

TOMORROW'S TECHNOLOGY – OUT OF AFRICA - TODAY

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1. Introduction

The use of valuable minerals is a necessity to maintain a modern society. Not only the iron, aluminium, coal and oil that are used in large quantities, but also the uranium, copper, vanadium, tungsten, antimony and many others play an essential role in the bigger picture of our modern civilisation. Minerals occur in a form and in places determined by a long history starting at the dawn of creation. Over billions of years the elements have combined in wondrous combinations and structures. They have been broken up by massive explosions, movements in the earth's crust and erosion by wind and water. They have been restructured and recreated in even more configurations by the application of heat and pressure, leached by and exposed to new chemical compounds. The result is that most valuable minerals are found in impure form and mixed up with other, less useful waste material.

2. Mineral Beneficiation

The processes used for the purification and enhancement of an ore, to satisfy the needs of downstream applications, are collectively referred to as mineral beneficiation. Mineral Beneficiation starts in the mine where only that portion of the ore, that can be economically processed, is selectively extracted. It may also include ore blending, to ensure a more consistent feed to the following stage of valuable mineral recovery.

The next stage in mineral beneficiation is the liberation of the valuable minerals from the gangue. This is achieved by blasting, crushing, milling and grinding down to an adequately fine grain size to facilitate good separation.

Separation can be achieved by a variety of different techniques.

- Screening coarse from fine particles is an easy method if the valuable mineral is dominant in a certain screen fraction.
- Magnetic separators can differentiate minerals on the basis of their difference in magnetic susceptibility.
- Electrostatic separators differentiate on the basis of electrical conductivity.
- The differences in density are exploited in spirals and jigs.
- Particular surface properties provide a separation technique in flotation.
- The selective sorption properties of a collector medium are another option.

Sometimes the particular properties being exploited must first be enhanced e.g. by the application of heat or cold or by ageing to create adequate differentiation between the mineral species present.

3. **Process Control in mineral beneficiation plants**

All the techniques mentioned above are based on the physical properties of the minerals being processed. To set up and control the separation equipment optimally, operators require information on the mineral composition at various stages of the separation process. Unfortunately, most analytical instruments presently available determine the elemental composition of the substances being analysed. This can be confusing to operators e.g.:

A mineral sample is reported to contain 10% Fe
Is this: 12.9% FeO Ferrous Oxide ? or
 14.3% Fe₂O₃ Haematite ? or
 17.6% Fe₂O₄ Magnetite ? or
 An uncertain mixture of the above ? or
 Another Fe containing compound like FeS₂ (Pyrite)

Another difficulty being faced by the operators of mineral beneficiation plants is the time delay from taking a sample to the analytical results becoming available. There are a variety of laboratory type analysers available. Most of them provide elemental analysis only and is not suitable for operation in a harsh plant environment. The few in-line type instruments available are expensive and require highly skilled operators to set up and calibrate. Calibration is done by reference to standard samples using standard emission or absorption peaks. But ore bodies are not standard. Each ore body contains a unique blend of minerals with different phases and concentrations. Not only is each mine unique, but also each separation point in a mineral separation plant is unique.

The absence of suitable analytical equipment has severely hampered the introduction of advanced process control systems in mineral beneficiation plants.

4. **Wish List for In-line Analysis**

The following is a wish list of the 10 top properties that mineral beneficiation plant operators will like to see in an in-line analyser:

1. It must relate to mineral phases – not elemental composition
2. It must calibrate easily on local ore
3. It must be accurate
4. It must be fast – response time in minutes if not seconds
5. It must be robust – suitable for in-plant use
6. It must provide sensible and useful output for the user
7. It must come at reasonable cost
8. It must be reliable
9. There must be rapid supplier support and servicing

10. Installation must be hassle-free

5. How to detect Mineral Phases rapidly?

Mineral Phases cannot be defined by colour alone. Minute impurities can cause dramatic colour changes. For example Quarts (SiO_2) can be rosy, smoky or purple (amethyst).

Nevertheless, plant metallurgists succeed pretty well in setting up and running their processes without in-line analysers. How do they achieve this? Because they have learnt that in a particular mineralisation zone, mineral appearances are surprisingly consistent. Although the brain is sharp in recognising differences in hue, sheen, and reflectivity, the human eye has limitations. Human observation capabilities are mostly qualitative, rather than quantitative. The basis for determining mineral composition is there but we need to overcome the limitations of human vision.

Modern technology has come to the rescue.

The latest optical spectrometers are capable of detecting weak light signals at wavelengths falling far outside the limited range of the human eye. Furthermore, instead of the 7 colours of the rainbow, modern spectrometers can typically measure in excess of 2000 different wavelengths of light simultaneously, with high accuracy and repeatability, within a time span measured in milliseconds. We also have the modern electronic data processors available to do millions of calculations and comparisons from the vast array of optical data that can be provided by the spectrometer.

6. Practical application of the technology

With such modern tools now available, a young technology company, Blue Cube Systems (Pty) Ltd, based at Stellenbosch, in the Western Cape province of South Africa, has developed an in line mineral quantification system based on Diffused Reflective Spectroscopy (DRS). As the spectra from mineral mixtures change in sympathy with changes in mineral composition, techniques were developed to accurately detect and measure the reflected light from minerals in motion. Simultaneously, algorithms were developed to convert the optical data to mineral composition by comparison to the optical data of samples with known composition. The instruments therefore “learn” to interpret the data using the local ore as handbook. As all mineral mixtures are always subject to segregation, specific techniques were developed to ensure that optical scanning remains representative of the bulk.

Particular in-line scanning techniques were defined for dry free-flowing mineral mixtures in a transfer tube or at a transfer point, as well as for slurries in a pipeline or transfer point. A particular configuration is available for the scanning of filter cake or for material that is not free flowing. Quantification is then done in batch mode.

For all the different models, the optical components, algorithms and data processing remain the same. Only the method in which the sample is presented to the optical scanner is adapted to suit the specific application.

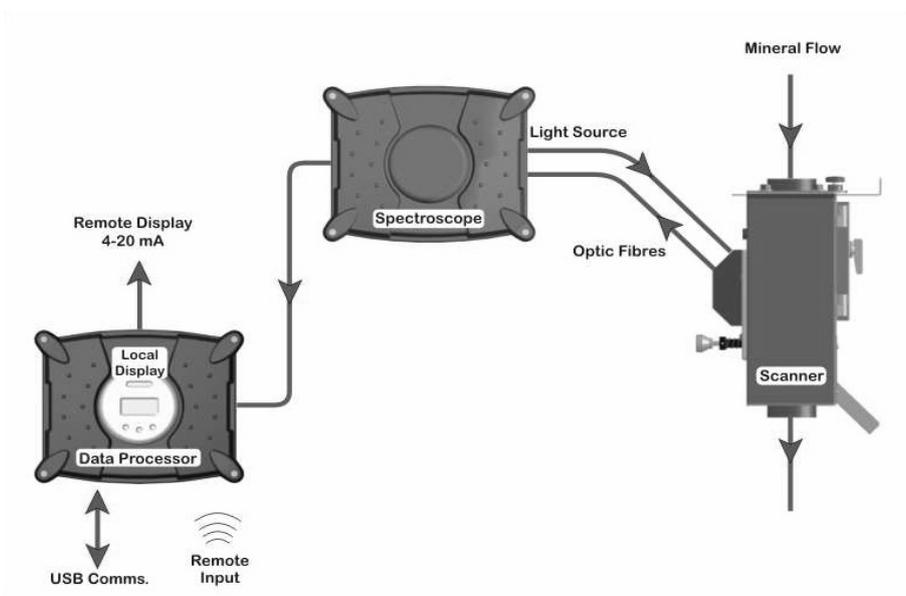


Figure 1: Components of the MQi

Output is provided on a LCD display on the unit as well as via a cable link, suitable for easy connection to a supervisory control and data acquisition (SCADA) system.

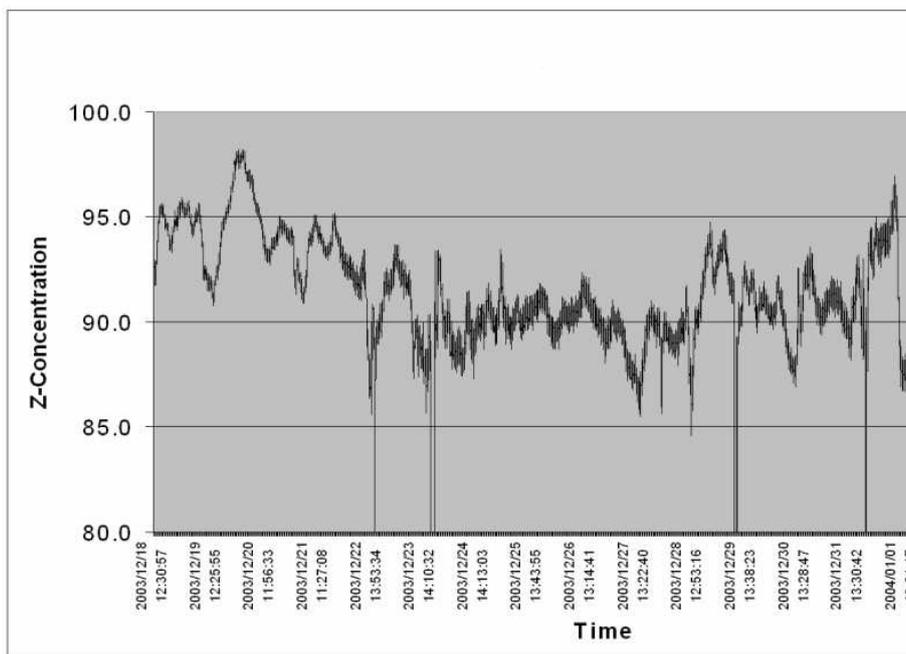


Figure 2: Typical SCADA display generated by a Blue Cube MQi

Development is underway for the application of the technique to measure mineral components in solution, as found in leaching applications.

The hardware is robustly packaged in water- and dust proof housings suitable for the harsh conditions inside a mineral beneficiation plant. All field components are intrinsically safe. There are no radioactive sources, x-ray, high voltage, high intensity

laser or high temperature components present. Therefore there is no requirement for licences, permits or appointment of responsible persons.

All units are equipped with a communication system that provides a direct link to the manufacturer via GPRS (Mobile phone or other available data link). This enables rapid remote supervision, recalibration and diagnostic procedures from and to any position around the globe where GPRS services are available.

7. Calibration

Calibration is achieved by the comparison of the optical scan data with the known composition of calibration samples. Reference values can be obtained from any available technology acceptable to the client. Good use can be made of any of the following methods:

- Manual Grain counting using stereomicroscope. This is a well-developed technique commonly applied to determine mineral composition.
- X-ray Fluorescence (XRF) analysis will provide elemental analysis rather than mineral analysis. Although the new technology's quantification will be measured on the basis of mineral composition, it can be calibrated to report the elemental composition as determined by XRF based reference values.
- X-ray diffraction (XRD) analysis can give a good indication of mineral composition
- Atomic Absorption (AA) analysis will also provide useful elemental composition values
- Scanning Electron Microscope (SEM) techniques can provide very useful values elemental as well as on mineral composition. * *See Reference 2.*

The basis of calibration will be part of the discussion with prospective clients prior to the installation of a unit. The supplier will insist on a number of samples, with known composition, to verify that the sensitivities, required by the client, can be met.

8. Tomorrow's Technology – Out of Africa - Today

The development of this in-line mineral quantification technology is a world first. DRS technology has been in use for a long time but never yet in a robust in-line mineral quantification role. This technology provides a valuable new tool to operators of mineral beneficiation plants, assisting them to improve their efficiencies by better grade control, improved recoveries, increased production levels and better utilisation of the scarce natural resources.

9. Track Record

Electrostatic Separation. There are already 11 units installed on heavy mineral separation applications in South Africa and Australia. It has been proven that automatic grade control and automated optimisation of recovery on an electrostatic roll separator

can make a substantial impact on improved profits. * *See Reference 1.*

Rock Phosphate Flotation. A filter cake analyser tracks the mineral composition of flotation feed to pro-actively adjust plant settings when ore quality changes.

Platinum ore flotation. The grade of final flotation concentrate slurry is measured and continuously displayed on a SCADA trend graph as performance feedback to operators.

Base Mineral Furnace Product magnetic Separation. A Spot quantifier determines product grade



Figure 3: A Blue Cube MQi installed in a dry mineral stream

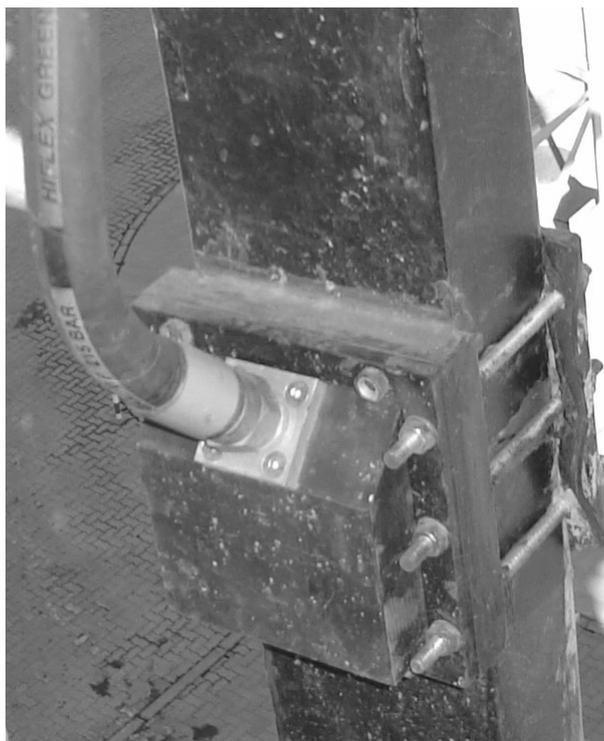


Figure 4: A Blue Cube Scanner head installed in a slurry stream

10. Demonstrated Benefits

A number of benefits have been demonstrated by the use of the new technology.

Rapid feedback to operators. Operators now have a “speedometer” to measure equipment performance in real time. The impact of any adjustment made to separator equipment is immediately visible.

More Reliable Information. The in-line data collection is totally free from human hands. Problems relating to sample identification, timing and source as well as time delays due to sample transport, sample preparation and sample analysis are all eliminated.

More stable plant operations. As plant equipment is controlled more pro-actively, plant stability improves.

Closer grade control. With product grade becoming more consistent, product grade can be tuned to a selected “sweet spot” where the play-off between grade and recovery is optimised.

Optimised Recovery. By the addition of in-line mass flow meters and in line mineral composition measurement, real time plant optimisation has become a reality. * See Reference 1, Reference 3.

Motivated Operational Staff. By having immediate feedback, production staff take a new interest in what they do and becomes motivated to do better.

Improved Financial Returns. The net result of the benefits listed above automatically give rise to higher financial returns. The payback period of a unit is measured in months – if not in weeks.

11. Conclusion

The knowledge and innovative skills of the technologists involved in the African mineral beneficiation industry has demonstrated their ability to develop world-class new technology. This technology is being made available for export to any African mining and mineral beneficiation operation as well as to the wider world. Apart from the track record highlighted above, three other studies are presently under way to introduce the technology to other base mineral applications.

11. Recognition

Thank you to the organisers of this conference for acceptance of this paper.

I wish to express my appreciation to Blue Cube Systems (Pty) Ltd for their permission and support with the preparation of this paper.

12. List of Illustrations

Figure 1: Components of the Blue Cube MQi

Figure 2: Typical SCADA display generated by a Blue Cube MQi

Figure 3: A Blue Cube MQi installed in a dry mineral stream

Figure 4: A Blue Cube Scanner head installed in a slurry stream

13. List of References

1. DE WAAL, P., and DU PLESSIS, F.E., Automatic control of a high tension roll separator. *Heavy Minerals 2005*, Society for Mining, Metallurgy, and Exploration, 2005.
2. FREI, D., KNUDSEN, C., McLIMANS, R.K. and BERNSTEIN, S., Fully automated analysis of chemical and physical properties of individual mineral species in heavy mineral sands by computer controlled scanning electron microscopy (CCSEM). *Heavy Minerals 2005*, Society for Mining, Metallurgy, and Exploration, 2005.
3. RIFETT, T. and PAX, R.A. Implementation of control and control issues in mineral sands plants – In-line mass flow meter. *Heave Minerals 2003*, Johannesburg, South African Institute of Mining and Metallurgy, 2003.