tags that resist extreme manufacturing conditions.

The basic Radio Frequency Identification system can be described as follows:

RFID tags: The tags (also called RFID chips) are attached to physical objects and store at least a unique identifier of the object that they are attached to. They can also store other user data.

RFID readers: These hardware devices interact ditrectly with the RFID tags. Higher-level applications can access RFID readers through a well-defined protocol. RFID readers provide at least reading, and in some cases writing, functionality. In addition, they might offer functionalities for aggregating or filtering read operations and for disabling RFID tags either temporarily or permanently.

RFID middleware: The middleware is software that can run centrally on a single server or be distributed over different machines. Its major role is to coordinate a number of RFID readers that are usually located close to one another, for example within a single plant or production line. The middleware buffers, aggregates, and filters data coming in from the readers to reduce the load for the applications.

Applications systems: The RFID data may be used by a great variety of software systems. In a manufacturing environment, the applications are typically part of the MES or ERP system.

The tag is placed on the object that is to be identified. The tag contains the suitable information of the object. The reader has a number of different responsibilities like powering the tag, identify the tag, read, and sometimes, write data to the tag. The reader also communicates with the database in which the information from the tags will be processed. When the tagged object comes into a reader's interrogation zone or reading zone, the reader sends out a radio wave to the tag, which powers up and sends back its information to the reader. In some cases, new information is sent from the reader to the tag. The reader sends the information to a database that processes the data from the tag in a suitable way. Because RFID uses radio waves, it is not necessary to have clear line of sight between the reader's antenna and the tag.

2.2 Wireless communication

The communication between the tag and the reader is wireless. Different methods are used to achieve wireless communication. An inductive coupling usually operates at low or high frequencies. The principle is that a reader generates a strong electromagnetic field that induces voltage in the coil of the tag. The coil of the tag functions as an antenna. The electromagnetic field supplies energy to the microchip in the tag. Data transmission to the reader is achieved through a signal that makes the tag transmit its information by modulating the signal. Changing one of the parameters of the transmitting field (amplitude, frequency or phase) modulates the signal. The tag short-circuits the signal from the reader and this change of the load of the field (amplitude or phase) constitutes the return transmission of the tag.

RFID systems have various frequencies. The frequency is one of the factors that determine the reading range between a tag and a reader. It also determines what type of RFID technology should be used for a specific implementation. The frequency is divided into five groups: Low, High, Middle, Ultra High Frequency (UHF) and microwave. Low frequency RFID systems usually operate at 125 kHz to 134 kHz. The RFID systems of high frequency operate at 13.56 MHz. The frequency of the middle band is 433 MHz. The UHF band operates typically on 868 MHz (Europe) and on 915 MHz (USA). Microwave operates at 2.45 to 2.5 GHz.

An RFID system's reading range is defined as the maximum distance for successful communication between the reader and the tag. The range can vary from a few millimetres to tens of metres. The maximum range between a tag and a reader can vary depending on three main areas:

+ Frequency
+ Signals
+ Readers and antennas

The reading range increases when the frequency increases. The signal strength from the antenna differs depending on whether it is an active or passive tag in use. The reading range is longer when an active tag is used. How the antenna of the reader is directed in relation to the tag is important. The size of the antenna and the power of the reader are also significant.

Different materials also have an effect on the reading range and the readability. Metal and water are two substances that make it difficult to read tags. Where metal or water is a factor, low and high frequency systems work better than UHF and Microwave do. One drawback is that the reading range decreases when using the lower frequencies. The radio waves are absorbed by water, and they bounce off metal when using UHF.

3. Stark Technologies solutions

3.1 Introduction

Stark Technologies uses RFID technology to assess complexities in any system, providing valuable parameters in optimising processes. To create long-term value, the company employs a holistic approach, examining the entire project ecosystem, from resource to end-user – throughout the life of the project. In mineral processing, Stark Technologies uses RFID specific density tracers to audit mineral processing equipment ranging from sensor-based sorters to DM plants, and from diamond verification tracers to audits.

Figure 1: *Schematic illustration of RFID application through-out the mining and beneficiation process.*

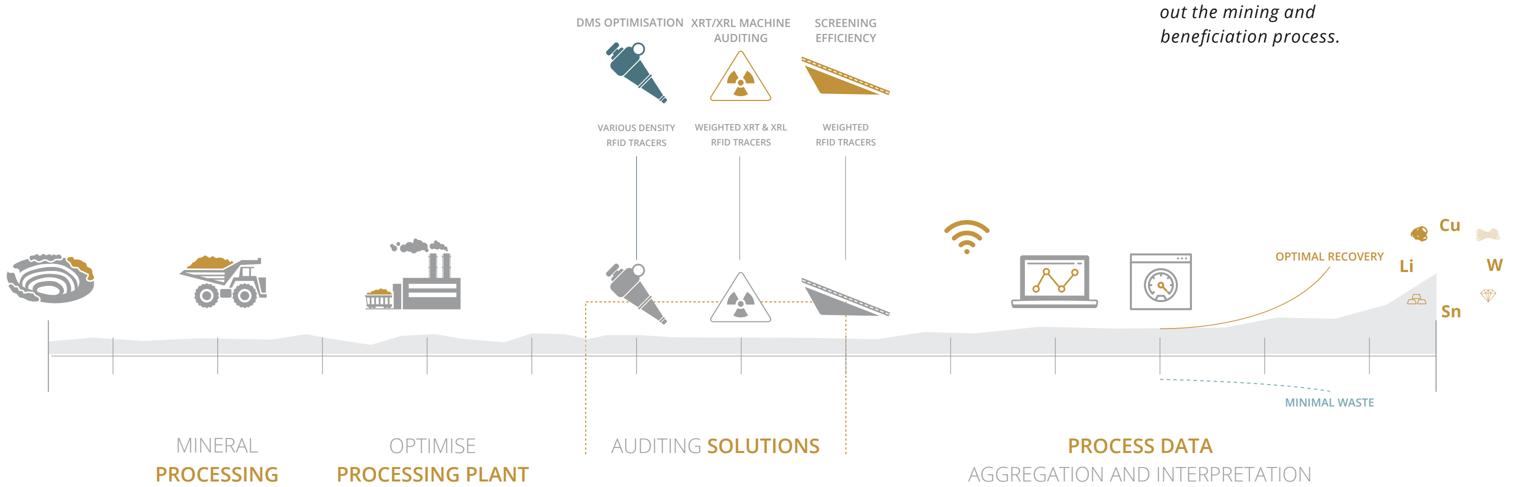


Image: *RFID detection equipmnet ANT 1500*

3.2 Hardware specification

Antennas

Stark Technologies has developed its own market leading, in-house designed, engineered and manufactured, high-efficiency smart antennas (Table 1) that are compatible with Stark Technologies' RFID Inventory and People Management systems. The Radio Frequency antennae are designed for better saleability, read-ability and overall increased durability, enabling high RFID tag read rates.

DETECTION EQUIPMENT	ANT10004 ; ANT15004
Housing	Completely enclosed formed housing
Condition monitoring	Advanced condition monitoring system (add-on)
Maintenance	Easily accessible for maintenance and future expansion.
High RF readability	Precision engineered components for optimal RF readability.
Polarization type:	Circular
Form factor:	Stationary fixed
Connector type:	TNC female
Connection location:	Side mounted/Back panel mounted
Primary frequency range:	915 MHz – 919 MHz
Input impedance:	50 Ohm
Dimensions:	1014 / 1462 mm x 270 mm x 58 mm

Table 1: *Detection equipment description*

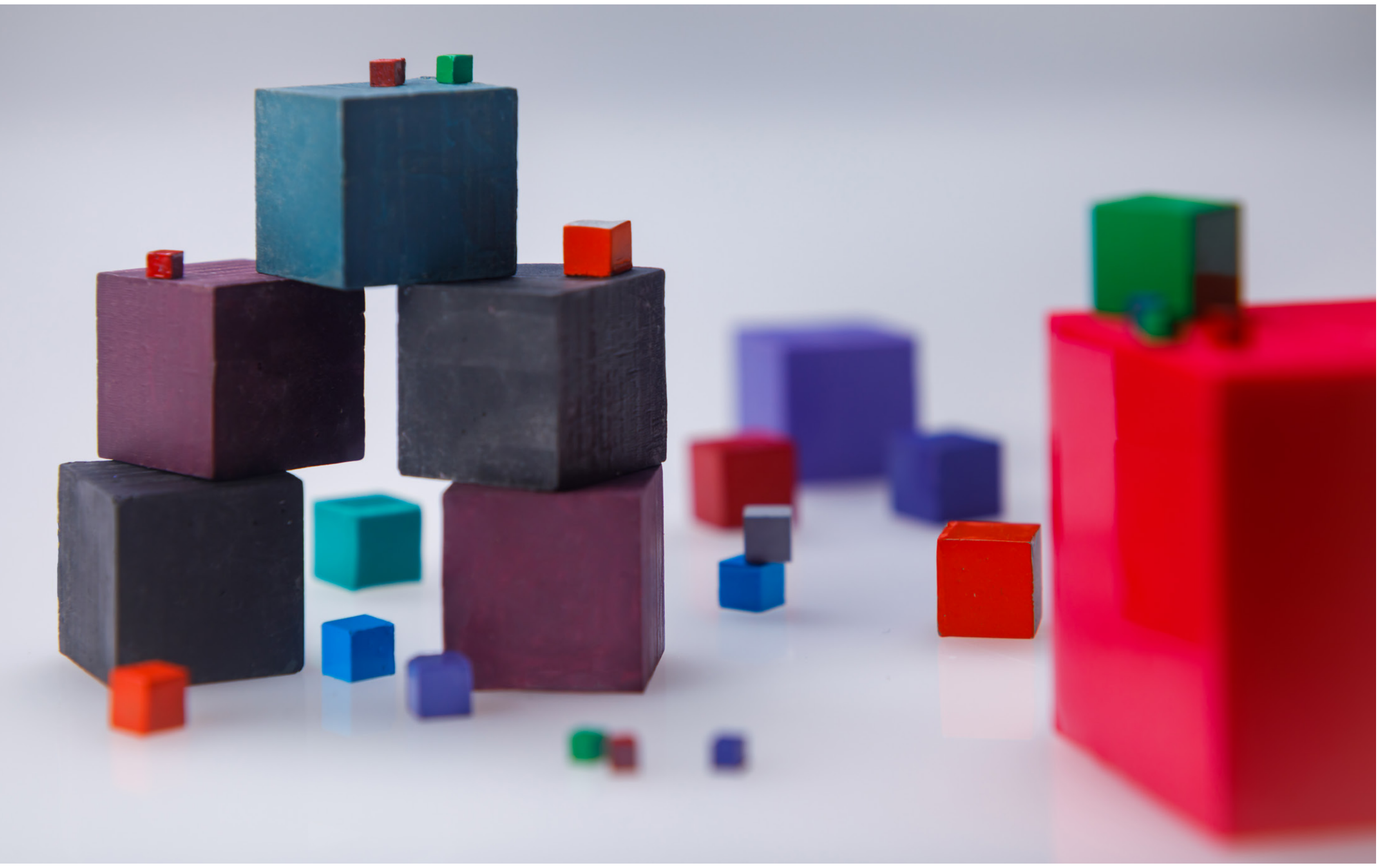


Figure 2: *RFID density tracers*

Tracers

RFID Specific Density Tracers

The RFID density tracers (embedded with unique RFID tags) provide online and accurate results for dense medium beneficiation processes. This enables real-time process control with the AudeX proprietary Dense Media Optimisation System. The tracers that Stark Technologies manufactures are particles made of polymers. A filler material is added to the polymer to adjust the density of the particle. By varying the amount of filler material used, particles can be manufactured in a range of densities.

TECHNICAL INFORMATION

Standard sizes [mm]	4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50 (Custom sizes available on request)
Shape	Cubic
Colours	Customisable (relative to the commodity)
RD ranging	1.3 – 4.8 RD
Lead free	
Each tracer undergoes a verified QC/QA process	
Suitable for AudeX's Dense Media Optimisation System or machine performance audit	

Table 2: *RFID density tracers' technical detail*

4. Stark Tech DMS auditing solution

4.1 Stark Technologies Solution

The main purpose of any coal preparation plant is to ensure that as much as possible of the raw coal sent to the plant is turned into saleable coal. Optimal efficiency of the plant is therefore required and if the efficiency of the plant can be known or, alternatively, if any reduction in efficiency can be signalled, then corrective action can be taken without delay. The misallocation of just 1% of saleable coal to the discard dump can have an enormous effect on the bottom line of a company.

Ideally any plant manager or metallurgical engineer would like to reduce the time-to-detect and time-to-correct for any deviation on the cut-point of the coal in order to minimise the potential yield loss. Consistent availability of near real-time data would provide any plant operators with practical, applicable information, which will allow for rapid and accurate decisions to be made.

While techniques exist that provide at least some of the information required to control a coal preparation plant, some of these can be labour-intensive and their results are subject to human error.

Stark Technologies has developed an online DMS auditing system that provides a business with an online QA/QC solution to assess, optimise and ensure optimal performance in order to maximise the ROI and bottom-line profit of a company. It uses Stark's proprietary RFID technologies. The tracers, detection hardware and software are in-house developed and customisable to meet the needs of any application, allowing a business to manage and optimise material processing in real time. Stark's real-time management service and Web interface ensure optimal metallurgical performance 24/7.

The online DMS audit solution works as follows (Figure 3):

+ Provide specific density tracers for the selected density range (1.4 – 1.9 g/cc for coal application, according to specifications). All tracers are evaluated through a quality control system to provide controlled tests.

+ Set up detection equipment on select equipment to evaluate sinks and floats. The high-efficiency smart antennas of Stark Technologies are mounted at material transfer points in order to ensure optimal taction of the RFID tracers
    - Feed – Specific density tracers are introduced into the system
    - Sinks – Dewatering screen, discard (relative to the commodity)
    - Floats – Dewatering screen, product (relative to the commodity).

+ Introduce allocated RFID specific density tracers on feed prep screen manually or with automatic dispensing unit manufactured by Stark.

+ The RFID density tracers are detected on either the sink or float dewatering screen with the antennae.

+ Real-time calculation of Tromp/washability curves to provide EPM, cut-point.

+ A report is generated on a custom built dashboard to provide the process or metallurgical engineer with an immediate, real-time partition curve from which the EPM and d50 can be read.

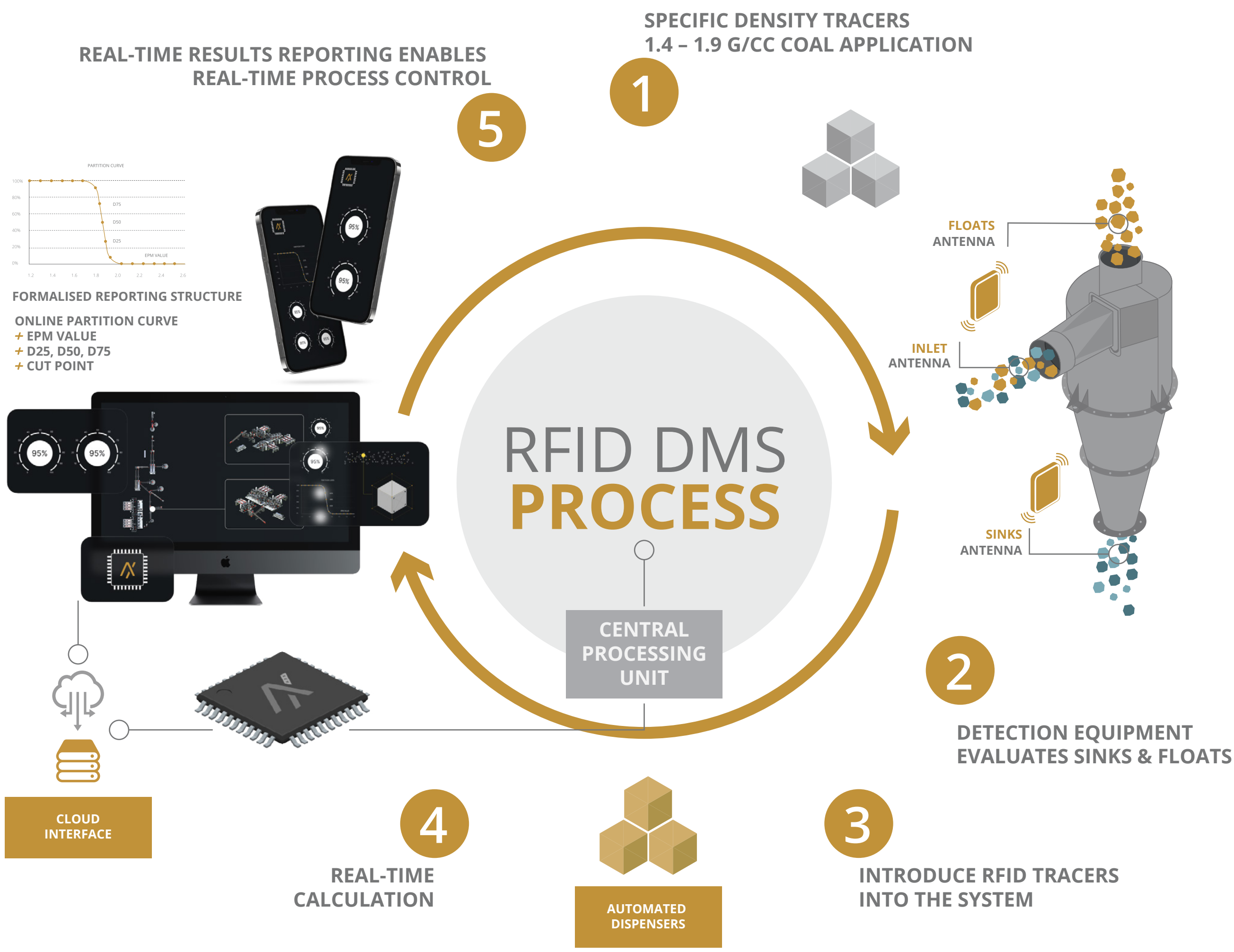


Figure 3: *Schematic flow of a DMS auditing solution provided by Stark Technologies*

Tracers are very useful for providing a quick check on the efficiency of any particular processing unit and an excellent method for 'troubleshooting'. They are also very flexible in use; for example, a single cyclone in a module can be tested separately, provided the tracers can be introduced into the feed stream of that particular cyclone.

> *... time-to-detect' and 'time-to-correct' intervals are drastically reduced ...*

4. 2 Benefits

The immediate benefits of implementing the online DMS auditing system from Stark Technologies are:

+ Live running plant testing: The tracers can be introduced to the plant manually or via Stark Technologies' automated dispensing unit at set time intervals without shutting off the plant.
+ Real-time results: Real-time results are obtained and produced on a fit-for-purpose custom built dashboard. By obtaining real-time results the 'time-to-detect' and 'time-to-correct' intervals are drastically reduced and any deviations from the intended cut-point can be mitigated, and yield loss minimised.

+ Application-specific particle size and density RFID tracers: Thanks to the in-house manufacturing capabilities of Stark Technologies, tracers can be manufactured for any density, size, shape, and colour. This allows Stark to implement online DMS auditing systems on any commodity where density separation is conducted.

+ Improved safety of employees: The online DMS auditing system from Stark reduces the need for continuous sampling; this minimises both the risk of employees getting injured during sampling and the occurrence of any sampling bias from samplers.

+ Comprehensive test results: Efficiency curves (including all peripheral information) are reported per size fraction, including a combined report. This delivers more comprehensive test results when compared to traditional methods of testing and reporting.

Due to the in-house manufacturing capabilities of Stark Technologies, tracers can be manufactured in a wide range of sizes, shapes, colours and densities to suit the requirements of different commodities.

Image: *DMS coal operation, process evaluation*

5. Case study

5.1 Problem statement

When reference is made to the efficiency of a coal preparation plant or a specific coal processing unit, the sharpness of separation is usually inferred. The sharpness of separation reflects the ability of a unit, such as a dense-medium cyclone, to selectively separate coal and non-coal particles from one another based on the difference in their relative densities.

A number of parameters are used to define efficiency. The most popular method of defining the efficiency of coal processing plants and equipment is to record the mean error or 'Ecart Probable Moyen' (EPM). Other popular parameters are 'organic efficiency' (OE) and 'misplaced material'.

In such a case, saleable coal is being lost without the problem being detected.

Partition density (also called the 'd50'), equal errors cut-point density, ash error, and a number of other terms are used in combination with the EPM and OE to define the efficiency of coal processing equipment.

In practice, it is often found that even inherently efficient equipment, such as dense-medium vessels and cyclones, do not perform at the expected level of efficiency for a number of reasons. In order to obtain the maximum realisable value of a coal resource, all the equipment in a coal preparation plant should operate at the best possible level of efficiency at all times. However, it is not always possible to detect when a unit is operating at reduced levels of efficiency.

If a unit becomes blocked or breaks down, it is usually obvious that there is a problem and corrective action can be taken immediately. There are, however, times when a unit may appear to be functioning normally when, in fact, something is wrong, reducing the efficiency of the unit without this being noticed. An example is the partial blockage of the feed inlet of a cyclone. In such a case, saleable coal is being lost without the problem being detected and this situation may continue for extended periods.

Yield loss

It is also possible to lose yield of saleable coal even when the equipment is in a good state of repair and being operated correctly. Johan de Korte (de Korte, 2002) provides a simplified example of such a scenario when two or more cyclones, operating as a single module, could be cutting at different densities. The reason for this may be uneven wear of the cyclone spigots, uneven distribution of the feed coal or unequal feed pressures. The data in Table 3 below illustrate the effect of two cyclones in a module cutting at different densities.

ASH % CYCLONE 1	ASH % CYCLONE 2	TONS CYCLONE 1	TONS CYCLONE 2	COMBINED TONNAGE
12.0	12.0	41.43	41.43	82.86
12.5	11.5	42.47	40.17	82.63
13.0	10.9	43.39	38.59	81.99
13.5	10.2	44.20	36.55	80.75
14.0	9.3	44.94	33.67	78.62
14.5	7.8	45.64	26.98	72.62

Table 3: *Effect of two cyclones cutting at different densities*

In the event of the two cyclones operating at the same density, both will produce a 12% ash product and a combined tonnage of 82,86. If the cyclones operate at different densities, with cyclone 1 producing (say) a 14,5% ash product and cyclone 2 a 7,8% ash product, a 12% overall ash is still produced, but the combined product tonnage would be reduced to 72,62.

Control of medium density

Control of the medium density is a very important factor in any dense-medium plant. Under normal conditions, a fluctuation of the density about the set-point value will occur due to the nature of the control system. The fluctuation will usually follow a sine wave pattern. In some plants, the variation of density, both below and above the set point, can be relatively large. This may be due to large tank volumes, insufficient amounts of density-control water, poor design of the density-control system or incorrect operation of the system. Even though the overall, average density of the medium is the same as the set-point value, yield is lost.

Figure 4 Illustrates an example of where the variation in relative density of the washing medium about the set-point value of 1,55 can be significant. The net effect of this is that the product quality is higher than specification for one half of the time and below it for the other half of the time. The overall product is still on specification.

However, there will be a yield loss. The larger the variation in quality between the upper and lower limits of the range of qualities produced, the more severe will be the negative effect on the product yield.

The same argument applies to the quality of coal produced, and follows logically from the above discussion on density control. Two wrongs do not make a right in the case of control of the quality of coal produced. If below-specification coal is produced for, say, half a shift, and above-specification coal for the balance of the shift, it is possible that the average quality of the coal could be exactly on specification. However, yield would have been lost.

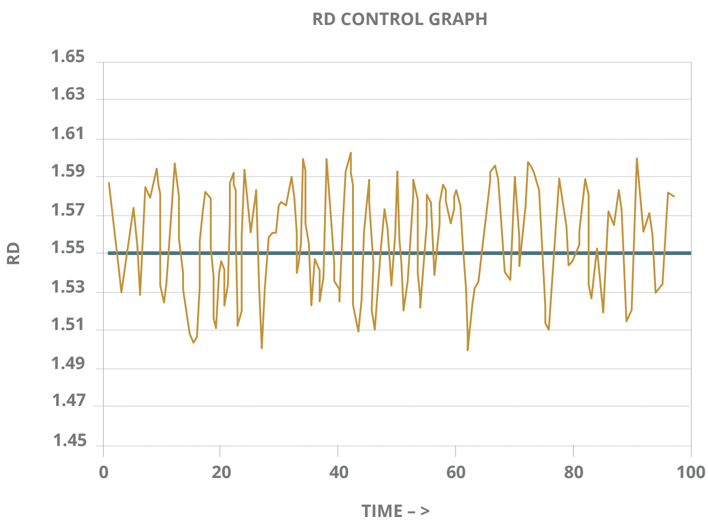


Figure 4: *Example of medium density fluctuation*

Control of product quality

When coal is produced at a quality better than required, yield is lost. Often, a penalty is incurred if out-of-specification coal is produced. The penalty may be in the form of a reduction on the price of the coal delivered or even the rejection of a shipment of coal. The financial implications of this can be significant.

To avoid the penalties associated with out-of-specification coal and also to ensure continued good relations with customers, many coal producers tend to err on the 'safe' side. This means that they produce coal that is usually slightly better than specification.

On most plants there is a delay of several hours or even days between producing coal and knowing what the quality is of the coal produced. This is due to the process of procuring samples of the coal production, and then drying and analysing these samples.

5.2 Audit Conducted

Stark was requested to conduct an online DMS audit at a large coal mine in the SADC region. The objective was to demonstrate that modern RFID technology can be applied in a processing plant and that real-time data can be obtained on the cut-point of the density medium cyclones.

Three different size (6 mm, 12 mm and 25 mm) RFID specific density tracers were introduced manually into the feed preparation screen. The smart antennas of Stark Technologies were mounted at material transfer points in order to optimally detect the tracers that are segregated to the 'sinks' and 'floats'.

The tracers used for the audit were RFID specific density tracers with the following characteristics:

+ Embedded with unique RFID tags
+ Sizes ranging from 6,12 to 25 mm
+ Relative density ranging from 1.4 to 1.9 g/cc
+ Density increments of 0.05 RD
+ Lead free
+ Each tracer underwent a verified QC/QA process
+ Suitable for Dense Media Optimisation
+ System or machine performance audit

Image: *Coal dewatering process*

Figure 6: *Photo collage DMS auditing being conducted.*

The smart antennas that were mounted at the two transfer points were the ANT10004, designed to provide superior readability and overall increased durability.

From the data obtained Stark was able to use its proprietary software to compile a real-time summarised dashboard for comparing size class efficiency differences (Figure 7). Tracer size distribution table and partition curves based on the Erasmus Model Fit were drawn-up. Such information allows a metallurgist to monitor if the cut-point between coal and non-coal product is maintained as sharply as possible.

Stark was able to use its proprietary software to compile a real-time summarised dashboard for comparing size class efficiency differences.

Results

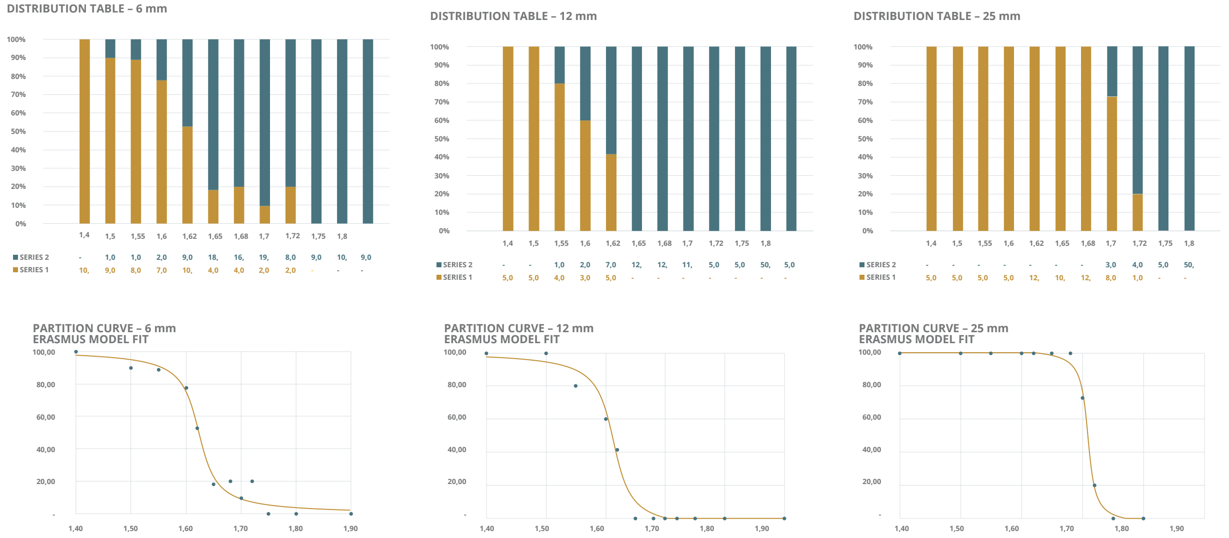


Figure 7: *Summary of real-time dashboard presented.*

5.3 Business case

A theoretical business case was drawn up using the actual operational data of the mine. The consistent misplacement of even a small percentage of saleable coal due to yield loss can amount to significant loss of potential income.

Table 4 provides a summary of the operational parameters for the mine and illustrates the annual accumulated increase in earnings before interest and tax (EBIT) if only 1% of misplaced material is avoided. While a 1% reduction of misplaced material may seem insignificant, such a saving could amount to an annual increase in EBIT of about $5,6 million.

Table 4: *Operational parameters for business case.*

INPUTS/ASSUMPTIONS	UNITS
Export coal production	400 t/h
OEE availability	80 %
Production rate	24 h/daily
Coal export price	$ 200 (at Q4 2023)
Misplaced material recovered	1 %
Saving in misplaced material (annually)	Circa $ 6 000 000

Table 5 illustrates how the earnings before interest and tax (EBIT) of a mine can increase when a small percentage of material being misplaced (saleable product discarded as waste) is avoided.

The RFID tracer is a modern tool to help metallurgists ensure that plant optimisation and efficiency settings are maintained. By using Stark's online DMS auditing system, process managers can ensure that yield recovery is maximised and misplaced material is minimised, which will result in the increase in the bottom line of the organisation. Inefficiencies are detected rapidly and can be corrected without unnecessary analysis delays.

EBIT INCREASE PER ANNUM (USD/A)

% SAVINGS IN MISPLACED MATERIAL

$/TON	0,50%	1,00%	1,50%	2,00%	2,50%	3,00%	3,50%	4,00%
100	$1,402,560	$2,805,120	$4,207,680	$5,610,240	$7,012,800	$8,415,360	$9,817,920	$11,220,480
120	$1,683,072	$3,366,144	$5,049,216	$6,732,288	$8,415,360	$10,098,432	$11,781,504	$13,464,576
140	$1,963,584	$3,927,168	$5,890,752	$7,854,336	$9,817,920	$11,781,504	$13,745,088	$15,708,672
160	$2,244,096	$4,488,192	$6,732,288	$8,976,384	$11,220,480	$13,464,576	$15,708,672	$17,952,768
180	$2,524,608	$5,049,216	$7,573,824	$10,098,432	$12,623,040	$15,147,648	$17,672,256	$20,196,864
200	$2,805,120	$5,610,240	$8,415,360	$11,220,480	$14,025,600	$16,830,720	$19,635,840	$22,440,960
220	$3,085,632	$6,171,264	$9,256,896	$12,342,528	$15,428,160	$18,513,792	$21,599,424	$24,685,056
240	$3,366,144	$6,732,288	$10,098,432	$13,464,576	$16,830,720	$20,196,864	$23,563,008	$26,929,152
260	$3,646,656	$7,293,312	$10,939,968	$14,586,624	$18,233,280	$21,879,936	$25,526,592	$29,173,248
280	$3,927,168	$7,854,336	$11,781,504	$15,708,672	$19,635,840	$23,563,008	$27,490,176	$31,417,344
300	$4,207,680	$8,415,360	$12,623,040	$16,830,720	$21,038,400	$25,246,080	$29,453,760	$33,661,440

The RFID tracer is a modern tool to help metallurgists ensure that plant optimisation and efficiency settings are maintained.

Table 5: *Increase in EBIT due to savings in misplaced material.*

6. Conclusion

RFID technology has become an increasingly important tool in various industries, including the mining industry. By using RFID technology, companies like Stark Technologies can identify and track data using radio waves, providing greater visibility into the actual performance of a plant. Stark Technologies uses RFID specific density tracers to audit mineral processing equipment, enabling businesses to optimise their processes and maximise their ROI.

Additionally, this paper highlights the importance of monitoring equipment and control systems to ensure efficient operation and avoid unnecessary loss, especially in coal processing plants. By using RFID technology, companies can improve their efficiency and reduce the risk of yield loss, ultimately improving their bottom-line profits.

Stark Technologies uses RFID specific density tracers to audit mineral processing equipment, enabling businesses to optimise their processes and maximise their ROI.