DEVELOPMENT OF A RF TRACER FOR USE IN THE MINING AND MINERALS PROCESSING INDUSTRY

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SYNOPSIS

Two of the most important issues mines have to deal with are tracking the ore mined from pit to plant and to test the efficiency of beneficiation equipment.

Kumba Resources and Saco Systems are working together at moment to develop a RFID tracer system to help address these issues. This paper will focus on the tracking of ore from pit to plant.

The main advantages for ore tracking is to ensure plant feed blending and dilution according to plan.

The RFID tracer system works on the basis of a tracer that physically simulates the ore properties and radio frequency technology that facilitates communication with the tracer and allowing information to be stored on the tracer.

This paper tends to indicate the progress on the application of RFID tracer technology in the minerals processing environment as tested at Kumba Resources so far.

It is concluded that the system has great potential, but some important problems remain

1 INTRODUCTION

A problem common to most mines and their beneficiation plants is optimising the feed blend to the plant and determining the dilution of the feed blend to the plant. This is then built into the short and medium term mine plans. Having done this the next problem is to ensure that the actual operation implements the plans as far as possible and if not, to detect variations as soon as possible, to enable corrective action as soon as possible.

The purpose of this paper is to discuss progress made by Kumba Resources and Saco Systems to develop a system through which RF-enhanced tracers are used to improve the tracking of ore from mine to plant. This enables early detection of variations from the mine plan, to enable corrective action as soon as possible.

A tracer is a synthetic device designed to simulate the relevant properties of the material that is being processed as close as possible and yet still be distinguishable, to enable identification within the material flow. One of the best known applications of tracers in the mineral processing industry is to use them to measure efficiency of physical beneficiation equipment [1, 2, 3].

RFID is the acronym for Radio Frequency Identification. This technology uses radio frequency waves to exchange information between two points. In a typical application, the system would consist of a tag, an antenna connected to a reader (from now on referred to as the primary antenna) and some means of communication between the reader host PC or PLC. The tag itself contains a microchip, for data storage and an antenna, for communication (from now on referred to as the secondary antenna).

2 DISCUSSION

2.1 The advantages of ore tracking

A problem common to most mines, and their beneficiation plants, is variation of feed properties. One of the most common ways of combating this is feed blending. However, with the increasingly complex ore bodies being extracted the instances in which the overall recovery of valuable minerals is affected negatively by these practises is increasing.

Following are three examples in Kumba where the advantages of managing ore feed to the plant in this manner has added significant value.

The first example of this philosophy, as applied at Rosh Pinah base metal mine, is shown in Figure 1. This indicates a typical mixing curve derived from actual plant data for a period of 6 months, where predominantly Eastern ore field and Western ore field material were mined. Both these ores where classified as carbonate ores. At a 50% blend, for example, the lead grade would be 18% lower than of the ores were processed separately. The penalty for Zinc grade is quite significant as well, and Lead recovery is also affected negatively.

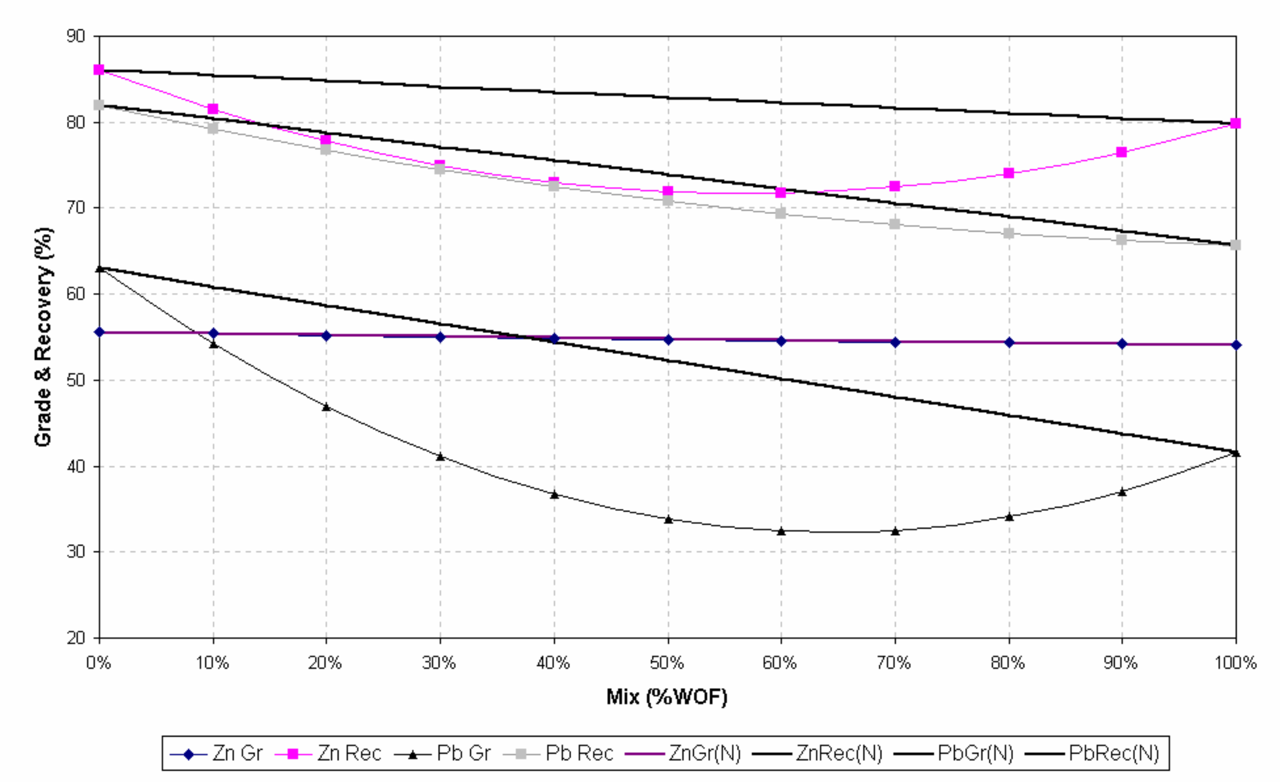

Figure 1 Mixing curve for Western and Eastern ore field blends at Rosh Pinah. [4]

The other examples of concrete gains realised by implementation of such a strategy are shown in

Table 1 and Table 2. In these cases it is once again of paramount importance to track the optimised ore-blends from the pit to the plant.

Thabazimbi Iron Ore Mine	
Cost savings (lower stripping ratio)	R 10.4 m/annum
Higher throughput	R 28.51 m/annum

Additional LOM	4.5 years

Table 1 Advantages of good ore management on an iron ore mine. [4]

Tsikondeni Coal Mine	
Improvement in yield (12 %)	R 14.27 m/annum
Steelworks productivity increase	R 28.56 m/annum
Decrease in magnetite consumption	R 0.33 m/annum
Decrease in mine pillar size	R 1.22 m/annum
Less rock handling	R 0.2 m/annum
Lower hauling costs	R 0.57 m/annum
Less waste handling	R 0.13 m/annum
Total	R 45.3 m/annum
Additional LOM	3.1 years

Table 2 The financial advantages of implementing a good ore management policy at a coal mine.

Ore tracking and management can be divided into two broad segments for the purpose of this presentation; mine-to-mill and mill-to-client. From a base-metal mining perspective tracking of ore from mine-to-mill is the most important facet. This will therefore be the focus of this paper, but mill-to-client tracking will also be touched on.

2.2 RF Tracers

To keep track of all these different materials would seem almost impossible at first glance, but by adding a tracer that tells you exactly what you are dealing with it can be done with relative ease, even in a highly dynamic environment.

2.2.1 RFID Technology

RFID technology uses radio frequency waves to exchange information between two points. In a typical application, the system would consist of a tag, an antenna connected to a reader (from now on referred to as the primary antenna) and some means of communication between the reader host PC or PLC. The tag itself contains a microchip, for data storage and an antenna, for communication (from now on referred to as the secondary antenna).

A tracer consist of
-host (the tracer itself)
-packaging
-chip
-antenna

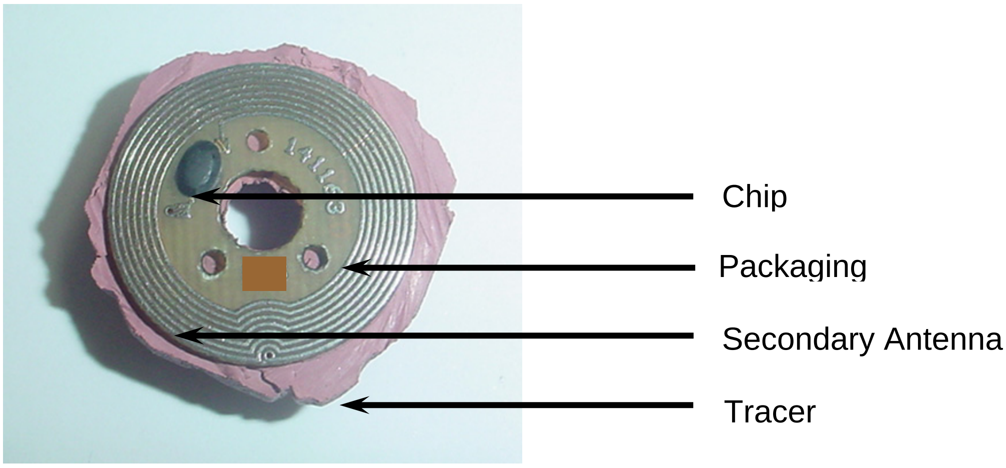

Figure 2 Macroscopic layout of a 22mm stone-shaped tracer.

The chip stores the data, and the energy received from the reader, while the secondary antenna is used for communication. The packaging is the substrate on which the chip and antenna is mounted and can vary significantly based on tracer size and usage. Shown in Figure 2 is a section of the tracer developed through this project. In the later stages this was modified some what, but the basics stayed the same.

Tracers can also be active or passive. The primary antenna powers passive tracers by charging a capacitor on the chip. This has a negative impact on tracer range when compared with active tracers, which is battery powered, but the cost and size-reduction advantages far out weights this.

Tracers can be read-only, or read-write. In the case of read-only tracers, it would be necessary to refer to a remote database to establish what material you are dealing with. However, the tracers that we are employing are of the read-write type, making it possible to add a mobile database to the material.

Figure 3 Antenna over a conveyor at Rosh Pinah

The primary antena (Figure 3) is linked to the reader by means of a cable which also supplies its power. The reader needs to be connected to a power source and communicates with PC or PLC.

2.2.2 Tracers

A tracer is a tool used to gain some insight into how a material behaves. The tracer therefore needs to have the same characteristics as the ore which it simulates. These physical characteristics include size, shape, density, hardness and shore hardness (elasticity). Since these tracers are rubber-based, any shape required in this industry can be moulded.

Figure 4 shows design drawings of three tracer shapes that were used for the majority of the tests conducted.

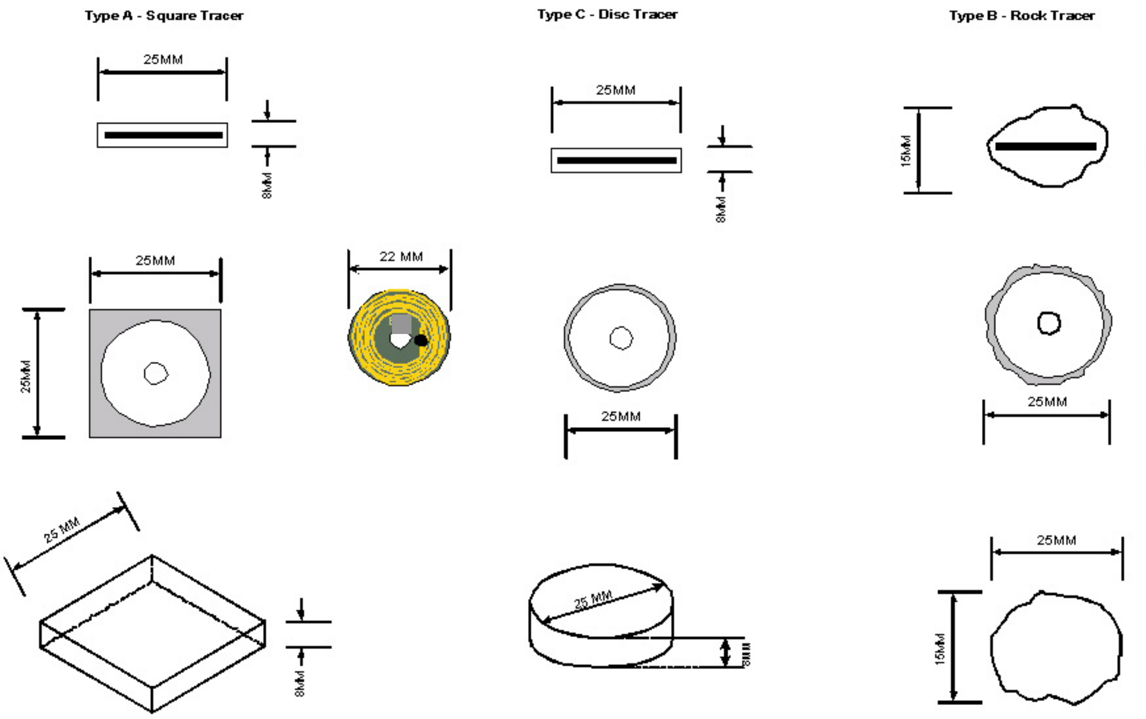

Figure 4 Design drawings of the commonly used tracer shapes.

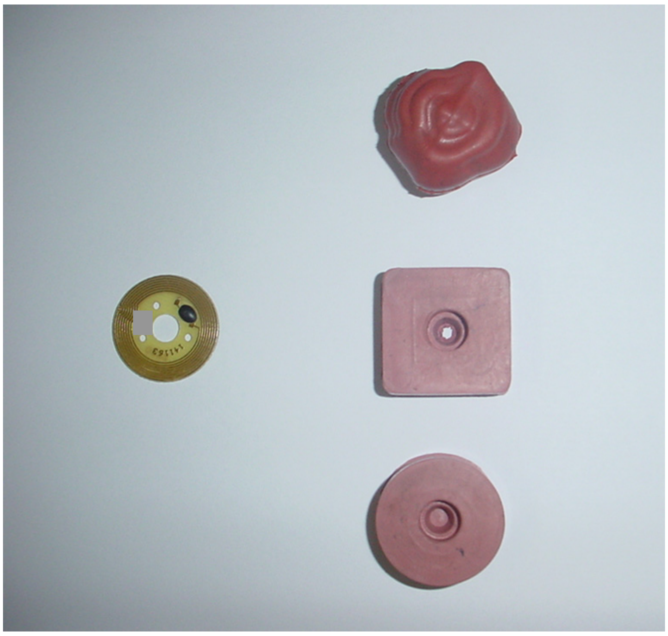

Figure 5 One of the early generation stone shaped tracers with the later disk and square tracers. The tag shown on the left was also later changed.

2.3 Application of RF Tracers in the Mineral Processing Industry

Specific uses in the mineral processing industry are to numerous to list here, but general fields include:

- Ore tracking
- Sample management
- Plant auditing
- Plant maintenance
- Vehicle tracking
- High cost items
- Personnel

Some applications, mainly in the personnel field (e.g. access control and attendance monitoring) are already widely implemented. The others were investigated in the initial phases of this project, and for the purposes of this project, ore tracking and plant auditing were selected as the applications with most favourable risk-reward profiles at this stage. In this paper only ore tracking is focused on, but the requirements are the same in most of the cases mentioned above.

With ore tracking, a network of readers in strategic locations (on conveyors and mobile equipment like front-end-loaders, trucks etc) can with relative ease be linked to each other and the process control system. If such a system is mated with technologies like GPS and mobile communications like GPRS and 3G new doors for precision process control and inventory management are opened up.

In application of RF tracers in an ore tracking function certain operational issues need to be taken into account.

The system must allow for multiple tags in field reads and bouncing of tracers to eliminate possible re-reads at the same station. For example if a tag moves through the antenna’s range slowly, or bounces back it should still not be read more than once. The tracers must also accurately follow flow of ore in and through stockpiles and ore passes, and tracers should not segregate from the ore it is associated with during these steps.

Ideally tracers would be able to survive a blast. This would enable tracking of the material from in-situ through the plant and greatly ease management of stockpiles in and around the mine and beneficiation plant. The tracer must also survive the next few steps like primary crushing, screening and general transfer steps (conveyors, chutes, front loaders and dumping).

Tracers must not negatively affect operations, for example blocking screens and crushers, or getting stuck in beneficiation equipment. If the latter happens the ore which passes through the equipment will not be subjected to the intended processes, for example if tracers should accumulate inside a cyclone. If ore is tracked to the client, it becomes more important that tracers must also influence the downstream processes in any negative way, for example by forming toxic gasses when burnt or reducing
efficiency of the process. The tracers will also have to conform to all relevant legislation, which is especially important if the ore is being exported. In such a case, all legislation applying to materials in transit and materials being imported into the country of destination must be adhered to. The behaviour of the tracer when processed (usually burnt), and the compounds which are formed through any such steps must conform to all health, safety and related regulations as well.

The readability of the tracers is a potential pitfall, and the tracers must be readable through relatively thick beds of ore, on and through conveyors, inside pipes and through water and medium. Data transfer rates could be limiting if the reading antenna's range is short, especially if long data strings must be transferred and/or the tracer is moving through the read-range at high speed. Tracers must have a unique id and having read-write capability will greatly reduce network traffic and increase reliability of the whole tracking system. In the case of tracking ore to the client, this is no longer a luxury, but rather a necessity. Both the tracers and tracking system must be affordable as well. This could be a bigger problem than appear at first, as the tracers are not recovered (at this stage).

The reading equipment must be robust enough to handle a tough environment (dust, vibration, wetting and hard knocks) with minimal maintenance requirements. The system must also be user friendly, both in terms of maintenance and usage. For example, the data generated by the tracking system must be transformed into easy to understand information that operators can use to the benefit of the operation. This also implies that information must be processed and accessible readily and in time. "In-time" will be defined differently for different processes. For slow processes it could extend to hours, but for quick processes seconds could be crucial, for example if a screen lost a panel and oversized material is entering fines beneficiating and handling equipment. Linking onto this, the whole tracking system must be easily integrated into existing systems.

With the main emphasis being the ability to retrieve and view real time data, the system must have the following ability;

- Read and display each individual tracer passing through the measured area
- Distinguish each individual tracer detected
- On-line specification of the position of each tracer in the system
- Summary of tracer recovery
- Automatically generate graphs
- Generate efficiency curves
- Real time and historical reports

As far as possible, all relevant information (e.g. properties and history of associated ore) should be carried on the tracer, to reduce network traffic and dependency.

For the readers and the tracers the following specifications flowed from the above discussion.

The features required from tracers in the mineral processing industry include:

- 100% Read / Write accuracy
- The ability to survive demanding environment (blasts, heavy impacts, abrasive slurries)
- No need for line-of-sight to establish data transfer
- Accurate representation of the ore behaviour (during material handling, stockpiling and beneficiation steps)

The readers need to meet the following requirements:

- 100 % read accuracy
- Detect the tracer within streams containing ore, dense medium powder and water
- Detect the tracer within pipes At the discharge lip of a screen or feeder and on a moving conveyer belts
- Provide on-line information as to the number of tracers in the system at any one time as well as their location in the process
- Detect and distinguish between multiple tracers in the same detection area at any one time
- Read each tracer only once
- Interface to a PC and/or PLC

In addition to the specific requirements for both the tracer and detector, the following generic requirements must be considered:

- The whole system must operate in a safe non-hazardous manner and
- Comply with the relevant requirements of the health and safety legislation bodies of the country of operation

Problems currently existing include the physical characteristics of tracers, tracer read/write ranges, tracer survivability and costs of system implementation. This project endeavoured to find solutions to these problems.

2.4 Current technology status

The 25mm tracers currently employed have the following specifications:

Memory	48 Bytes
Data Transfer Rate	Read Speed 1200 Bytes/second Write Speed 500 Byte/Second
Operating Temp	-40 ºC to +80 ºC

Material Content	85 % Rubber- Zinc Oxide
	10 % Bakelite
	5 % Copper

The current maximum read range for these 25mm tracers is 600mm.

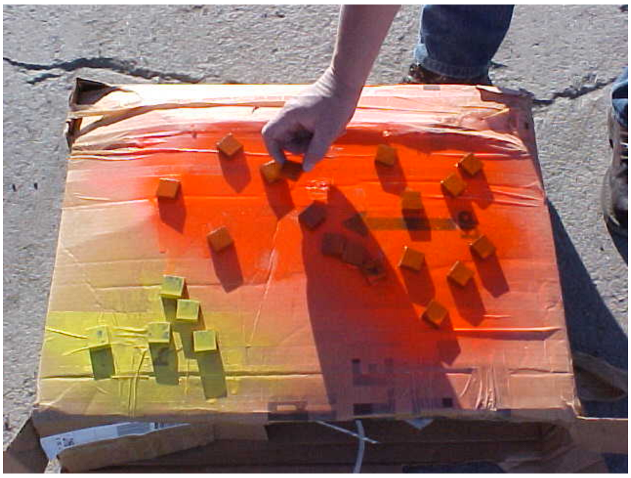

Figure 6 Initial cubical tracers hand painted to visually indicate density differences

Figure 7 1st generation stone shaped tracers

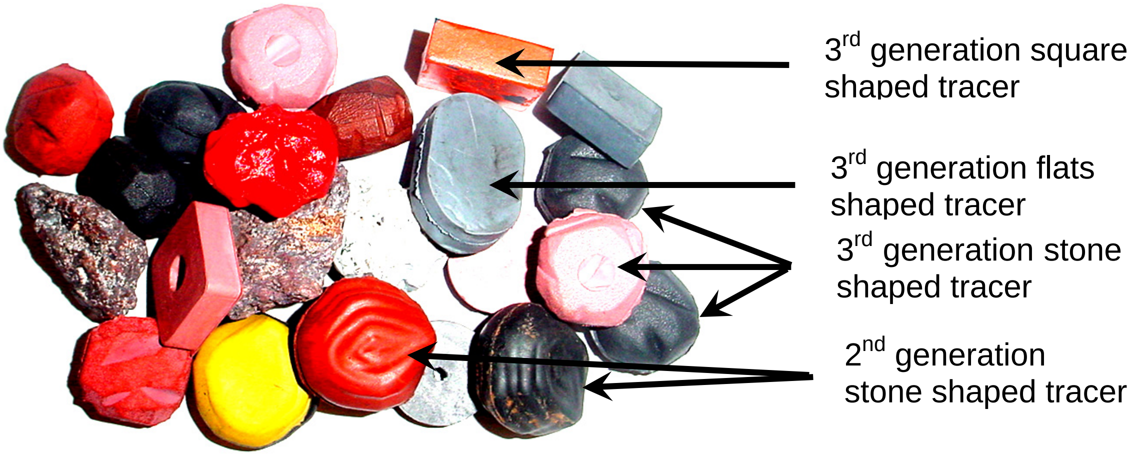

Figure 8 A selection of different shape and generation tracers

Figure 9 The youngest generation of 25mm tracers

Figure 6 through Figure 8 show from where the tracer was developed to the stage shown in Figure 9. The youngest tracer was proven to follow material flow patterns accurately. The 1st generation stone shaped tracers were hard plastic, with the RF tag sliding into a slot. They were not strong enough to survive the handling processes, and they were too light, so they separated from the ore in the stockpiles. They were definitely not suitable for dense medium separation efficiency testing! The next generation had the correct density, and was strong enough, but they were too "bouncy" and therefore not suitable either. The formula was changed, and the 3rd generation tracers were physically strong enough, of the correct density, shape, size and shore-hardness to accurately follow ore flow in all handling steps.

Most recent developments include a 12mm tracer. However, this tracer remains largely untested, and more work will be needed before it can be placed in the blast holes.

3 TEST PROCEDURE

Initial underground tests were conducted at Rosh Pinah Base Metal Mine in Southern Namibia. These tests included readability, survivability, and handling characteristics of tracers. The number of tracers required for ore tracking and ore managing was established at this mine. The initial open cast tests were conducted at Thabazimbi Iron Ore Mine, in the Limpopo province in South Africa.

3.1 Rosh Pinah

The initial underground tests were carried out here. It includes the development of the tracer material and shape, as well as establishing the number of tracers required for tracking and managing of ore and waste material.

Figure 10 Bags of tracers used in the blast tests at Rosh Pinah.

Figure 11 Blast caps lined up before placement at Rosh Pinah.

Figure 12 Tracers placed in the booster at Rosh Pinah.

In order to determine the number of tracers to be placed in a pile of ore to ensure accurate tracking and management a stockpile was selected, its mass estimated and a number of tracers added. Based on the frequency of reads of tracers coming from that stockpile the "dosage" was increased until satisfactory intervals were reached. Shown in Figure 10 to Figure 12 are photographs taken during blast-testing. The tracers were placed within the booster caps before loading of the blast-holes, and the survivors were picked up by an antenna doing similar duty to the one in Figure 10.

3.2 Thabazimbi

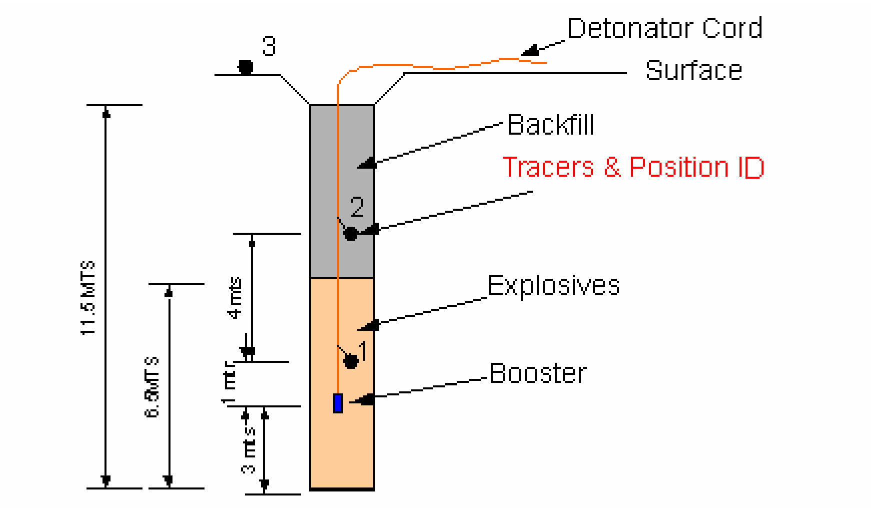

Figure 13 Positioning and labelling of tracers for the blast-survivability tests

Tracers were placed in and around each hole in the way shown in Figure 13. 20 holes out of 302 were loaded with three packs of five tracers each in the blast block shown in Figure 14. The tracers in positions 1 and 2 test resistance to the blast in close proximity and those in position 3 the resistance to an attenuated blast. “Chicken Feed” was added after the blast. These tracers were strewn by hand over the muck pile, hence this name, and their purpose is to serve as a benchmark against which survivability of the tracers in the blast can be checked by removing effects of loading and primary crushing.

Figure 14 A photograph of the blast block on which the survival rates of the tracers were tested

The following information was written to each tracer beforehand:

ID	:	(0 – 9999)
Shape	:	(Q = Square, S = Stone, D =Disc)
Density	:	(3.2 – 4 Excluding ".")
Size	:	(26 mm)
Mine	:	(TBZ – Thabazimbi)
Site	:	(B = Buffelshoek, D = Donkerpoort)
Hole ID	:	(0 – 999)
Position	:	(1= Bottom, 2= Centre, 3=Surface, 4 = Chicken Feed)
Grade	:	(TBA)
Example	:	0124-Q-38-26-TBZ-B-019-2-011

20 bytes (characters) were used in total. The different groups making up the name were separated for ease of readability here.

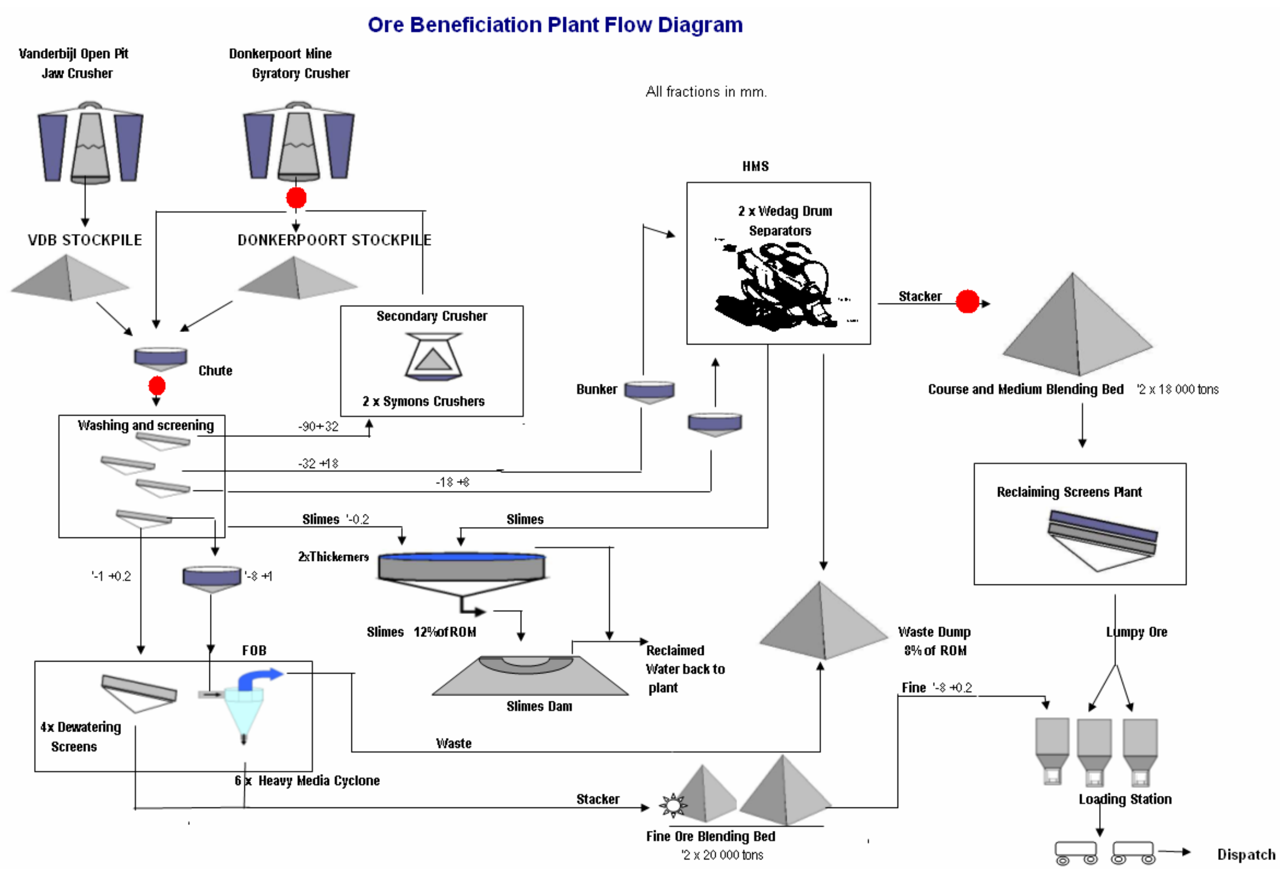

Figure 15 Process Flow Diagram of Thabazimbi showing placement of antennae and tracer addition points with big dots.

Figure 15 is a PFD of Thabazimbi, showing graphically where in the process readers were placed and tracers added.

4 RESULTS

4.1 Rosh Pinah

Table 3 shows the required ration of tracers to tons of material to optimally track and manage ore and waste at Rosh Pinah.

Table 3 Tons per tracer for tracking and managing waste and ore as determined at Rosh Pinah.

	Waste tracking	Ore tracking	Ore management
Ton per tracer	500	100	10

The survival rate of the tracers in a pilot blast test at Rosh Pinah was only 10 percent[5], but it must be noted that the tracer packaging was not designed to withstand the blast at this stage. This result however indicated that the option of using a blast site to disperse the tracers through the ore body was viable.

4.2 Thabazimbi

After some modifications to the tracer design, most notably using a flexible packaging instead of the initial rigid packaging, tests were conducted at Thabazimbi to test the survival rate of the tracers.

Figure 16 illustrates the layout of the blast block that was tested at Thabazimbi. The numbered holes are those in which tracers were placed, with the yellow holes (numbers 8,9,10 and 19) denoting those of which some tracers survived. Of the 300 tracers placed before the blast only 8 survived, 4 of which was in position 3, 3 in position 2, and 1 in the booster. It is presumed that all 100 chicken feed tracers survived, however, these have been displaced during the blast, and not all have been recovered. This translates to no losses in the primary crusher and ore pass, and only 2.6% survival rate among those tracers in the blast.

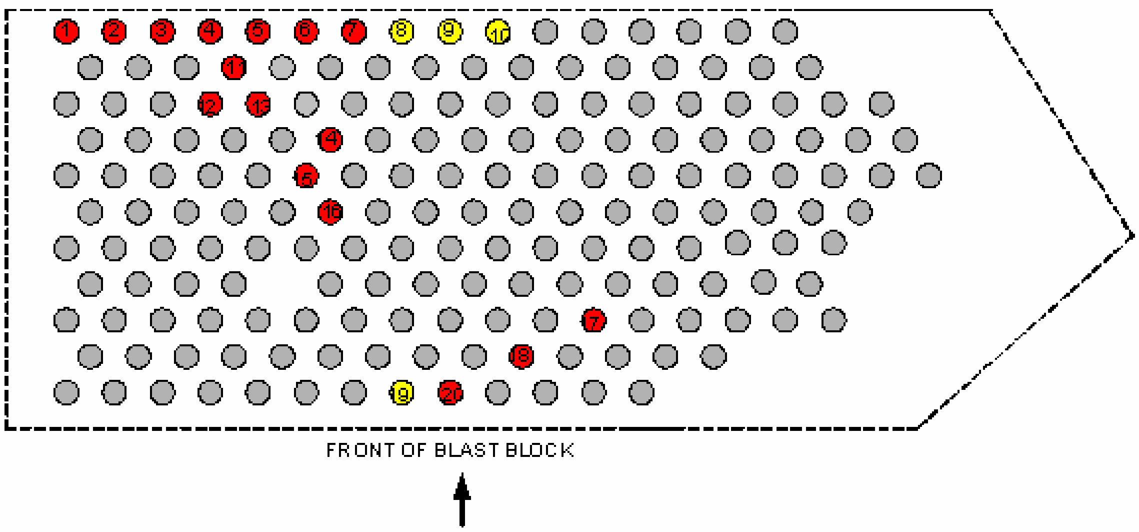

Figure 16 Diagrammatic illustration of the blast block lay out with dark holes indicating holes with tracers and light holes those whose tracers has been read.

4.3 General

4.3.1 Software

Although not explicitly mentioned above, a large part of this project was dedicated to the development of a software package with which data generated mainly by the DMS tests can be viewed, and separation curves automatically drawn up. Recent tests done with the system indicated that although the system is working, it still requires some work to make it more user-friendly.

4.3.2 Readers

Developments during the course of this project lead to reading antennae with increased ranges from 200mm to 600mm.

5 CONCLUSION

What can we conclude about the project status and latest tests' results?

A tracer has been developed with which it is possible to track ore and measure separation efficiency on gravity and size based separation processes. The number of tracers required to track and manage ore was established. The minimum tracer size was reduced from 25mm to 12mm with only a 20% penalty in tracer range.

Improved reading antennae were designed which increased range on the 25mm tracers to 700mm.

Survivability of the tracers remains an issue. If tracers are to be distributed in the blast, major work still needs to be done. Tracers can however survive all the subsequent steps, therefore the system can work with tracers seeded on the muck pile after the blast.

A software package has been developed through which separation efficiency can be automatically measured. Some work remains on the package, however, with main areas of concern being increased flexibility and interfacing with a database.

The next steps will be:

- Improving survivability of tracers with the aim of distributing them with the blast
- Rounding off the software package

6 ACKNOWLEDGEMENTS

The authors gratefully acknowledge the work on this project done by colleagues at both Kumba Resources and Saco Systems. Jeremy Bosman provided valuable insights about using the system for DMS efficiency monitoring.

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