AN INTRODUCTION TO THE RADOS XRF ORE SORTER

RS Fickling
Metanza Mineral Processors (Pty) Ltd

1. ABSTRACT

RADOS has developed ore sorters in Russia over the last two decadesand there are currently 49 mines that have been supplied with about 200 RADOS XRFOre Sorters. The sortersuse X-ray Fluorescence (XRF) to analyse and sort each particle.

The Rados XRF Ore Sorter is distributed in Africa by Metanza-Rados (Pty) Ltd

The RADOS XRF Ore Sorters have been used to sort a variety of ores including precious metals, base metals, ferrous metals, industrial and rare earths. The effectiveness of the sorters largely depends on whether there is a degree of liberation on the macroscale or alternatively that there are particles with a range of grades in any sample.

Preliminary tests on a manganese ore have been successful in upgrading an ore sample produce saleable concentrates.

This paper reviews the design and operation of the sorter and presents some preliminary results of tests on a sample of manganese ore and finally presents a possible approach to testwork in determining whether the sorter could be successful in processing any specific ore.

2. INTRODUCTION

RADOS has developed ore sorters that use X-ray Fluorescence (XRF) to analyse and sort each particle in real-time on line over the last two decades(as shown in Figure 1).There are currently 49 mines that have been supplied with about 200RADOS XRF Ore Sorters over the past 15 years.

The RADOS XRF Ore Sorters utilise well established X-Ray Fluorescence technology to sort ore by simultaneously measuring the concentration of up to fourmetals in the surface of each particle. A matrix of these elements (including actual quantities and/or ratios) is then used to determine whether any individual particle reports to either the discard or concentrate fractions.

Figure 1: A General Layout of the RADOS XRF Ore Sorter

The RADOS XRF Ore Sorter analysis detection limits range between 0.05% to 0.1% for most metals and increasing for lower atomic number elements. Fromrepeatability tests on the same particle standard deviations of 0.02 have been measured although this does depend on the metal analysed and the metal content of each particle.

The RADOS XRF Ore Sorters have been used to sort and analyse:-

- Precious Metal Ores, e.g. gold and pgm ores;
- Base Metal Ores, e.g. copper, nickel, lead and zinc ores;
- Ferrous Metal Ores, e.g. iron, manganese and chrome ores;
- Industrial Minerals, e.g. uranium, wollastonite, tungsten and tin, and;
- Rare Earth Metals. e.g. ytrium, lanthanum, cerium, and neodymium

The RADOS XRF Sorters can be used to:-

2.1. Pre-concentrate run of mine ores resulting in:-

2.1.1. Reduced waste dilution;

2.1.2. Higher grades processed in the plant; and

2.1.3. Processing of marginal and waste ores / dumps.

2.2. Cost effectively sort ores to produce lumpy concentrates where other processes are inefficient leading to:-

2.2.1. Higher concentrate grades;

2.2.2. Higher selling prices;

2.2.3. Lower transport costs for the same metal content; and

2.2.4. Increased Life of Mine as waste dilution is reduced.

This paper will review the technology behind the RADOS XRF Ore Sorter and present some preliminary test results on Southern African ores.

3. A DESCRIPTION OF THE RADOSXRF ORE SORTER

The RADOS XRF Ore Sorter has a feed hopper that discharges via a vibrating feeder onto a static grizzly to remove undersize, misplaced ore particles. The ore particles are then transported in up to four channels or chutes to discharge the ore particles.

The RADOS XRF Ore Sorter modules can process 20mm - 250mm particles at up to 8 particles per second per channel with each module treating 10 – 30 tph depending the ore density and particle size. The throughput increases proportionately with higher densities and larger particles.

During free fall the individual particles are exposed to X-rays resulting in the production of characteristic photons / fluorescence from the metals of each rock. This fluorescence is analysed and quantified by the detectors as each element produces fluorescence with a characteristic energy and wavelength. The quantity of each characteristic photon is proportional to the concentration of each metal in each particle.

The RADOS XRF Ore Sorter employs either proportional gas counters or solid state sensors to analyse the characteristic X-Ray Fluorescence to determine the metal content of each particle. The selection of either analyser depends on the application of the sorter.

The RADOS control unit analyses the XRF data, determines the metal concentrations and/or metal ratios, and compares these against the sorting matrixto determine whether the ore particle should be ejected, in which cases it energises the electromechanical ejector and the ore particles drop onto the respective product/concentrate or discard conveyor belts.

The layout of the Feed Chutes, XRF Sensors, Ejectors and the Concentrate and Discharge Chutes in the RADOS XRF Ore Sorter is shown in Figure 2**Figure 2**.

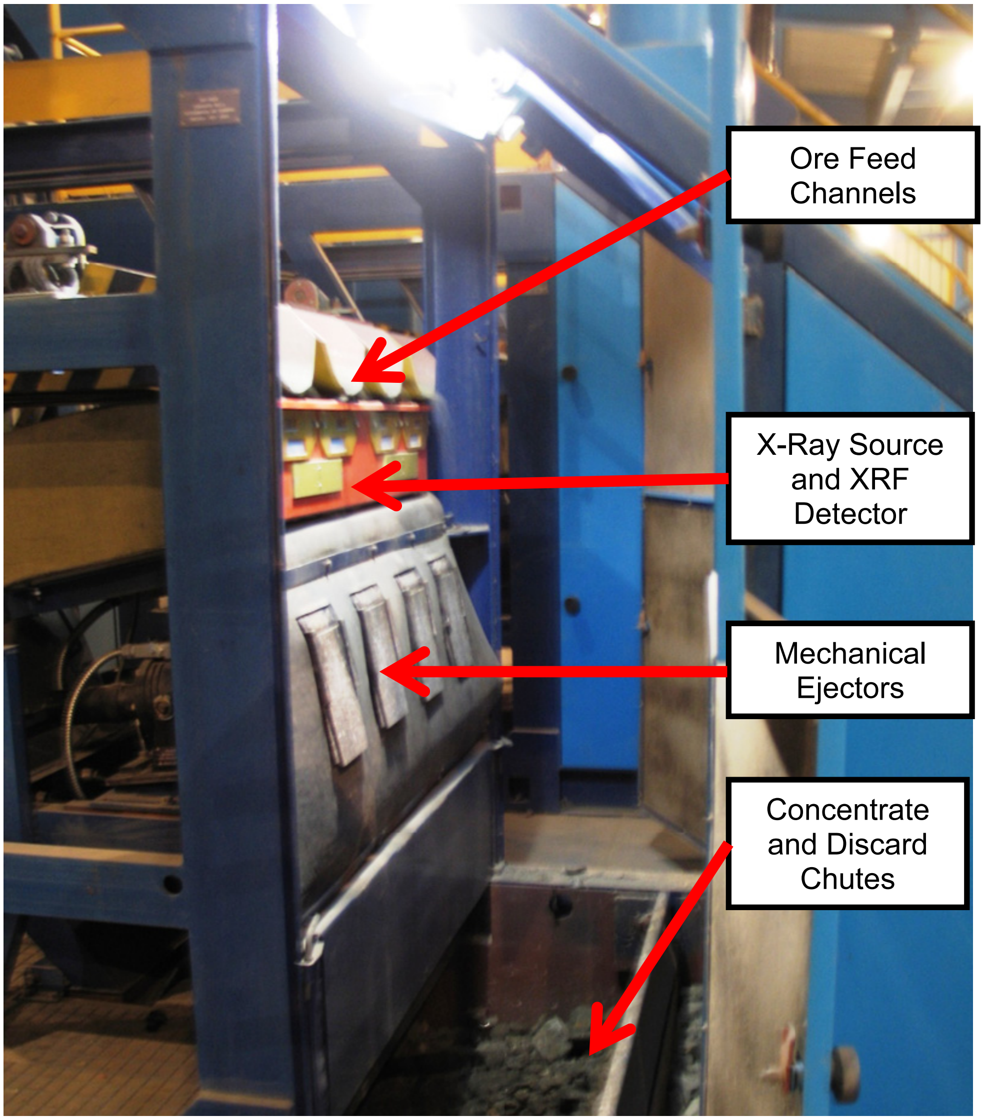


Figure 2: Layout of the RADOS XRF Ore Sorter

The RADOS XRF Ore Sorter employs low power X-ray florescence to analyse one surface of each particle and therefore the analysis and sorting is based on first principles and is not a derived characteristic such as colour or reflectance.

RADOS sorters utilise an X-ray source with a width of 40mm-70mm perpendicular to the path of the falling ore particles. The distance of the X-ray block to the ore surface does not vary to accommodate the different particle sizes as shown in Figure 3.

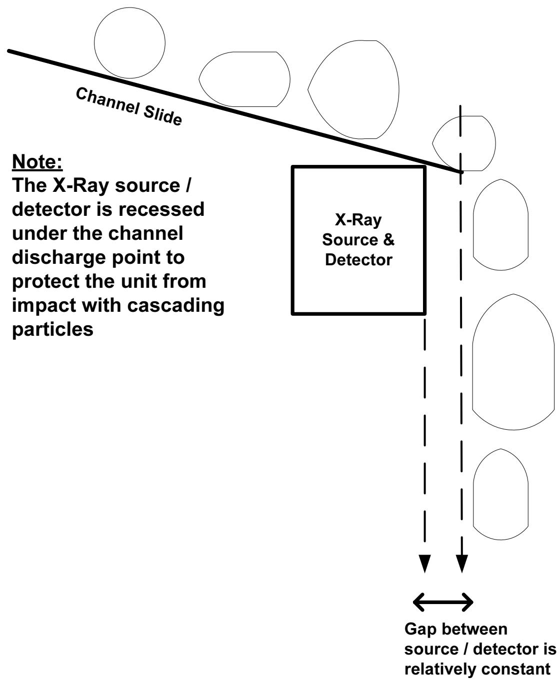


Figure 3: ***Schematic view of the RADOS XRF Ore Sorter.***

The sorting algorithm has been developed by RADOS and is supported on a Linux operating system. The Linux operating system has been found to be extremely stable and interactive with different software.

The RADOS XRF Ore Sorter provides an online estimate of the mass split reporting to concentrate, an estimate of the grade of the feed, concentrate and discard as well as an estimate of the particle size distribution of the feed.

The RADOS XRF Ore Sorter can handle variations in ore feed quality to produce varying mass fractions of concentrate and discard. Ideally the RADOS XRF Ore Sorter is generally set up to eject the smallest mass fraction of either concentrate or discard.

The RADOS XRF Ore Sorter can process 15 to 30tph depending of the particle size and ore density utilising less than 6kW or 0.2 to 0.4kWh/t.

4. PRELIMINARY TEST RESULTS AND DISCUSSION

Rados have installed a full scale sorter at Mintek in Randburg(Figure 4) that is available for testwork.

Figure 4: The Rados XRF Ore Sorter at Mintek

A series of tests were conducted in three phasesat Mintek on a manganese sample i.e.:-

- Phase 1: Determine whether the RADOS XRF Ore Sorter can be used to identify particles with variable grades and that the analysis of the surface using the RADOS XRF Ore Sorter corresponds to the bulk analysis of each particle;
- Phase 2: Determine a characteristic recovery-grade relationship of an ore sample to processing in the RADOS XRF Ore Sorter, and;
- Phase 3: Determine the efficiency of the RADOS XRF Ore Sorter and/or in DMS terms, near density material.

4.1. Phase 1 Testwork

In Phase 1 testwork 50-100 particles are selected representing the range of ore and waste types and grades. These particles are individually analysed in the RADOS XRF Ore Sorter and then crushed and pulverised for analysis in a laboratory.

The typical results are presented in Figure 5 showing that the RADOS XRF Ore Sorter can be used to produce a concentrate and discard fraction given that there is a direct relationship between the analysis of the surface of each particle and analysis of the bulk particle in a laboratory.

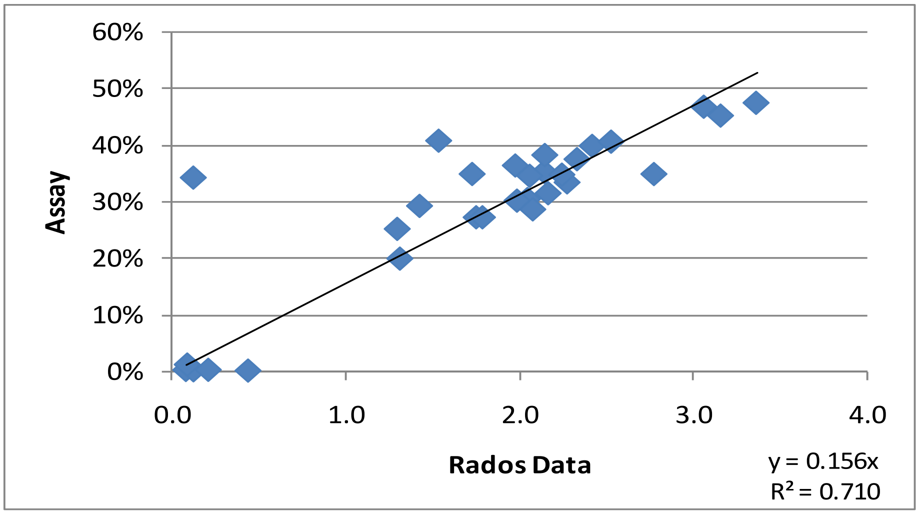


Figure 5: Typical Results obtained from the analysis of individual particles showing a relationship between the surface and bulk analysis.

In addition these results can be used to determine the thresholds to be used with the RADOS XRF Ore Sorter in future testwork.

By comparison Figure 6 shows that the RADOS XRF Ore Sorter might not effectively process this specific ore.

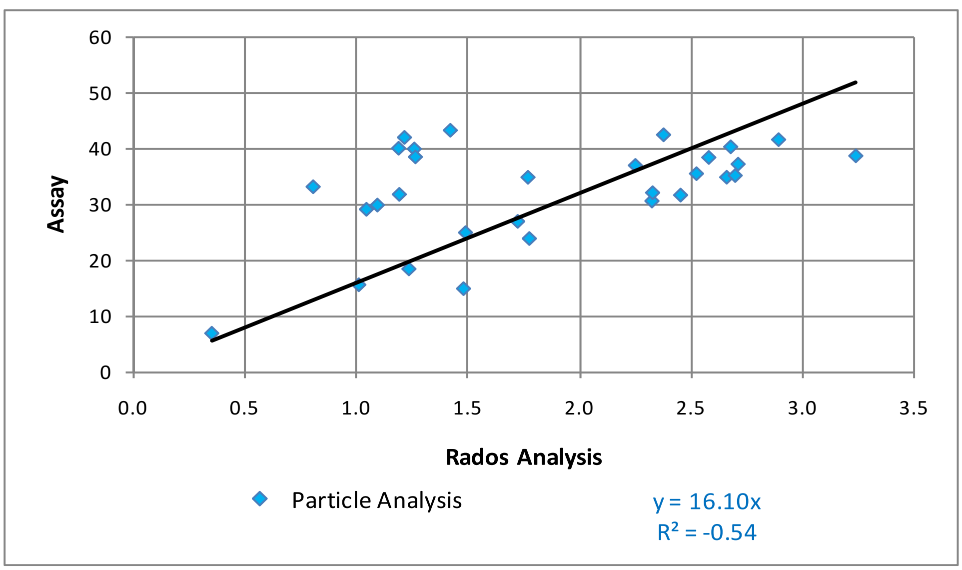


Figure 6: Typical Results obtained from the analysis of individual particles showing that there exists a tenuous relationship between the surface and bulk analysis.

In order to confirm whether these results were due to inadequate accuracy of the RADOS XRF Ore Sorter or the ore characteristics the residues from the laboratory analysis were used to manufacture briquettes. The briquettes with a known metal content were then individually analysed in the RADOS XRF Ore Sorter. This data was compared with the original data in Figure 7.

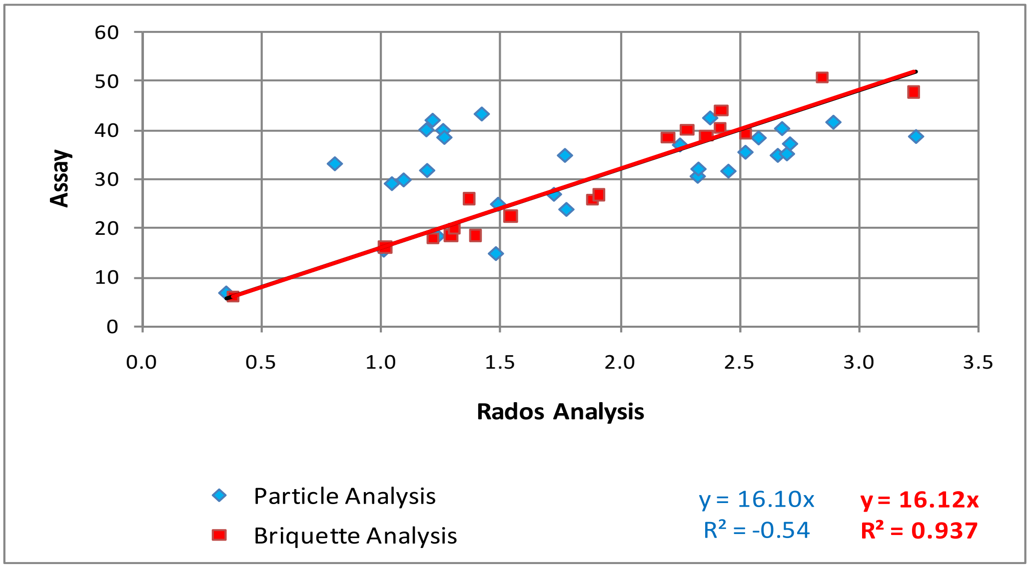


Figure 7: A comparison of the results obtained from the analysis of individual particles and briquettes manufactured from the pulverised residues from analysis.

Figure 7compares the results from the analysis of the individual particles and briquettes show conclusively that the difference between the data sets is as a result of the surface analysis by the RADOS XRF Ore Sorter not representative of the analysis of the particle in a laboratory after crushing and pulverising. Alternatively this means that the particle is not liberated and might be a composite of various mineral or rock types.

4.2. Phase 2: Grade-Recovery Testwork

It is possible to determine a grade-recovery or grade-yield relationship for any ore by processing an ore sample at a specific grade and there after analysing the concentrate and determining the metal recovery or yield. The discard from successive stages is then reprocessed at lower grade thresholds. A typical flow sheet for this testwork is shown in Figure 8.

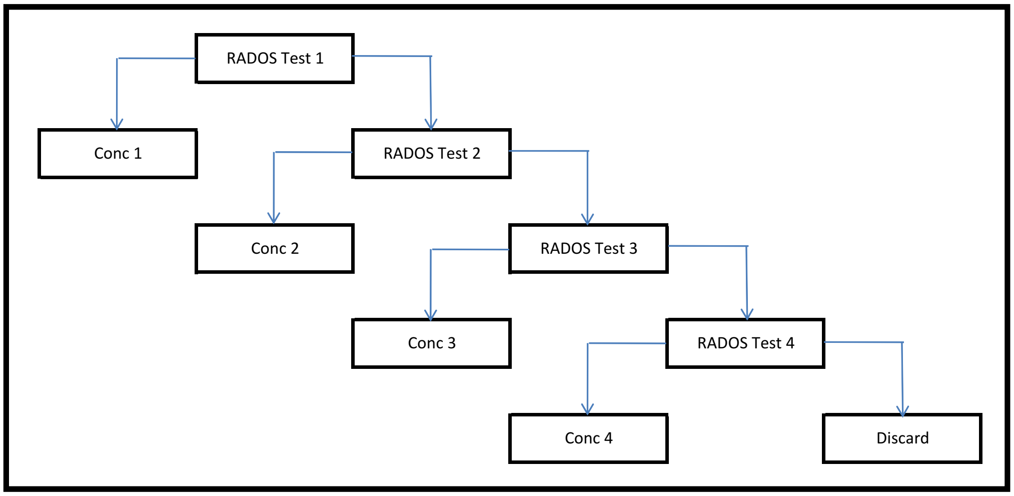


Figure 8: Flow Diagram showing the Grade-Recovery Testwork procedure

A typical grade-yield curve is shown in

Figure 9. This data is then used to select the Threshold for further tests and to determine the Threshold for any plant that is constructed.

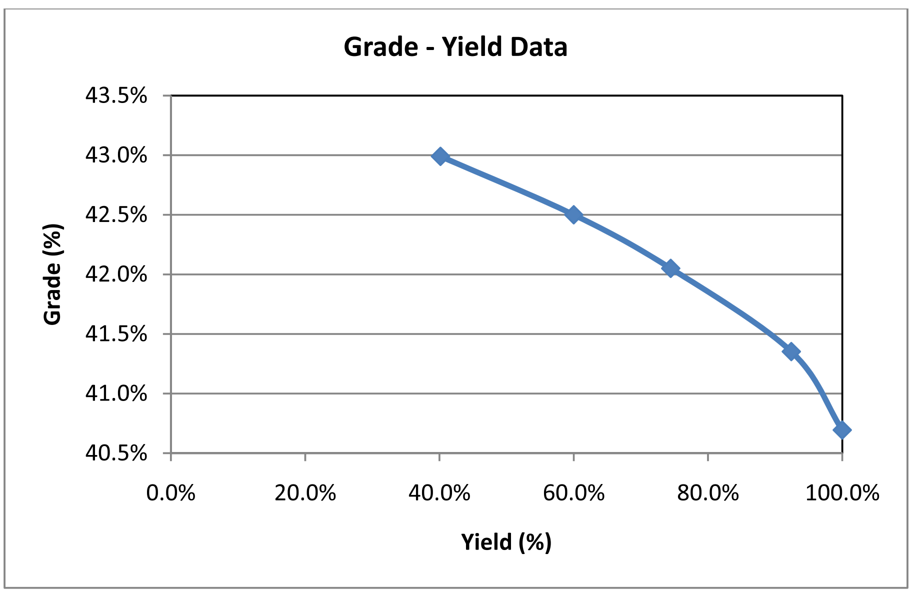


Figure 9: Typical Grade – Yield Data

4.3. Phase 3: Efficiency of the RADOS XRF Sorter

It is possible to evaluate the efficiency of the RADOS XRF Sorter by processing an ore sample in a Rougher, Cleaner and Scavenger circuit using the same thresholds in each test.

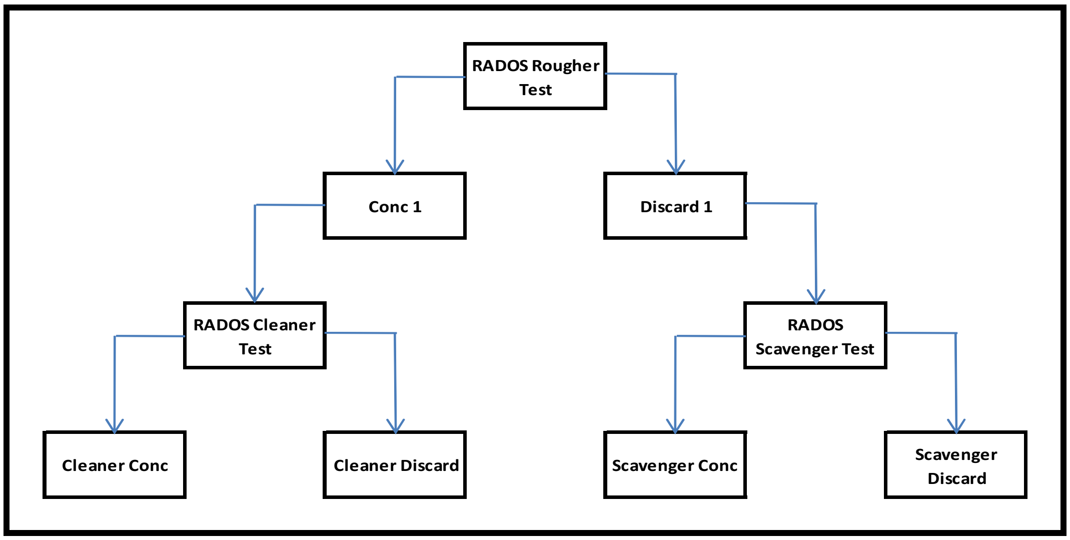


Figure 10: Block Flow Diagram showing the test procedure used to measure the efficiency of the RADOS Sorter

The efficiency of the RADOS XRF Ore Sorter maybe calculated:-

- by the mass of misplaced material recovered in the cleaner discard as a percentage of the discard recovered in the rougher stage, or
- by the mass of misplaced material recovered in the scavenger concentrate as a percentage of the concentrate recovered in the rougher stage.

The results of the efficiency test of the RADOS XRF Ore Sorter on a manganese ore sample are presented in Table 1 which shows that of the 64.3% of the feed that reports to the Rougher Concentrate an additional0.3% by mass was recovered in the Scavenger Concentrate indicating that there is 0.4% misplaced material in the rougher tailings.

Table 1: The Results of the efficiency test on the RADOS XRF Sorter

	Mass (%)	Assay (%Mn)	Mn Distribution (%)	Misplaced (%)
Rougher Feed	100.0%	37.1	100.0%	
Rougher Concentrate	64.3%	47.9	83.1%	
Rougher Discard	35.7%	17.6	16.9%	
Cleaner Feed	64.3%	47.9	83.1%	
Cleaner Concentrate	61.6%	48.2	80.2%	
Cleaner Discard	2.7%	40.1	2.9%	7.1%
Scavenger Feed	35.7%	17.6	16.9%	
Scavenger Concentrate	0.3%	49.1	0.4%	0.4%
Scavenger Discard	35.4%	17.3	16.5%	

The Cleaner test shows that of the 35.7% of the feed reporting to the Rougher discard an additional 2.7% is recovered indicating that there is 7.1% misplaced material in the Rougher Concentrate.

This misplaced material is a result of a combination of the Rados XRF Ore Sorter efficiency but possibly also as a result of the presence of material in the feed that has a surface analysis very close to the threshold used in this test. In the latter case this is in gravity separation is termed near dense material.

5. CONCLUSIONS

From this data the following conclusions can be drawn:-

5.1. The RADOS XRF Ore Sorter can be used to sort a variety of ores into concentrate and discard fractions where there is:-

5.1.1. A degree of liberation on the macroscalealternatively this can be expressed as there are range of particles with varying grades and;

5.1.2. There exists a relationship between the analysis of the surface of a particle and the grade of individual particles;

5.2. The efficiency of the RADOS XRF Ore Sorter maybe affected presence of material in the feed that has a surface analysis very close to the threshold used to sort the ore;

5.3. The RADOS XRF Ore Sorter can be calibrated using briquettes manufactured from pulverised samples with a known grade;

5.4. The RADOS XRF Ore Sorter can be used to develop Grade-Recovery relationships to maximise the recovery and grade in plant circuits;

5.5. Not all ores are amenable to sorting using the RADOS XRF Ore Sorter as this depends on the existence of ore particles with vary grades;

5.6. A structure testwork program will quickly determine whether the RADOS XRF Ore Sorter is suitable and how to configure the circuit. Typically this testwork comprises the following three phases:-

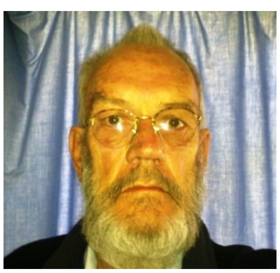
5.6.1. Phase 1: In Phase 1 a number of particles are selected by the client representing typical ore and waste, these can even be core samples. These are analysed using the Rados XRF Ore Sorter and the individual are then crushed and pulverised for laboratory analysis. Selected pulverised samples are used to create briquettes for calibrating the sorter.

In addition a 1-2t sample is processed at selected thresholds and the resulting fractions crushed, pulverised and analysed to create a preliminary grade-recovery curve.

5.6.2. Phase 2: Providing that there is a potential sorting solution that meets the client's requirements Phase 2 comprises a number of further tests to determine repeatability and to select an optimal throughput.

5.6.3. Phase 3: Phase 3 can include a bulk trial and testwork to determine the variability of the ore and the impact on the sorter's effectiveness.

The Author



Ron Fickling, *Managing Director*, Metanza Mineral Processors (Pty) Ltd

Ron has almost 30 years' experience in minerals processing including research, design, consulting to and operation of minerals processing facilities processing a wide range of mineral commodities including pgm's, chromite, coal, gold, base metals and diamonds. Ron was a director of Trans Hex Mining Limited and E+PC's outsourced operations division involved in the toll treatment of minerals ROM ores and waste streams. Ron has been author and co – author of a number of publications in the field of minerals processing technologies and the onsite outsourcing of minerals processing operations. Ron is a shareholder of Metanza Mineral Processors (Pty) Ltd and Metanza-Rados (Pty) Ltd