CARBON CONCENTRATION MEASUREMENT AND CONTROL IN A COUNTER CURRENT CARBON ADSORPTION CIRCUIT

H.S. Smit[1]

[1]MINTEK
200 Malibongwe Drive
Randburg, 2125, South Africa
(stefans@mintek.co.za)

ABSTRACT

The control of carbon concentration in a counter current carbon absorption circuit is critical to optimise gold recovery. MINTEK has developed a carbon movement controller to address this potentially problematic area in gold extraction. This controller reduces operator interaction by automating carbon movement. Elution schedules are entered into the control system, which then moves the carbon through the circuit into the first adsorption tank until enough carbon is available for elution. This is done while maintaining the specified carbon profile within the circuit. MINTEK has also developed an online-carbon-concentration-meter to measure carbon concentration in pulp. The meter uses an ultrasonic measurement technique. Long term testing has shown the measurement to be robust and require minimal maintenance. Results from a gold mine in South Africa's well known Witwatersrand gold producing area has shown a decrease in soluble gold loss between 30 – 50% when the controller was used.

KEYWORDS

Carbon Concentration Measurement, Carbon Concentration Control

INTRODUCTION

MINTEK developed a carbon movement control system to automate the control of carbon in Carbon-in-Pulp (CIP) and Carbon-in-Leach (CIL) gold processing circuits. The system was tested on a CIP plant in South Africa using manual carbon concentrations as input to the controller. It controls the carbon concentration in each tank by taking over the control of the carbon transfer pumps. This is typically controlled manually by plant operators. The objective of the controller is to keep the carbon concentration within a band specified by metallurgical staff and acts as a stabilising controller.

With the development and implementation of the carbon movement controller MINTEK have realized a shortcoming to the effective use of the controller is the accurate input of carbon concentrations to the controller. In order to eliminate this shortcoming and ensure accurate data input to the controller, MINTEK developed an online-carbon-concentration-meter based on the attenuation of ultrasound. This instrument was originally developed by MINTEK and commercialised and marketed under license by an external company in the 1990’s. MINTEK have now re-developed this instrument to improve the robustness of the electronic circuitry and also simplified the installation and calibration of the instrument.

CARBON MOVEMENT CONTROL

Background

Carbon is added to the last CIP tank. Carbon transfer pumps are used to transfer carbon upstream. When sufficient carbon is available, the carbon is pumped to the elution column. Once elution is completed, the carbon is transferred to the kiln for regeneration. On exiting the kiln it is transferred into a carbon regeneration hopper. The process is then repeated. A typical CIP circuit is shown in Figure 1.

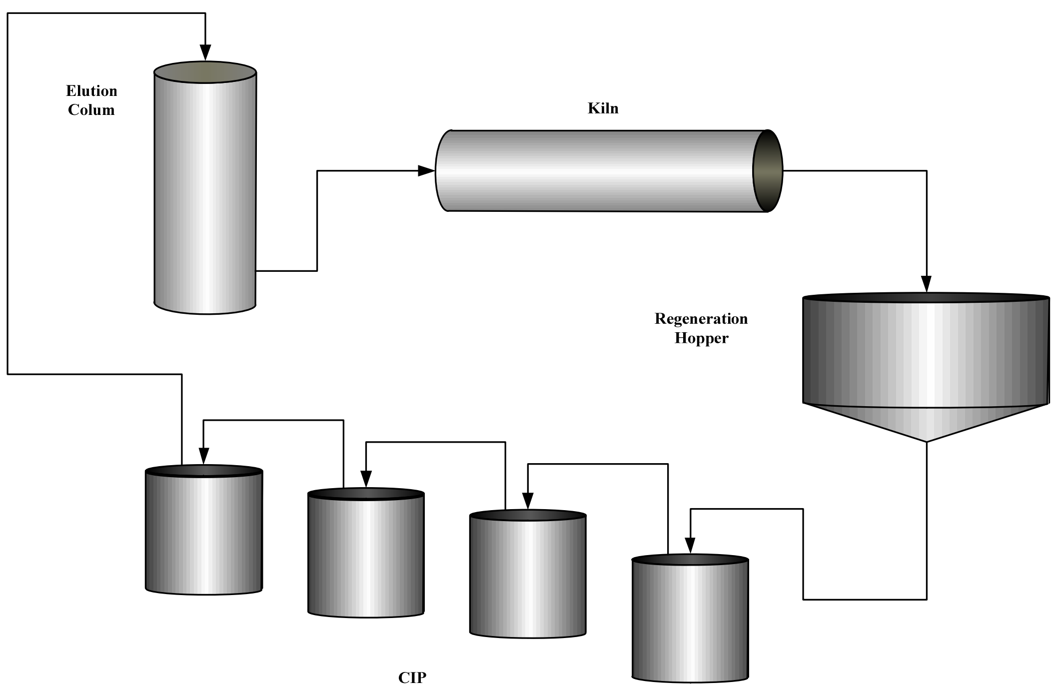

Figure 1 - Typical CIP circuit

The process is regulated by the elution schedule. Carbon addition and carbon transfer is based on when the required mass of carbon needs to be ready for elution.

Methodology

The control system is divided into three modules: an optional blow-case (automated carbon addition) controller, the carbon movement controller, and the signal conditioner.

Required Controller Inputs

For the controller to function correctly the following inputs are required:

1. Elution Schedule
    - Times
    - Required Mass
2. Carbon Profile (Desired Carbon concentration for each cell)
    - Desired value
    - High Limit
    - Low Limit
3. Manual Carbon Concentrations (once per shift) **or** Online Carbon Concentrations

Examples of the required controller inputs are shown in Table 1 and Figure 2.

Table 1 - Controller Input Example, Elution Schedule

Carbon (Tons)	Hour (Time)	Date
5	8:00	11/10/2013
3	18:00	11/10/2013
3	8:00	12/10/2013

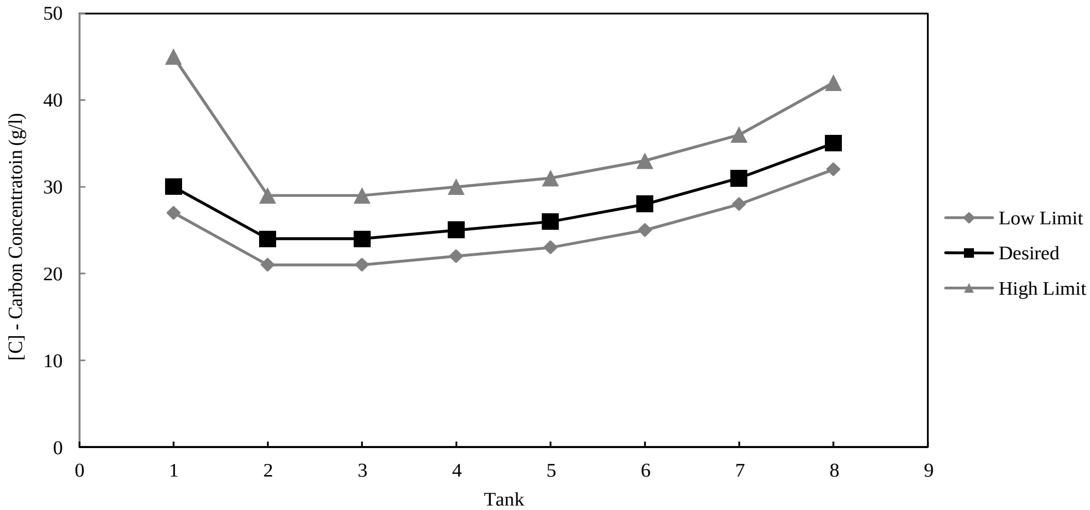

Figure 2 - Controller Input Example, Carbon Profile

Blow-case controller (optional controller)

Elution is typically performed once or twice per day. The blow-case controller ensures that sufficient carbon is introduced into the circuit taking into account the required elution mass and any carbon that may be held up in the circuit.

The blow-case controller examines the top cell (date/time and mass) in the elution schedule, and calculates a blow-case schedule from this. To ensure consistent circuit operation the blow-case schedule spreads out the carbon additions evenly over the time to elution. The number of blow-cases required is calculated from the elution mass. The current carbon concentrations and the specified carbon concentration limits are also taken into account as this affects the amount of carbon holdup in the circuit. The available time for the blow-cases is continuously calculated from the time to elution, pumping times, and any other additional delays.

When all blow-cases for an elution have been completed, the blow-case controller shifts the elution schedule up one position, indicates that all blow-cases have been completed and calculates a new blow-case schedule for the following elution.

Carbon Movement Controller

The carbon movement controller does not initiate any blow-cases, but simply reacts to measured/estimated carbon concentrations and user-defined limits. Accurate concentration measurements (manual or online) are thus essential for the optimal performance of the controller.

The user specifies three concentration limits as per Figure 2. The high limit determines the concentration above which the transfer pump will be switched on. The desired concentration value determines the value at which the pump would be switched off. The additional low limit is only used close to the elution time if insufficient carbon is available in the circuit to meet the required elution mass. In this instance, the controller would attempt to “find carbon” in the circuit by lowering the concentration limits. Under these conditions, the controller would switch on the pumps at the desired concentration limit, and switch them off at the low limit.

When the high limit is exceeded in any cell, a “Carbon Transfer Pending” flag is set for that cell. The controller then checks if any conditions exist that prevent the pump from being switched on. These conditions include:

- Pump not available
- Upstream or downstream pump on (possible short-circuiting)
- Upstream cell above high concentration limit
- Busy sampling
- Delay in bottom cell after blow-case

A flag is set when the carbon in the top cell exceeds the required mass for elution, indicating that carbon may be transferred to the elution column. Cells may be taken offline for maintenance, at which time the controller would automatically bypass the offline cells and perform the control accordingly. The controller will then pump carbon to the next available cell that is available.

If the carbon movement controller is not using online measurements but rather estimating the concentrations of the carbon, accurate pumping rates are critical as small discrepancies over time can cause large concentration errors. To minimise errors, the controller is able to update the pumping rates by calculating the change in carbon concentrations from the manual samples and the time the pump has been on since the last manual concentration entry.

<u>Signal conditioning / Error Detection</u>

A number of checks are carried out to ensure signal integrity and to warn the user in advance of potential problems in the carbon circuit. These checks include:

- Limit checking of online carbon concentration measurements
- Flat lining and noisy signals
- Carbon leaks
- Requested blow-case mass and actual mass difference

Plant Trials

The control system was tested on a Witwatersrand (South Africa) CIP circuit that consists of eight counter-current adsorption tanks. Unloaded activated carbon is injected at the bottom of the CIP circuit by a batch blow-casing sequence. The loaded carbon in Tank 1 is removed approximately once per day.

<u>Results and Discussion</u>

After commissioning of the controller, an on/off comparison was done. Soluble gold losses were compared to determine the performance of the controller. Filtrate samples were collected for the duration of the sample campaign. The sample campaign started with the control system switched off for two days. The controller was then turned on for nine days, turned off for seven days and the switched on again for five days. The filtrate samples were sent for soluble gold analysis. The soluble gold loss results are depicted in Figure 3. The data was first presented at the *II International congress on automation in the mining industry*, Santiago, Chile (Vardy & Smit, 2010).

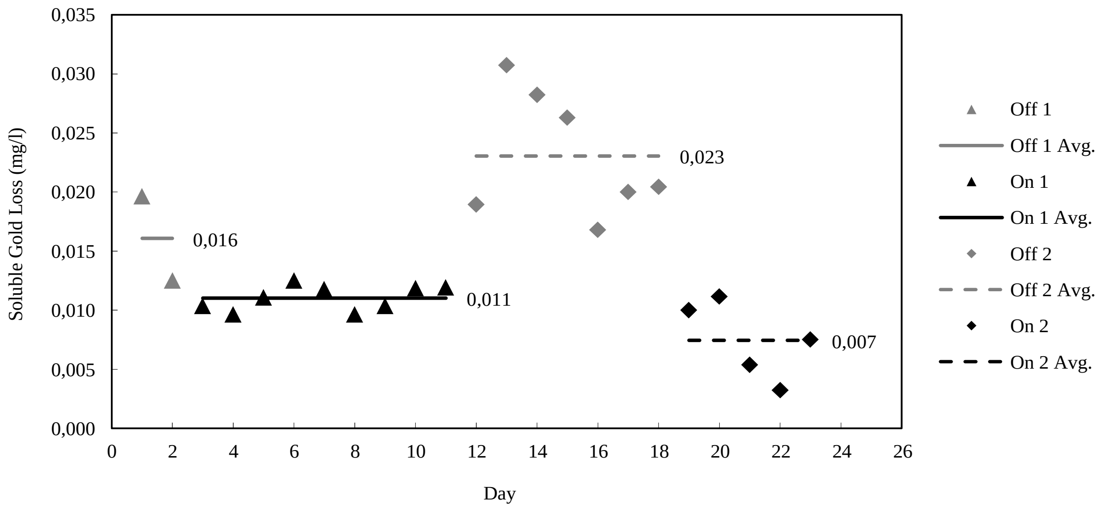

Figure 3 - Soluble gold loss results for the controller On/Off comparison.

Figure 3 shows one soluble gold loss point for each day. Three samples, one for each shift, were taken each day and averaged to represent that day's soluble gold loss. Table 2 summarise averaged soluble gold losses for when the controller was on compared to when it was off. It also indicates the percentage decrease in soluble gold loss for each period as well as the average decrease over the combined testing periods.

Table 2 - Reliability Tests, Measurement Error

	Period 1	Period 2	Combined
Controller off (Average Soluble gold loss; mg/l)	0,016	0,023	0,022
Controller on (Average Soluble gold loss; mg/l)	0,011	0,007	0,009
Average Decrease in soluble gold loss (%)	31,5	67,7	58,1

CARBON CONCENTRATION MEASUREMENT

The carbon movement controller is designed such that it accepts both manual and online carbon concentrations. Although the controller performs well with the use of manual carbon concentrations as input, the effectiveness of the controller can be compromised by inaccurate carbon concentration values or incorrect entry of data. This is minimised by assigning a weight to manual data entries. Pumping rates are therefore calibrated not by one set of carbon concentration values, but by multiple sets. When the controller uses online measurements, maintenance and operator dependency is significantly reduced. Online measurements also allow the controller to indicate conditions such as faulty pumps or screens to the user. It is for these reasons that MINTEK developed an online carbon-concentration-meter.

Background

MINTEK developed a carbon-concentration-meter based on the attenuation of ultrasound in the past. This instrument was commercialised and marketed under license by an external company in the 1990's. The company has since been dissolved and are no longer manufacturing carbon-concentration-meters or supporting existing installations.

In 2011 MINTEK conducted a feasibility study to establish if a new meter using, as far as possible, the original electronic components could be designed. During 2012 a new meter was designed using the same electronic boards and using a commercially available microcontroller and user interface. The focus in 2013 was the design of new circuit boards. These new boards were successfully assembled and tested in mid-2013.

Plant Trials

Plant trials were conducted at South African CIP and CIL plants from late-2013 to early-2014. One instrument was installed at each site. Reliability tests (long term testing) were done at each site while precision tests (short term testing) were only done at the CIP plant.

Reliability Tests

The instruments were run for a period of 6 weeks to test the reliability. No re-calibration or any other maintenance was done in this period. Weekly spot samples were taken after entering the relative density as input to the meter.

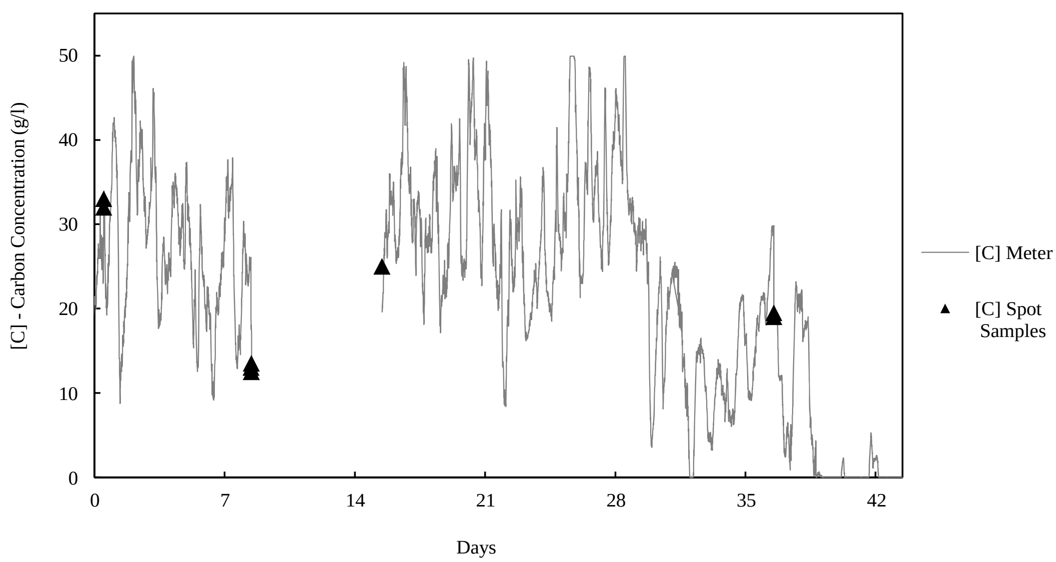

Figure 4 and Figure 5 show the data for these tests.

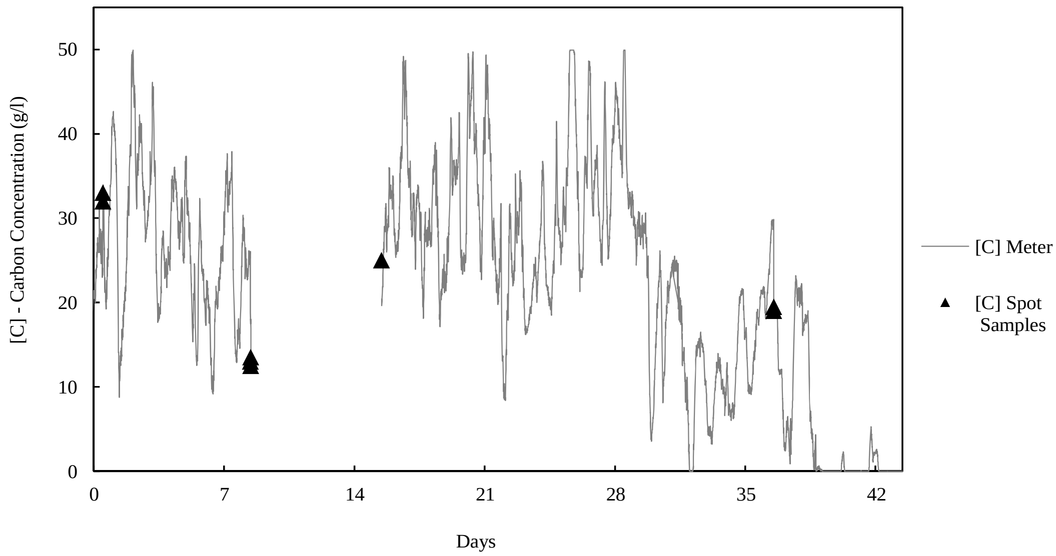

Figure 4 - CIL Reliability Tests Data

The instrument at the CIL plant was switched off from day 8 to 15. The reason for this could not be established.

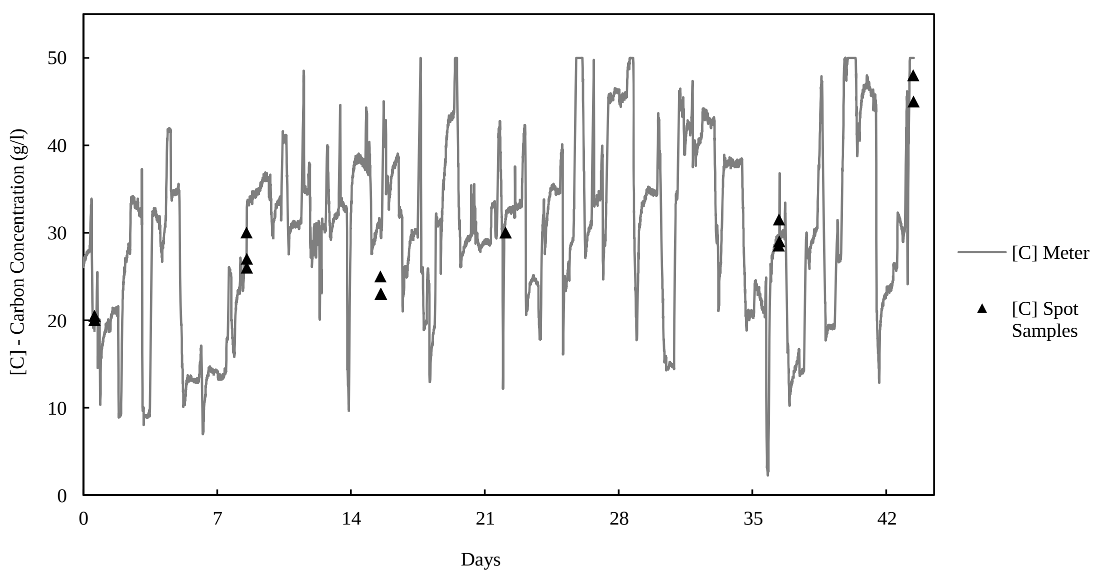

Figure 5 - CIP Reliability Tests Data

The average absolute error and the percentage error (calculated over the full calibration range) for both the CIL and CIP instruments are shown in Table 3.

Table 3 - Reliability Tests, Measurement Error

Error Type	CIL Plant	CIP Plant
Average Absolute Error (g/l)	2.40	3.35

Error over calibration range (%)	5.27	6.70

The reliability test results show that the percentage error is well within the targeted error percentage of 10%, and can therefore be used reliably for the monitoring and/or control of carbon concentration in both CIL and CIP gold extraction processes.

Precision Tests

Precision tests were done for the instrument installed at the CIP plant. The tests involved the taking of spot samples by MINTEK employees for a few hours on a daily basis for 5 consecutive days.

The results are shown in Figure 6.

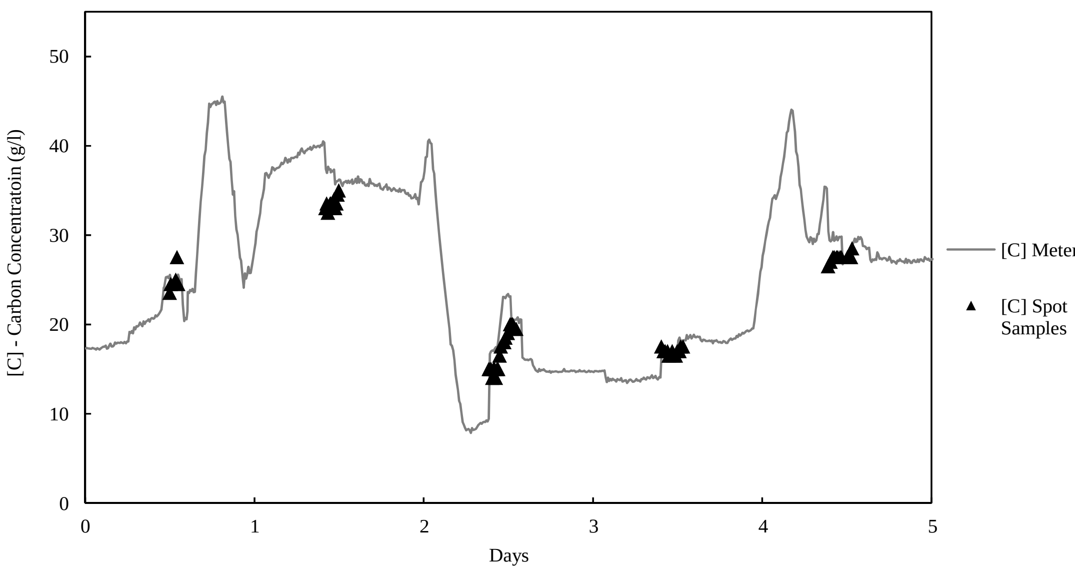

Figure 6 - CIP Precision Tests Data

Table 4 shows the average absolute error and the percentage error; calculated over the full calibration range.

Table 4 - Precision Tests, Measurement Error

Error Type	CIP Plant
Average Absolute Error (g/l)	2.05
Error over calibration range (%)	4.12

CURRENT AND FUTURE WORK

With the availability of a commercial carbon-concentration-meter, MINTEK have initiated the re-implementation of the carbon movement controller at the same site where the original controller was installed. The work will assess the variance in carbon concentration when the controller is in use compared to when carbon is controlled manually. Soluble gold samples will be taken again and the controller will be tested for a longer period (compared to the original test work). Test work is expected to start in mid-2014.

MINTEK will in the future investigate controller schemes to optimise carbon profile once carbon profile stabilisation has been achieved.

CONCLUSION

A consistent carbon concentration profile within the CIP/CIL circuit is achievable when an automated carbon movement controller is used. The MINTEK LeachStar carbon movement controller can use either manual carbon concentrations or online carbon concentrations as input to the controller. Test data from soluble gold loss samples have shown that a 30 – 50% reduction in soluble gold loss is possible if an automated carbon movement controller is used.

MINTEK has furthermore developed an online carbon-concentration-meter to supplement its carbon movement controller. The instrument design has shown good results when instruments were trialed at CIP and CIL gold processing plants.

REFERENCES

Vardy, J. J. L., & Smit, H. S., (2010). Carbon management in a carbon counter current adsorption circuit. *II International congress on automation in the mining industry*. Santiago, Chile: Gecamin.