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University of Cape Town

# AN INVESTIGATION INTO THE USE OF FROTH COLOUR AS SENSOR FOR METALLURGICAL GRADE IN A COPPER SYSTEM

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A dissertation submitted to the Faculty of Engineering and the Built Environment at
the University of Cape Town, in fulfillment of the requirements for the degree of
Master of Science in Engineering.

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# DECLARATION

I declare that this thesis, submitted for the degree of Master of Science in Engineering at the University of Cape Town is my own unaided work. It has not been submitted prior to this for any degree or examination, at this or any other university.

Signed by candidate

Glen Sean Heinrich

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# SYNOPSIS

In recent years the development of Machine Vision systems has opened up new possibilities for non-intrusive process performance sensors and process control. There are currently various Machine Vision systems on flotation plants worldwide (Metso at Kennecott, Frothcam at Escondida). Extensive research has been done on using froth image analysis in closed loop control (Hyotyniemi et al, 2000; Kittel et al, 2001; Holtham and Nguyen, 2002; Cipriano et al, 1998) and recently plants have been using these systems to control the air or level of a flotation cell as a means of controlling mass pull using the froth velocity output.

As yet no flotation plants have reported the use of froth colour in their control strategies, however it is well accepted that an experienced operator can judge the metallurgical state of a flotation cell by the appearance of the froth, using colour as a key descriptor of grade, particularly in the case of copper froths. For this reason an investigation was undertaken to evaluate whether a relationship existed between concentrate grade and the froth colour obtained using a Machine Vision system. This relationship could be used to control reagent addition or for system diagnostics. Both would be invaluable tools for the flotation industry. A Machine Vision system called SmartFroth has been developed at University of Cape Town (UCT) as a research tool to investigate the relationships between froth surface indicators and metallurgical parameters. The relationship between froth colour and % solids was also investigated as it was believed that solids loading could be reflected by froth colour.

This work was aimed at evaluating the empirical relationship between froth colour and copper grade in the laboratory and then investigating whether a similar relationship existed on plant. Various colour spaces were examined to find one appropriate for the copper flotation froths in order to allow for accurate colour analysis. It also evaluated the use of calibration objects in the colour analysis of flotation froths. This work also evaluated relating froth colour to % solids on plant. Two batch flotation campaigns were done using different ores as well as a preliminary plant trial.

Calibration objects were used to correct the RGB values obtained from the cameras for changes in ambient light, as well as changes in the camera settings (auto focus and auto iris).

The use of calibration objects proved invaluable in the laboratory batch flotation tests when there were major changes in light settings between tests and also on plant where light and camera conditions changed during the testing campaign. Without the use of calibration objects significant relationships between froth colour and copper grade could not be developed for the tests when light or camera conditions changed.

Statistically significant relationships were developed between froth colour and copper grade for laboratory batch flotation tests done using both Kennecott and North Parkes copper ore. These relationships were developed in the 'Lab' colour space after a calibration was done using patches from the calibration board.

A strong correlation was developed between the 'Lab' luminosity component and copper grade in the Kennecott campaign as well as a weaker, yet still significant, correlation between the 'Lab' colour parameter 'a' and copper grade.

High correlation coefficients were obtained between all 'Lab' parameters and copper grade using the North Parkes copper ore both before and after calibration. The range of colours obtained in this campaign (blue-purple to yellow-gold) and corresponding range of grades (50% to 5%) contributed to the strength of the relationship between froth colour and copper grade. This change in grade and colour was due to a change in the dominant mineral in the froth, going from bornite to chalcopyrite.

Significant correlations with colour parameters were seen to exist between both top of froth and concentrate grades for each individual test. Due to this and the similarity between these grades it was decided to continue taking only concentrate samples and to focus the colour–grade correlations on concentrate grade rather than top of froth grade. This was also done because concentrate grade was the variable for which a sensor would be most valuable on plant.

After calibration was done on the colour data, significant relationships were observed between froth colour and copper grade in cell 2 and froth colour and % solids in cell 4. An estimation of the mineralogy revealed a distinct mineralogical difference between the two cells. It is presumed that the difference in mineralogy is the reason for the different relationships existing between froth colour and copper grade and % solids in the two cells.

This plant campaign showed that a relationship could be developed between froth colour and copper grade in cell 2 and froth colour and % solids in cell 4 with the aid of calibration objects. These relationships could be invaluable to the flotation industry if they could be used in the development of an online sensor or control device.

The possibility of using froth colour as sensor or a control variable on site should be investigated further in a full scale plant control trial. However in order to use froth colour as a sensor or control variable the colour-grade or % solids relationship would have to be recalibrated whenever an ore change took place, as the relationship between colour and grade or % solids could change with changing ore type.

The most effective way of doing this calibration would be to link the grade-colour and % solids sensor/controller to an online analyser so as to prevent the grade–colour and % solids relationship from becoming inaccurate with time. The obvious question arises of why not just using the online analyser independently. The answer is that the online analyser outputs grades infrequently and requires high maintenance to continue operating accurately. Using a Machine Vision system could increase the frequency of the grade outputs and could also yield a % solids estimate for the rougher scavenger cells. However the relationship between % solids and other froth surface descriptors should be tested to improve the reliability of this measure.

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The flotation process has been used to separate valuable minerals from the unwanted gangue particles for almost 100 years. Developments have been made to the mechanical flotation cells, the chemical reagents used, the circuit setup and in more recent years to the online analysis of process performance parameters.

Throughout these developmental years the main decisions to control the flotation process have been made by experienced operators, who, through visual inspection of the froth colour and state decided when reagents needed to be added or when process variables needed to be changed. Operators have had some assistance in monitoring the metallurgical performance of the plant through the advent of online X-ray analysers. The outputs from these online stream analysers are however infrequent and are not generally directly linked into process control loops.

In recent years the development of Machine Vision systems has opened up new possibilities for non-intrusive process performance sensors and process control. There are currently various Machine Vision systems on flotation plants worldwide (Metso at Kennecott, Frothcam at Escondida). Extensive research has been done on using froth image analysis in closed loop control (Hyotyniemi et al, 2000; Kittel et al, 2001; Holtham and Nguyen, 2002; Cipriano et al, 1998) and recently plants have been using these systems to control the air or level of a flotation cell as a means of controlling mass pull using the froth velocity output.

It is well accepted that an experienced operator can judge the metallurgical state of a flotation cell by the appearance of the froth, using, amongst other things, colour as a key descriptor. For this reason an investigation was initiated to determine whether a relationship exists between concentrate grade and the froth colour obtained from using a Machine Vision system. This relationship could be used to control reagent addition or for system diagnostics. Both would be invaluable tools for the flotation industry.

This work was aimed at evaluating the relationship between froth colour and copper grade in the laboratory and then investigating whether a similar relationship existed on plant. Various colour spaces were examined to find one appropriate for the copper flotation froths in order to allow for accurate colour analysis. It also evaluated the use of calibration objects in the colour analysis of flotation froths. This work also evaluated relating froth colour to % solids on plant. Two batch flotation campaigns were done using different ores as well as a preliminary plant trial.

The basis of this work lies in the relationship between the colour of the froth surface and its proposed relationship to grade. The light captured by the camera is a combination of the actual colour of the froth surface, the light shining on it and the filtering of that light by the camera. Therefore in order to "measure" or normalise the light from the froth surface for different tests an object of known and consistent colour must be placed in the field of vision of the camera so that the perceived colour of this object can be recorded and compared to the perceived colour of this object at other times for other tests.

This project examined the relationship between copper grade in the concentrate and froth colour and only an estimation of the mineralogy was made from the elemental assays. No detailed mineralogical analysis was done.

Although this work assumed that all of the copper came from a single mineral (hence reflecting a single colour), it has proved to suffice when one mineral was dominant in the froth or when the ratio between dominant minerals did not change drastically.

The schematic below illustrates the work done on this project as well as the recommended future work:

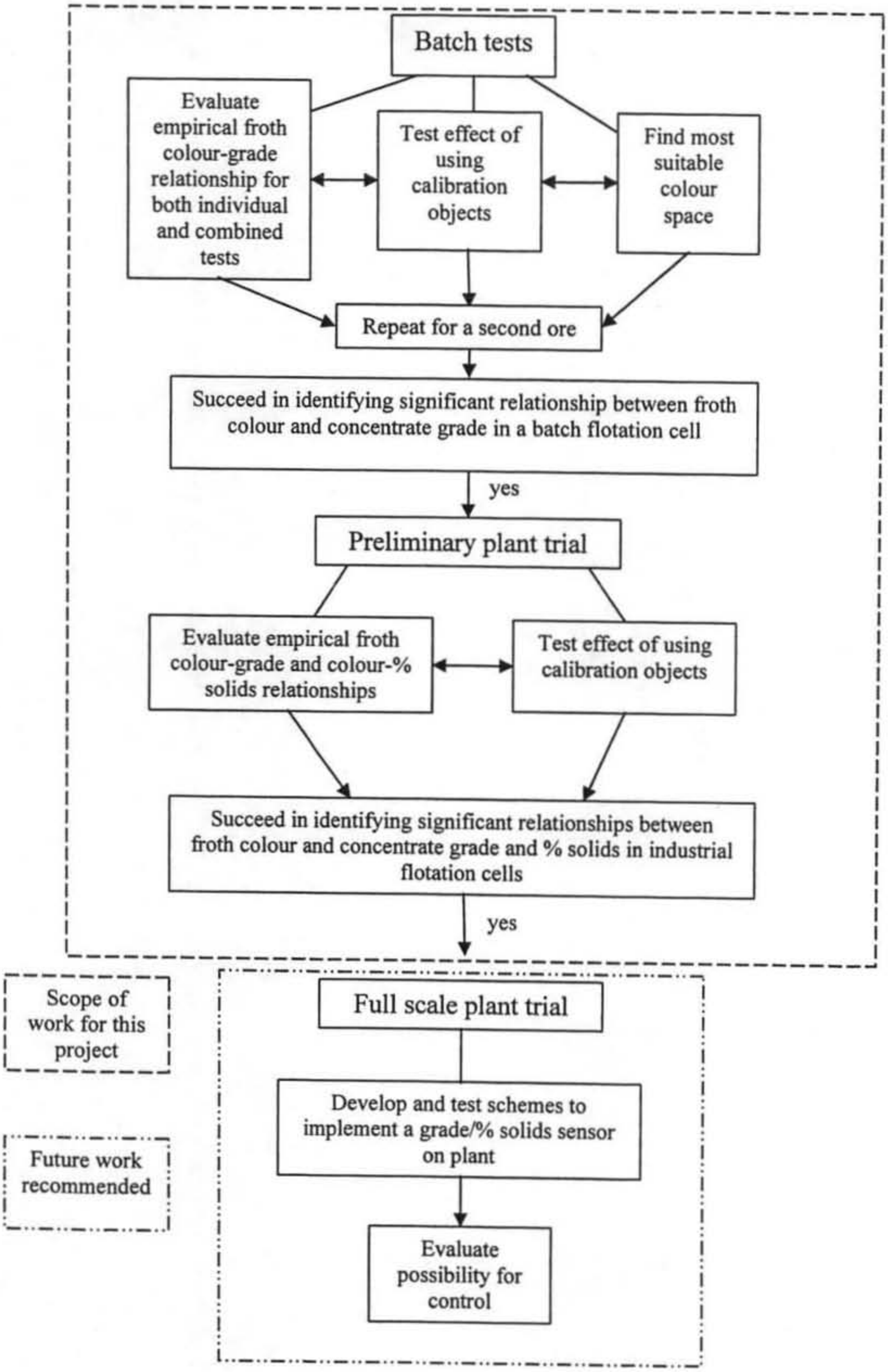

Figure 1.1. Summary of project sequence and boundaries

## 2.1. FLOTATION

Flotation is a physico-chemical process whereby the valuable minerals are separated from the unwanted gangue by the difference in the hydrophobicity of the minerals. Reagents are used to enhance this separation so that the valuable minerals selectively report to the froth while the unwanted gangue remains behind in the bulk. The efficiency and effectiveness of the process is dependent on many parameters and discussed in detail in classic texts such as Wills, (1992); King, (1982); Kelly and Spottswood, (1982); and Lynch and McKee, (1984).

Batch flotation tests are used to test reagents as well as to develop flotation procedures. The laboratory is an environment where tests can be performed under controlled conditions and where research can be done. It is also less expensive than performing tests on plant as it does not affect production.

## 2.2. MACHINE VISION

For many years operators have been controlling flotation plants by the visual appearance of the froth surface. Only in recent years, with the increased speed and computing capability available, have Machine Vision techniques been available to assist operators in their decisions.

UCT has developed a Machine Vision software program called SmartFroth. It has been developed from its original research prototype (Wright, 1999; Sweet et al, 2000) to its current version which is an industrial, modular based program complete with a dynamic user interface.

The main outputs currently exported from SmartFroth version 3 are: bubble size distribution, specific surface area, froth velocity (x-direction, y-direction and relative velocity), stability and RGB (Red, Green, Blue) colour values.

This work uses only the colour outputs from SmartFroth which are recorded as RGB.

There are currently various Machine Vision systems on flotation plants worldwide such as Metso at Kennecott and Frothcam at Escondida. Extensive research has been done on using froth image analysis in closed loop control (Hyotyniemi et al, 2000; Kittel et al, 2001; Cipriano et al, 1998) and recently plants have been using these systems to control the air or level of a flotation cell as a means of controlling mass pull using the froth velocity output from the Machine Vision System. However nobody has reported using froth colour as part of their control schemes yet.

## 2.3. COLOUR SPACES

Colour analysis is not a trivial exercise due to the complex nature of what we perceive as "colour" and its constituents. The colours we perceive are made up of the colour of the object itself, the light shining on that object and the filtration of the light reflected off that object by the viewer (camera).

Much research has been done to measure and characterize colour, particularly in the photographic and textile industry. In order to do accurate colour analysis, one needs to be able to separate the object from the light source and the camera filtration. One way of doing this is to evaluate the light in a colour space where the luminosity component of the light and the colour component of the light are separate, so as to reduce the effect changes in ambient light (usually luminosity) have on the colour of the measured object (in this case the froth surface). Several potential colour spaces were selected for evaluation and are discussed below:

### 2.3.1. Red, Green and Blue (RGB)

Most cameras output RGB signals to the image processing software. RGB can be used to look at trends in colour data but the signals are not suitable for accurate colour analysis due the coupling of colour and light intensity in the components. Changes in light intensity affect the colour readings more than in the colour spaces where the intensity and colour components are separate (Oestreich et al., 1995). However (Hargrave et al., 1996) used grey level measurement (average of red, green and blue for the image) to predict coal flotation performance in the laboratory for both a single cell and a bank of cells. Figure 2.1 shows a graphical representation of the RGB colour space:

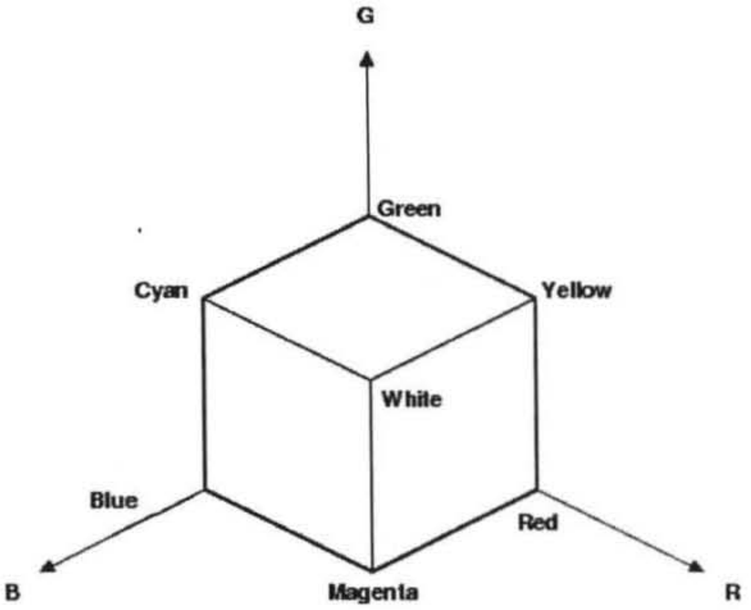

Figure 2.1. Graphical representation of RGB colour space

### 2.3.2. Normalised Red, Green, and Blue (RGB)

This colour space is a luminosity or light intensity corrected version of the RGB colour space. The components are calculated as follows:

$$Normalised\ \ red = \frac{red}{red/3 + green/3 + blue/3}$$

$$Normalised\ \ green = \frac{green}{red/3 + green/3 + blue/3}$$

$$Normalised\ blue = \frac{blue}{red/3 + green/3 + blue/3}$$

Normalised RGB gives a good approximation of the trends in colour independent of changes in luminosity and can be used for the colour analysis of flotation froths. However it has not been widely used in the image processing of flotation froths but a derivative of it (Relative RGB) has been used by some research groups (Hargrave and Hall, 1997; Hales, 1999).

### 2.3.3. Relative Red, Green and Blue (RGB)

Relative RGB is a derivative of the RGB colour space to yield the normalised difference between the light obtained from the individual colours: red, green and blue; and the grey level or brightness of the image. Relative redness was found to correlate strongly to the grade of industrial tin flotation froths (Hargrave and Hall, 1997) and also to the grade of industrial copper flotation froths (Hales, 1999).

The components are calculated as follows:

$$\mathrm{Re}lative\ red = \frac{red\ value - grey\ value}{grey\ value}$$

$$\mathrm{Re}lative\ green = \frac{green\ value - grey\ value}{grey\ value}$$

$$\mathrm{Re}lative\ blue = \frac{blue\ value - grey\ value}{grey\ value}$$

This type of analysis was proved to be more effective than using normalised RGB in the work done by Hargrave and Hall, (1997).

### 2.3.4. Hue, Saturation and Value (HSV)

HSV is a more commonly used colour space in image processing than RGB due to the entirely separate colour and luminosity components. It has been used by Hatonen et al., (1999) in the evaluation of flotation froths.

Hue, Saturation and Value are based on the artist concepts of Tint, Shade, and Tone, respectively. The Hue is a spectrum of colours ranging from 0 to 255. The Saturation is a measure of the concentration or dilution of that colour with white, ranging from 0 to 1. The Value is the luminosity component and is represented by a number between 0 and 1. Figure 2.2 shows a graphical representation of the HSV colour space:

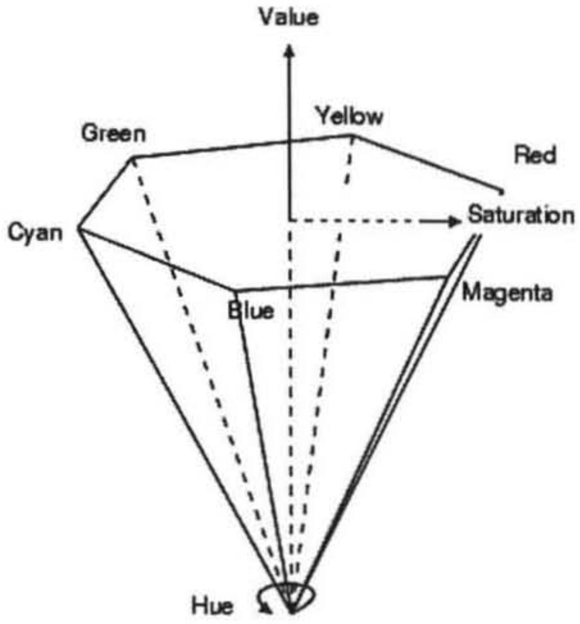

Figure 2.2. Graphical representation of the HSV Colour Space

The values for HSV can be calculated from the camera RGB values using an algorithm built into Matlab™. The algorithm used to calculate HSV values from RGB values varies slightly according the school of thought as there are cases when

Hue and Saturation become undefined. The different schools of thought handle the areas where Hue and Saturation are undefined in slightly different ways.

### 2.3.5. Colour Vector Angle

The colour vector angle is derived from the RGB colour space in terms of vectors drawn from the origin to the RGB co-ordinate points. Colour vector angles have been used by (Oestreich et al., 1995) as a grade sensor for dry mixtures, slurries and batch flotation froths of chalcopyrite and molybdenite. They observed that metallurgical grade correlated better to the colour vector angle than to RGB values and also that the colour vector angle was less affected by changes in light intensity. The colour vector angle is calculated from the 'chrominance red' ($C_R$) and the 'chrominance blue' ($C_B$) as follows:

$$C_R = 0.877 \times (0.701 \times red - 0.587 \times green - 0.114 \times blue)$$

$$C_B = -0.493 \times (-0.299 \times red - 0.587 \times green + 0.886 \times blue)$$

$$Colour\ \ vector\ \ angle = \arctan\left( {}^{C_R}\!\big/_{C_B} \right)$$

### 2.3.6. Hunter 'Lab'

The Hunter 'Lab' colour space was developed in 1942 by Richard Hunter and is used widely in the textile industry and in digital image processing. It is based on the human perception of colour, meaning that colours that seem to be similar to the human eye lie close together in the 'Lab' colour space. The colour and luminosity components are also separated allowing for accurate colour analysis. Figure 2.3 shows a graphical representation of the 'Lab' colour space:

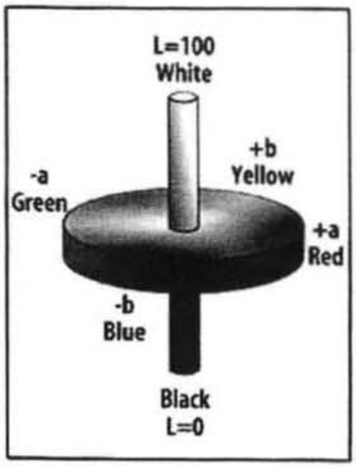

Figure 2.3. Graphical representation of the 'Lab' colour space

The 'Lab' co-ordinates can be calculated from CIE XYZ co-ordinates as follows:

$$L(Hunter\ lightness) = 100\left(\frac{Y}{Y_0}\right)^{1/2}$$

$$a(Hunter\ red - green) = 175\left(\frac{0.0102X_0}{Y/Y_0}\right)^{1/2}\left(\frac{X}{X_0} - \frac{Y}{Y_0}\right)$$

$$b(Hunter\ yellow - blue) = 70\left(\frac{0.00847Z_0}{Y/Y_0}\right)^{1/2}\left(\frac{Y}{Y_0} - \frac{Z}{Z_0}\right)$$

where X, Y, Z and $X_0$, $Y_0$, $Z_0$ are the tristimulus or CIE XYZ values for the sample and the illuminant respectively.

The values for $X_0$, $Y_0$, $Z_0$ are the values for the PAL white point of the camera. The X, Y, Z values can be calculated from the conversion between RGB and the CIE XYZ colour space by the following matrix:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} 0.431 & 0.342 & 0.178 \\ 0.222 & 0.707 & 0.071 \\ 0.020 & 0.130 & 0.939 \end{pmatrix} \times \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

## 2.4. COLOUR ANALYSIS OF FLOTATION FROTHS

Even though the conditions can be controlled in the laboratory or on plant, it is still not a trivial exercise to perform a colour analysis of the flotation froths. Some of the important issues are discussed below:

### 2.4.1. Lighting Issues

The effect of changes in ambient light on the colour of the froth has been studied for the purpose of accurate colour analysis. It has become common practice to use bright 500 W halogen lamps to directly illuminate the froth surface to effectively drown out subtle changes in ambient light. Flotation cells are also generally isolated as much as practically possible from sunlight.

Hargrave et al., (1996) reported that while using a 500 W Halogen lamp to directly illuminate the froth surface, the type of background lighting (combinations of florescent lighting, diffuse sunlight, darkness except for the halogen lamp and direct sunlight) with the exception of direct sunlight had negligible effect on the grey level measurement of the froth.

Other researchers (Oestreich et al., 1995) have investigated the comparative effect of changes in ambient light when using RGB and the colour vector angle. They observed that using colour vector angles reduced the effect of changes in ambient light.

In fact, using any colour space with separate colour and luminosity components will reduce the effect that changes in ambient light or background light intensity have on the colour results. Using different colour spaces will not however account for the changes in colour produced by direct sunlight on the froth surface.

The lighting requirements for doing accurate colour analysis on plant vary depending on the plant setup. If the flotation plant is outdoors or is not completely isolated from direct sunlight then the camera-light system has to be hooded, so as to isolate the section of the froth surface being filmed from direct sunlight. In the case of an unhooded camera, the light source is usually a bright 500 W halogen lamp, which effectively drowns out subtle changes in ambient light. For the case of a hooded system, a much smaller, 50 W halogen lamp can be used as there is far less light interference.

### 2.4.2. Camera settings

An issue that many authors do not address directly in publications on colour is that of the camera settings. In the experimental work of this thesis it was observed that if the auto-focus and auto-iris of the camera are not manually turned off before image capturing begins, the results are more "noisy" and there is more "drift" in the colour readings due to the camera attempting to correct for changes in light intensity on the froth surface.

### 2.4.3. Calibration objects

Although bright halogen lamps are used and the batch flotation cells are isolated from sunlight, there can still be changes in light caused by fluctuation in mains voltage and major differences in diffuse sunlight (overcast vs. sunny days). Due to the short period of time taken for one batch test to be completed there are not usually significant changes in light for a single test, but for consecutive tests or tests done on different days to be comparable calibration objects must be used.

The light captured by the camera is a combination of the actual colour of the froth, the light shining on it and the filtering of that light by the camera. Therefore in order to "measure" or normalise this light for different tests an object of known and consistent colour must be placed in the field of vision of the camera so that the perceived colour of this object can be recorded and compared to the perceived colour of this object at other times for other tests.

Figure 2.4 depicts a batch flotation cell with a small calibration object in place during a test.

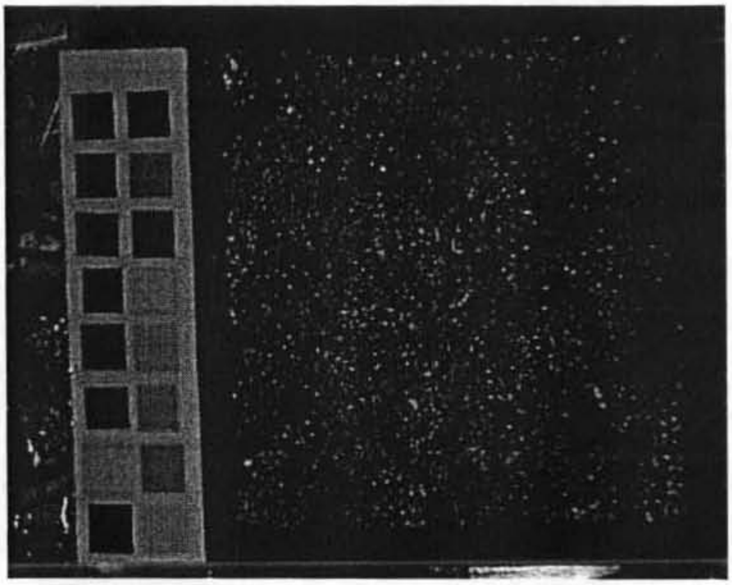

Figure 2.4. Camera view of a batch cell with calibration object in place during a test

It is not practical to use calibration objects on plant for prolonged period of time as they quickly become dirty and they need to be placed on a fixed surface. This is necessary because if they are not placed at the same angle each time the luminosity of the patches change with the light reflection. Without a hood the system would have to be recalibrated regularly because of large changes in ambient light (day-night). However this highlights another problem, which is that of changing ore types.

As ore type changes the relationship between froth colour and concentrate grade could change too. The only way to account for such ore changes would be to regularly update the co-efficients used in the grade-colour relationship. The most efficient way of doing this would be by linking the online X-ray analyser to the grade sensor system.

### 2.4.4. Relationship between Top of Froth and Concentrate Grade

The camera mounted above the flotation cell only 'sees' the top of the froth surface and the colour readings obtained from the camera are based on the froth surface only. If the difference between top of froth grade and concentrate grade is large then significant changes in concentrate grade can occur without noticing changes in the colour readings for the froth surface.

This difference between top of froth and concentrate grade depends on the site and the conditions at which cells are run. If the cells are 'pulled hard' then there should not be much difference between the variables, whereas if the froth is allowed to mature for long periods of time before it flows over the weir then there can be a significant difference between them. This is due to the time allowed for froth drainage and for entrained gangue particles to leave the froth before it is recovered (Warren, 1984; Heinrich et al, 2003). The amount of floatable gangue present in the froth will also affect this relationship.

### 2.4.5. Sampling techniques

Special sampling techniques should be utilised when doing Machine Vision analysis of batch flotation froths due to the interference of the sampling paddle with the results. Prolonged sampling intervals were used as this made post-test analysis simpler and the test results were not negatively affected (Heinrich et al., 2003).

It is also important to note that as the image results for each sampling interval are pooled and averaged it is imperative that the froth sample taken is representative of the entire froth surface for that interval. This can be accomplished by ensuring that the froth height is deep enough to allow for a complete surface sample to be removed.

### 2.4.6. Mineralogy and colour

The colour of the froth is made up of the combination of minerals present in it. Usually one or two minerals are dominant in the froth at anyone time and the colour seen is representative of the amount of those minerals present. However sometimes the colour of the minerals present are very similar (such as chalcopyrite and pyrite) and cannot be clearly distinguished. Therefore changes in the amount of one mineral can be masked by the presence of the other.

The relationship between froth colour and % solids can be seen in flotation froths because as the quantity of mineral in the froth changes, so does the colour or luminosity of the froth. This relationship is however dependent on the type of minerals present in the froth and their respective colours.

## 2.5. DATA PROCESSING AND RELATIONSHIP EVALUATION

### *Data correlation*

In the past, Partial Least Squares Regression (Hatonen et al., 1999) and Principle Component Analysis (Hatonen et al., 1999) have been used to correlate the image data obtained for flotation froths to the metallurgical grade. The reasons chosen for using more complex correlation methods was to separate the inter-correlations between variables and because often up to 7 variable were used in the models.

Linear Least Squares Regression (LLSR) was chosen to correlate the colour data to metallurgical grade in this project. It was chosen for reasons of simplicity, and because the correlations performed were limited to a maximum of 3 colour variables in one model. The inter-correlation between image variables was limited due to the small number of variables chosen for correlation purposes, and due to the separate colour and luminosity components of the variables chosen.

### *Interpretation of $R^2$ values for correlations*

In order to assign a statistical significance to the value obtained for the $R^2$ coefficient in the data correlations The Table of Critical Values of the Pearson Product –Moment Correlation Coefficient (Appendix D) was used. This table represents results of a two-tailed t-test showing the critical value for R that was needed to have a significant relationship between the variables, for a specific sample size at a desired confidence interval.

The aim of these experiments was to investigate the relationship between froth colour and copper grade in batch flotation tests in the laboratory and then to determine whether similar relationships could be developed for industrial size flotation cells. The effect of using calibration objects for ambient light and camera autoiris correction was also tested. The results were evaluated in different colour spaces in order to find the most suitable for the analysis for copper flotation froths.

## 4.1. BATCH TESTS

The experimental setup and details for the two sets of batch tests presented in this work are outlined below. The SmartFroth Machine Vision setup was the same for both testing campaigns.

### 4.1.1. SmartFroth Machine Vision system setup

A portable digital Canon MV 30i video camera was mounted 1,5 m directly above the batch flotation cell with a 500 W halogen lamp positioned adjacent to it. The camera zoom was such that most of the image was taken up by the froth and the small calibration object. The video footage was recorded into digital video tape and analysed later by direct 'fire wire' transfer from the camera into a HP omnibook XE3 laptop computer. The auto-focus was manually turned off after the correct zoom was set. The auto-iris was set on the large calibration board before it was turned off.

### 4.1.2. Image analysis

The video footage was fed directly into SmartFroth from the video camera after the tests were done. However before this could be done the video image was cropped so that only the froth surface was processed. The calibration object was processed separately.

After the tests were completed with the calibration objects in place, a normalisation was done to make the tests comparable on a colour basis. This involved taking the values obtained for the white or grey patch on the calibration board for each test and then scaling the test data set accordingly so as to normalise them. This was done in the RGB colour space before any of the colour space conversions were done. The average value for red, green and blue of the patch over the tests was used as it was observed that the light was almost constant within a single test. The data was then scaled up or down accordingly by dividing each of the red, green and blue values of the froth colour data by the average value of the calibration patch of the test and then multiplying it by a common scaling factor of 128. This was done to make sure all the data fell into the range of 0-255. The red, green and blue froth colour components were all scaled and multiplied by 128 so that no artificial colour shift was inferred on the data during scaling.

It must also be noted that although the calibration objects had many different coloured blocks only the white and grey patch were used for calibration. This was done because using coloured patches would infer an independent colour shift on the data.

Outputs from SmartFroth were obtained approximately every 2 seconds. The RGB values were then converted to the colour spaces discussed previously in Section 2.2 of the Literature review. These results were averaged for the time interval of each corresponding sample so as to have one set of colour readings for each metallurgical grade sample.

An overall correlation matrix was then constructed for each test to determine the correlation coefficients between the colour parameters from each of the colour spaces tested and the metallurgical copper grade.

The best colour spaces were then selected and the data for the various tests were combined to do an overall colour-grade correlation.

This procedure was repeated with and without calibration objects to determine their effect on the colour analysis of flotation froths.

### 4.1.3. Procedure for tests done using Kennecott ore

Tests were performed in the laboratory at UCT with ore received from Kennecott Copperton Concentrator, Salt Lake City, Utah, USA. The purpose of this testing campaign was to verify a relationship between froth colour and copper grade for an copper ore in which the predominant copper mineral was chalcopyrite. Tests were run with and without the addition of lime to change grade by depressing the flotation of pyrite.

***Sample preparation***

The ore arrived in 500 kg drums and was dried and crushed before it was split into 1.13 kg samples. Each flotation test used 1 sample. This sample was milled in a stainless steel rod mill for 7 minutes to obtain a grind of 82% passing 150 μm.

***Flotation procedure***

The 1.13 kg sample was combined with 600 ml of tap water in the mill and milled for 7 minutes to achieve a grind of 82% passing 150 μm. The milled slurry was transferred into a 3 liter open top Leeds batch flotation cell. The volume was made up to 3 liters by adding tap water.

After the impeller was set at 1200 rpm the Cytec collector (S-8985) was added at 12 g/ton and conditioned for 2 minutes. Then MIBC was added at 20 g/ton and allowed to condition for 1 minute. The lime was added before the collector and allowed to condition for 2 minutes in the tests when it was added.

The camera was turned on and the large calibration object was placed on top of the flotation cell and filmed for 5 seconds before being removed. The air was turned on at 5 l/min and the froth was allowed to mature for 30 minute before sampling. Concentrates were collected every 30 seconds for the first 2 minutes of each test and then at 1 minute intervals for the remaining 4 minutes of the test. This gave a total test time of 6 minutes with 8 concentrates being collected. The large calibration object was then replaced at the end of the test and filmed for another 5 seconds before the camera was turned off. Each sample collected was assayed separately so that each sample consisted of one concentrate and this could then be correlated to the colour outputs for that section of the test.

Copper analysis was done after acid digestion using an Atomic Absorption Spectrophotometer.

Table 4.1. below shows a summary of the testing conditions for this campaign:

Table 4.1. Summary table of conditions for batch flotation tests done using Kennecott ore at UCT

| **Ore** | Kennecott Copper ore (1.13 Kg) |
|---|---|
| **Cell Type** | 3 Litre open top Leeds cell |
| **Aeration rate** | 5 litre/ min |
| **Impeller speed** | 1200 rpm |
| **Froth height** | 1.5 cm |
| **Collector** | Cytec (S-8985) collector (12g/ton) |
| **Frother** | MIBC (20g/ton) |
| **Other Reagents** | Lime (0 g/ton, 25 g/ton and 35 g/ton) |

***Experimental program***

Tests were conducted under conditions of no lime, 25 g/ton lime and 35 g/ton lime with all other conditions constant. Two replicates were done at each condition.

### 4.1.4. Procedure for tests done using North Parkes underground sulphide ore.

The purpose of this work was to investigate the relationship between froth colour and metallurgical grade for North Parkes underground sulphide ore using batch flotation tests. This was done by establishing stable froth conditions yielding significant metallurgical results and then changing collector dosage to affect grade. These results were then used to try correlate colour parameters to copper grade. This testing campaign was done on site in the North Parkes laboratory.

***Sample preparation***

Ore was taken from the underground sulphide ore stockpile on site and was then dried crushed and split into 1 kg samples. Each flotation test used 2 samples and these were placed into a mild steel mill with 1200 ml of tap water and milled for 40 minutes to achieve a grind of -75 μm.

***Flotation procedure***

The milled slurry was transferred into a 6 liter open top Leeds batch flotation cell. Water was added to make up the volume such that the slurry in the cell was 38% solids.

After the impeller was set at 900 rpm, 1% SIBX was added (dosage according to test) and conditioned for 2 minutes. 25 g/ton of NaHS was added after the collector and allowed to condition for 2 minutes. Then IF 68 frother was added at 80 g/ton and allowed to condition for 1 minute.

The camera was turned on and the large calibration object was placed on top of the flotation cell and filmed for 5 seconds before being removed. The air was turned on at 11 l/min and the froth was allowed to mature for 30 minute before sampling. Concentrates were collected every 30 seconds for the first 2 minutes of each test and then at 1 minute intervals for the remaining 4 minutes of the test. This gave a total test time of 6 minutes with 8 concentrates being collected. The large calibration object was then replaced at the end of the test and filmed for another 5 seconds before the camera was turned off. Each sample collected was assayed separately so that one

## 4.2. PLANT TRIAL

This campaign was part of a preliminary investigation into the value that could be added to the existing vision system at Kennecott Copperton Concentrator by the Machine Vision group at the UCT. The work presented in this document is focused on the possibility of using froth colour as a sensor for copper concentrate grade and % solids.

### *Setup and procedure*

Two portable digital video cameras were set up on row 4, on cells 2 and 4. These cells were chosen because it was believed that significant changes could visually be seen on these cells when reagent changes were made.

The cameras were setup 1 meter above the froth surface, enclosed in a matt black, plastic and wire framed hood with a 50 watt halogen light inside. The base of the hood was 10 cm off the froth surface to allow as little outside light to shine on to the froth as possible.

Once the plant was stable, the cameras were turned on and 5 froth samples were taken from each cell over a period of 10 minutes. Then the cameras were turned off and a change in collector type was made. After a stabilization period of an hour the cameras were turned back on and 5 more samples were taken from each cell. This test was repeated as many times as possible over the campaign but due to plant stability this was limited to tests that evaluated 5 reagent changes.

Top of froth samples were collected by moving a bucket lid over the top of the froth surface and transferring this continuously into a sample bucket for 2 minutes. Concentrate samples were taken by placing a large sample tray below the lip of the cell, and taking samples from various points on the weir for 2 minutes.

Calibration objects were used to set the auto-iris for the video cameras before testing and for light normalisation of the different tests.

### *Image analysis*

The video footage was fed directly into SmartFroth from the video camera after the tests were done.

Outputs from SmartFroth were obtained approximately every 2 seconds. The RGB values were then converted to the colour spaces discussed previously in Section 2.2 of the literature review. These results were averaged for the time interval of each corresponding sample so as to have one set of colour readings for each metallurgical grade sample.

An overall correlation matrix was then constructed for each test to determine the correlation coefficients between each colour parameter from all the colour spaces tested and the metallurgical copper grade. The best colour spaces were then selected for further analysis.

The metallurgical grade samples before the reagent change were averaged as the plant was stable and any differences in grades were believed to be due to assay or sampling deviance. The colour values for these sampling periods were also averaged to correspond to the metallurgical grade readings. It was noted that the mean colour values were constant over this period as shown in Figure 6.3. The same procedure was done to the results after the change in reagent.

The data for the various tests were then combined to do an overall colour-grade and colour-% solids correlation for each cell over a number of reagent tests.

# CHAPTER 5 THE RELATIONSHIP BETWEEN FROTH COLOUR AND COPPER GRADE IN BATCH FLOTATION

Batch flotation tests are routinely used for the research and development of chemical reagent testing, different cell designs and different methods of flotation. They are often used as a scoping tool for proposed plant changes and innovations as the laboratory environment is easier to control and it is cheaper than testing on full scale plant operations. The limitations are however that the results are often not directly comparable to full scale operation.

The purpose for testing the relationship between froth colour and copper grade in the laboratory is that the lighting in a laboratory is easier to control than on plant, and because preliminary work needed to be done before a full scale plant trial can be justified.

The aim of these tests was to investigate the existence of a relationship between froth colour and copper grade of the concentrate obtained in a batch flotation cell. Two different ores with different dominant copper minerals were used to test this relationship. The first ore sample was obtained from Kennecott Copperton Concentrator (tests done at UCT) in which chalcopyrite was the predominant copper mineral and the other was obtained from North Parkes (tests done at North Parkes) in which bornite was the predominant copper mineral.

In the case of the Kennecott ore, concentrate grade was changed by adding lime to depress pyrite while in the case of the North Parkes ore, grade was changed with collector addition.

Metallurgical reproducibility was not required in these tests as correlations were drawn directly between individual froth colour and corresponding grade samples. Calibration objects were however used to increase the reliability of the colour results.

## 5.1. BATCH TESTS DONE ON KENNECOTT COPPER ORE

### 5.1.1. Introduction

The purpose of this testing campaign was to verify the existence of a relationship between froth colour and copper grade for a copper ore. Tests were run with and without the addition of lime to change grade by depressing the flotation of pyrite.

This ore had approximately 0.75% chalcopyrite and 23.65% pyrite. There were no significant amounts of bornite present.

Although the predominant copper mineral in the ore was chalcopyrite and large quantities of pyrite were present in the ore, no attempt was made to decouple the colours of the minerals even though their colours were similar but rather to investigate the relationship between froth colour and copper grade with varying quantities of pyrite.

In order to address the issue of ambient light, tests were conducted with calibration objects in place and the colour analysis was done both with and without calibration objects. Both the white and grey patches were evaluated as the white patch became saturated in some of the tests.

### 5.1.2. Results for individual tests

The results from each individual batch test were analysed and the relationship between froth colour and copper concentrate was evaluated in the colour spaces as discussed in Section 2.2 of the literature review. The results from a single test are shown below:

Figure 5.1. below shows the grade results for an individual batch flotation test (points have been joined to aid visual comparison with colour trends):

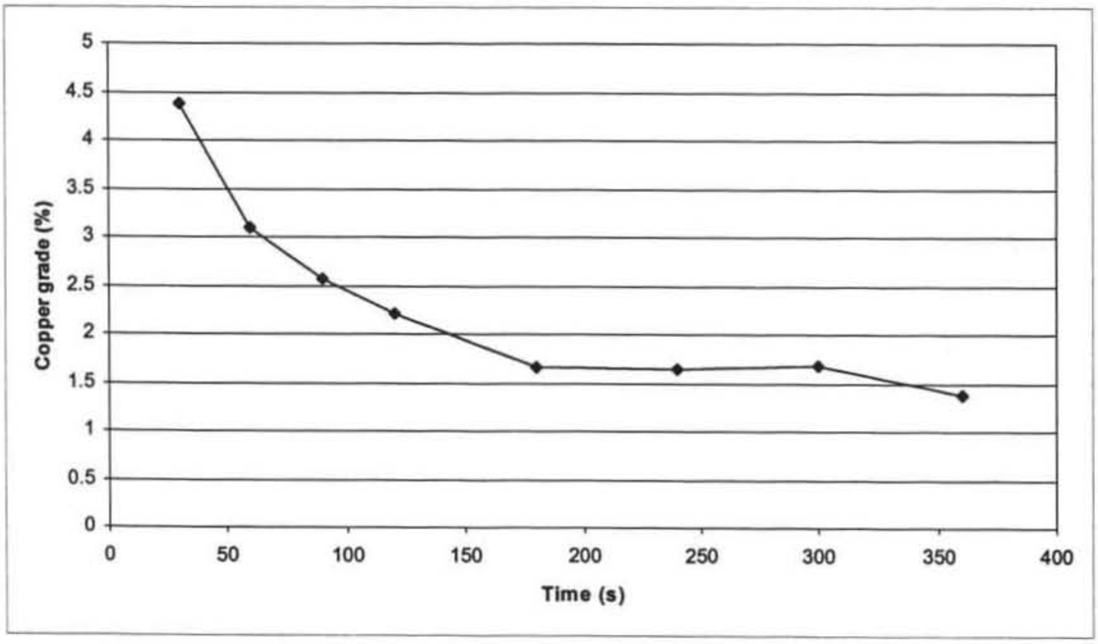

Figure 5.1. Graph of copper grade vs. time for an individual batch flotation test done with 2.5 g lime using Kennecott copper ore

The grade values are very low for this test. This is possibly due to high quantities of pyrite in the froth. The concentrate grade values do however decline with time in the first order manner expected.

Table 5.1. Table of correlation coefficients for an individual batch flotation test done with 2.5 g lime using Kennecott copper ore

| Colour parameter | R-value | Colour parameter | R-value |
|---|---|---|---|
| **Red (R)** | 0.949 | **Normalized blue** | 0.448 |
| **Green (G)** | 0.938 | **L** | 0.950 |
| **Blue (B)** | 0.995 | **a** | -0.963 |
| **grey** | 0.971 | **b** | 0.317 |
| **Relative red** | -0.467 | **Hue** | -0.414 |
| **Relative green** | -0.428 | **Sat** | -0.451 |
| **Relative blue** | 0.448 | **Val** | 0.949 |
| **Normalized red** | -0.467 | **RGB angle** | 0.514 |
| **Normalized green** | -0.428 | **'Lab' angle** | -0.451 |
| **Pearson's R-crit value for 99% confidence interval (Table in Appendix D) for 8 sample data set** | | | **0.765** |

As can be seen in the table above, very high correlation coefficients are obtainable for different colour parameters when looking at a single batch flotation test with this ore. The R-values for 'L', 'a' and 'Val' are well above the value indicated in the Pearson Table of Product Moment Coefficients for a significant relationship within a 99% confidence interval. This indicates that a strong relationship exists between froth colour and copper grade within a single batch test for the tests done on this ore. (Raw RGB data has been rejected on the basis that the colour space has no separation between colour and luminosity).

The colour results of individual tests were examined and some of the trends resembled those of the grade curves. It must be noted that some of the spikes in the raw colour data were caused by the paddle during sample collection. These were accounted for in later data processing.

The three colour parameters showing the highest correlations to copper grade are shown below for a visual comparison with copper grade. (The RGB colour space results are not shown as this colour space was rejected for analysis on the basis of there being no separation between the colour and luminosity components in this colour space):

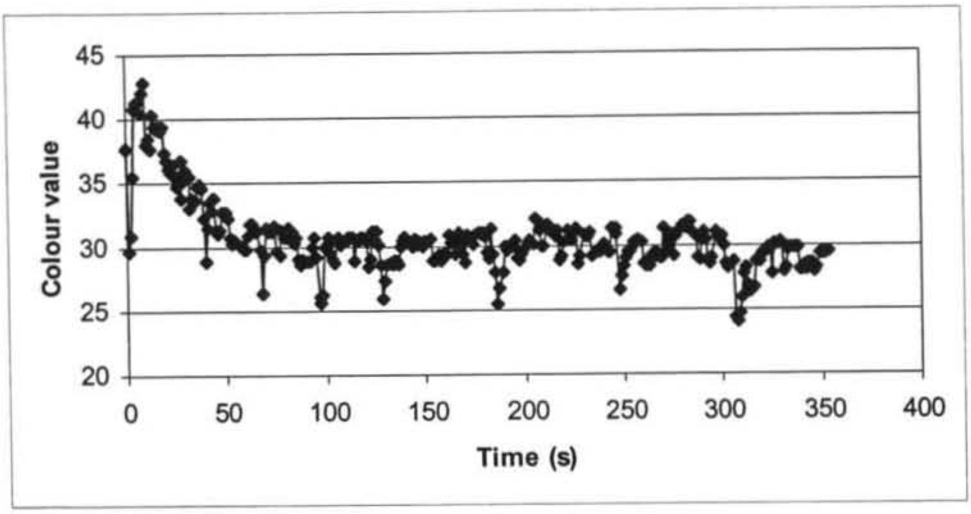

Figure 5.2. Graph of the unaveraged 'L' vs. time for an individual batch flotation test

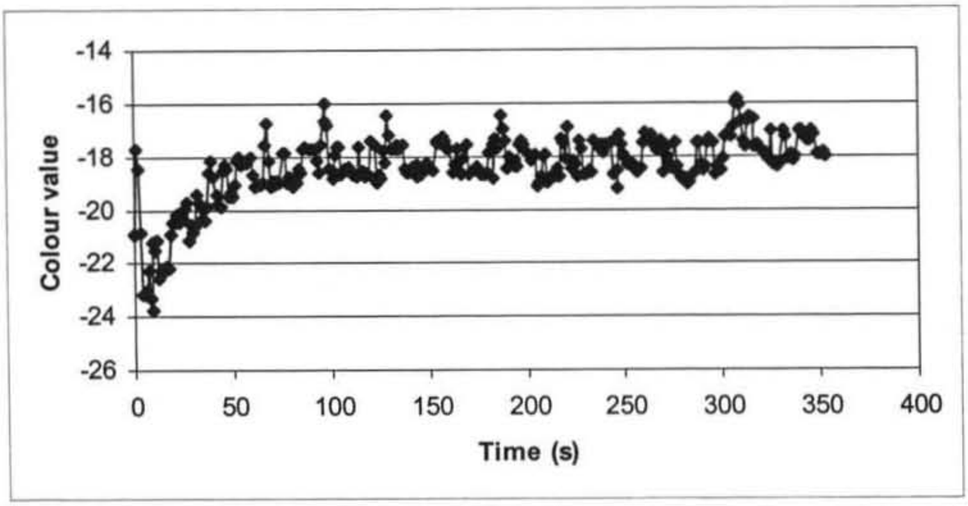

Figure 5.3. Graph of the unaveraged 'a' vs. time for an individual batch flotation test

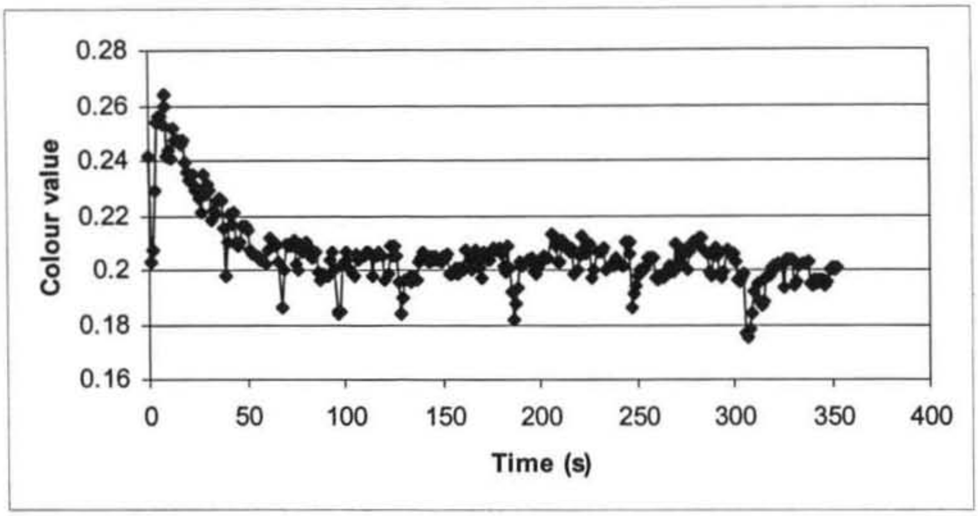

Figure 5.4. Graph of the unaveraged 'Val' vs. time for an individual batch flotation test

The colour parameters shown above decay with first order kinetics resembling the copper grade trends seen in Figure 5.1 above. The results show that significant relationships exist between various froth colour parameters and copper grade for individual batch flotation tests using Kennecott copper ore at a 99% confidence interval.

After the individual batch tests were analysed the overall results for the batch tests performed under different reagent conditions were examined:

### 5.1.3. Overall results for test performed under different reagent conditions

*Metallurgical results*

Tests were run at lime dosages of: nil , 2.5 g and 3.5 g with the intention of obtaining different grades to compare with froth colour by depressing pyrite flotation:

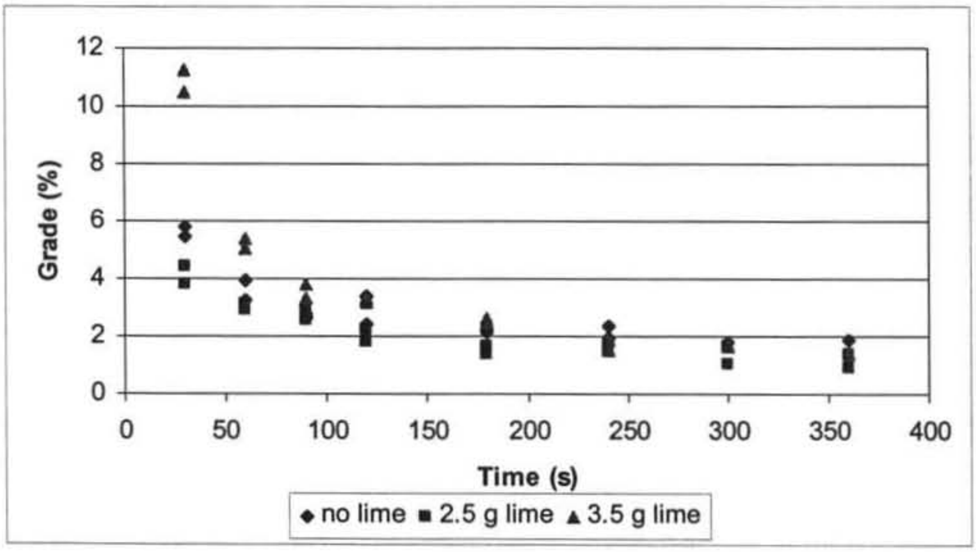

Figure 5.5. Graph of copper grade vs. time for tests conducted under different lime dosages

It can be seen in Figure 5.5. above that the initial grades for the tests run with no lime were slightly higher than the tests run with 2.5 g lime. The addition of 3.5 g of lime however resulted in a significantly higher initial grade than the previous two conditions.

The colour results were then examined to evaluate their relationship to copper grade for Kennecott Copper ore. The following results show the colour values of the froth without using calibration, then using the white patch for calibration and finally using the grey patch for calibration:

Table 5.2. Table of correlation coefficients between copper grade and colour values for tests done at different lime conditions using white patch calibration

| Colour parameter | R-value | Colour parameter | R-value |
|---|---|---|---|
| **Red (R)** | 0.711 | **Normalized blue** | 0.036 |
| **Green (G)** | 0.850 | **L** | 0.824 |
| **Blue (B)** | 0.823 | **a** | -0.523 |
| **grey** | 0.196 | **b** | 0.285 |
| **Relative red** | 0.027 | **Hue** | -0.108 |
| **Relative green** | 0.079 | **Sat** | 0.327 |
| **Relative blue** | 0.036 | **Val** | 0.702 |
| **Normalized red** | 0.027 | **RGB angle** | -0.081 |
| **Normalized green** | 0.079 | **'Lab' angle** | 0.129 |
| **Pearson's R-crit value for 99% confidence interval (Table in Appendix D) for 45 sample data set** | | | **0.372** |

Table 5.2 above shows that the 'Lab' colour space had the highest correlation coefficients overall for any colour space except RGB which was rejected on the basis of no separation between colour and luminosity. Due to the high R-values for the 'Lab' colour space parameters and the accuracy of using 'Lab' in colour analysis (see Section 2.2) this colour space was chosen for the analysis of the relationship between froth colour and copper grade for this ore.

### *Machine Vision Results (without calibration)*

The following graphs show the 'Lab' colour results of the tests performed before any calibration was done to account for the different light conditions for each test performed. The 'Lab' colour space was chosen as it yielded high correlations between colour and grade and it has separate colour and luminosity components.

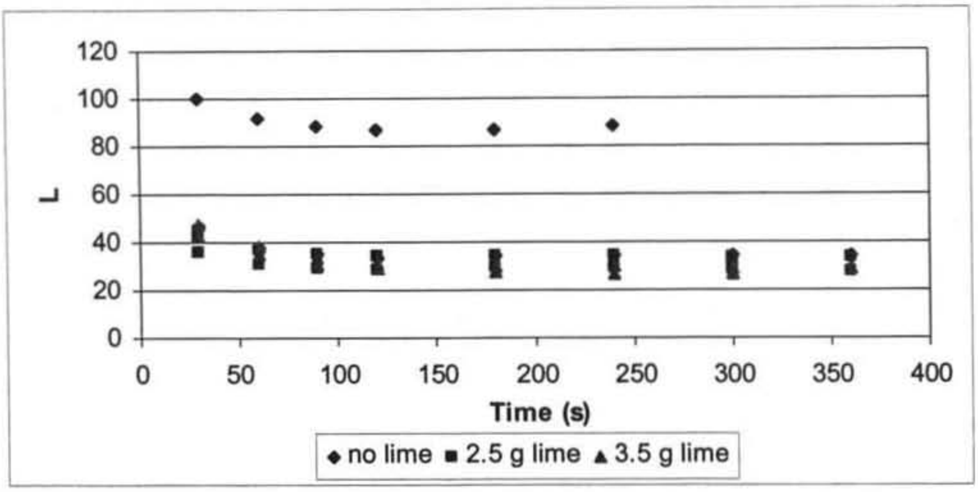

Figure 5.6. Graph of colour value 'L' vs. time for tests done at different lime conditions

It can be seen above in Figure 5.6 that the trends in the colour parameter 'L' resemble those of the metallurgical copper grade except for the one 'no lime' test that has a much higher 'L' value than the other tests. The reason for this test having a much higher 'L' value is because the auto-iris of the camera was set on the froth surface rather on the calibration board before that test began. This resulted in a much lighter image and hence higher 'L' values.

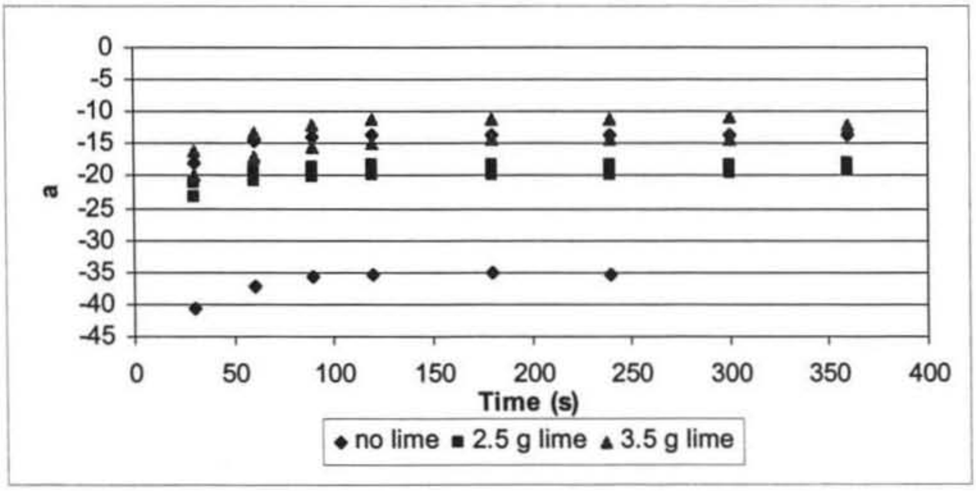

Figure 5.7. Graph of colour value 'a' vs. time for tests done at different lime conditions

The trends seen in the colour parameter 'a' are inverse to those seen in Figure 5.5. for the copper grade results, except again for the one 'no lime' test which has a much lower value for 'a' than any of the other tests. The results for each testing condition do however remain separated through the tests.

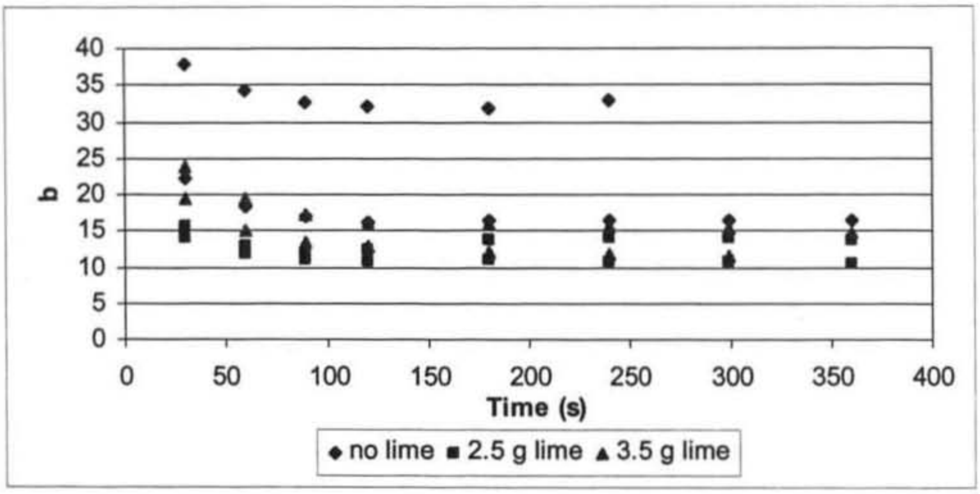

Figure 5.8. Graph of colour value 'b' vs. time for tests done at different lime conditions

The results for the colour parameter 'b' again show trends resembling the copper grade trends with time but once again the one 'no lime' test is an outlier.

These colour results were then compared directly with the measured copper grades and the correlation coefficients were calculated:

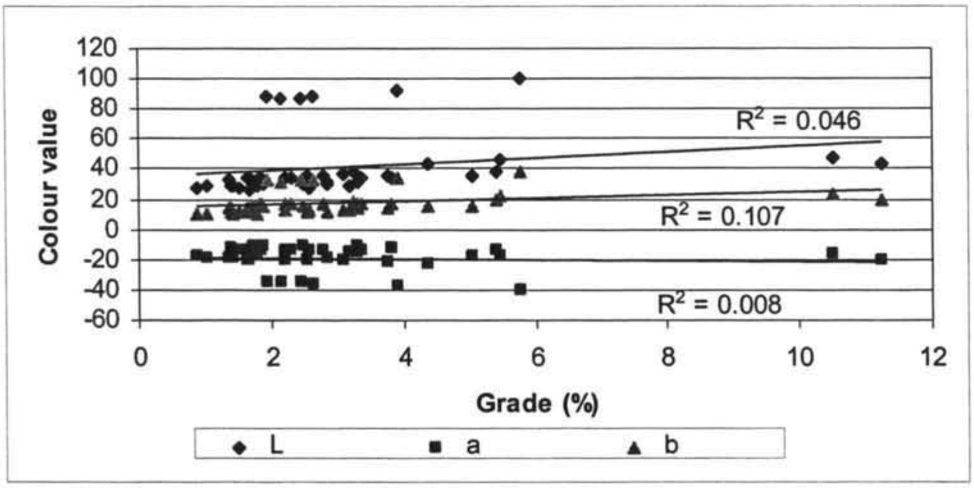

Figure 5.9. Graph of colour values 'L', 'a' and 'b' vs. copper grade for tests done at different lime conditions

Table 5.3. Table of correlation coefficients between copper grade and colour values for tests done at different lime conditions (without calibration)

| **45 sample data set** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.046 | 0.008 | 0.107 |
| **R** | 0.214 | 0.089 | 0.327 |
| **Pearson's R-crit value (99% confidence interval)** (Table in Appendix D) | 0.372 | 0.372 | 0.372 |

It can be seen that even though significant correlations existed for individual tests none of the 'Lab' parameters show correlations with copper grade that are high enough to be considered significant at a 99% confidence interval when the tests were combined. This is mainly due to the one test done at the 'no lime' condition.

A multi-variable linear least squares regression was then done to find a model using the colour parameters 'L', 'a' and 'b' to reproduce copper grade:

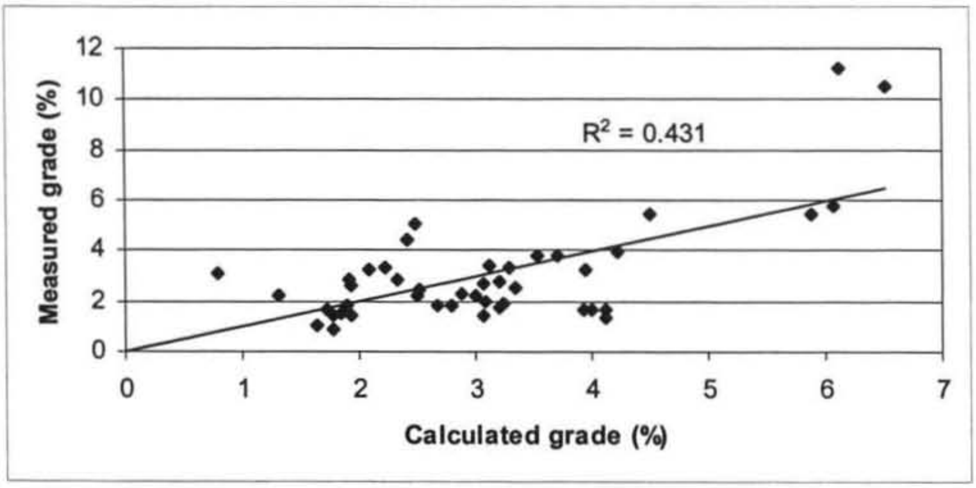

Figure 5.10. Graph of Calculated grade vs. measured grade for tests done at different lime conditions

The following model was used to calculated copper grade from the colour parameters 'L', 'a' and 'b':

$$Calculated\ \ grade = -0.00905 \times L_N - 0.00902 \times a_N + 0.01794 \times b_N - 0.07989$$

Combining the colour parameters into this model resulted in a large improvement in the correlation coefficient with the measured grade when compared with the individual colour components. However the overall correlation coefficient was still low.

***Machine Vision Results (calibrated with white patch)***

The following results have been calibrated using the white patch on the small calibration board. The colour values for the patch were averaged for each test as the mean of each colour value did not change much in each test. In most of the tests the auto-iris was set on the calibration object which in turn ensured that the white patch was not saturated, however in the tests where the auto-iris was set on the froth surface the white patch could saturate as shown below:

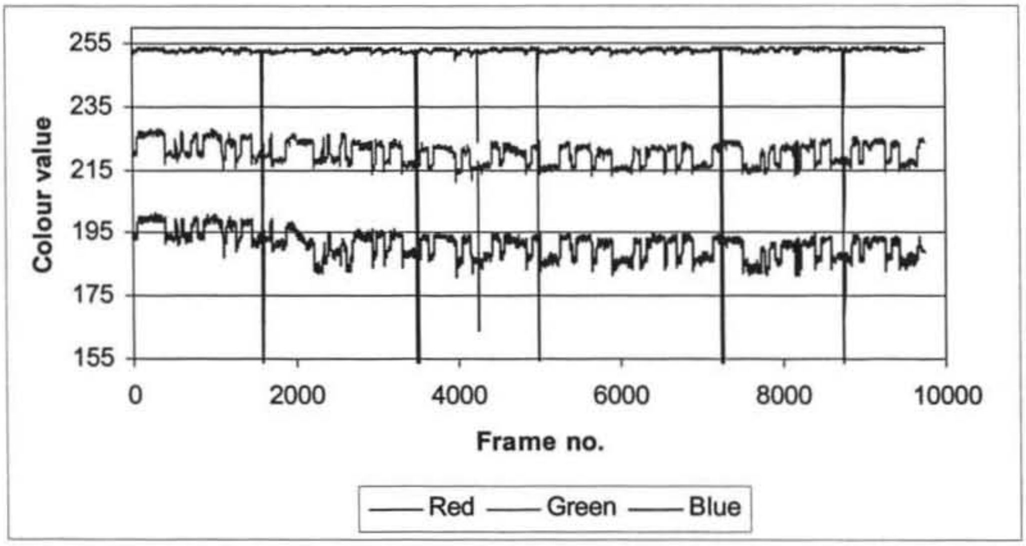

Figure 5.11. Colour values of white patch in a test when saturation occurs

It can be seen above that the red values do lie close to 255. This means that the value could have been higher relative to the other colour values had it not been limited to a maximum of 255 by the camera output system. This could then result in an inaccurate colour calibration for this test.

The following colour results were obtained after calibration was done using the white patch:

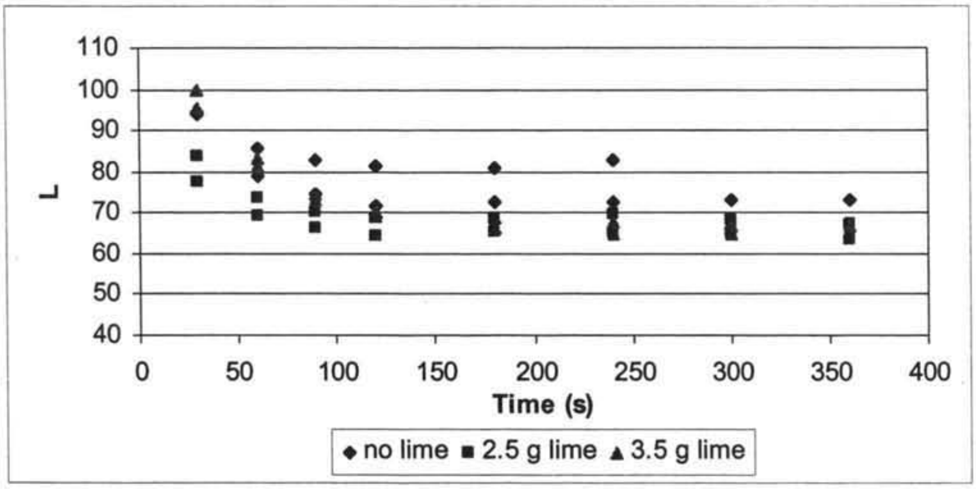

Figure 5.12. Graph of colour value 'L' vs. time for tests done at different lime conditions using white patch normalisation

The results for the colour parameter 'L' resemble the grade results shown in Figure 5.5 whereby the initial values for the tests done at 3.5 g lime are the highest followed by the no lime tests and then the 2.5 g tests. All test except the one 'no lime' test tend toward a similar end value, resembling the copper grade results. Although the values for the one 'no lime' test have been significantly improved by white patch normalisation they tend toward a higher end value than the other tests. This was due the saturation of the white patch in this test.

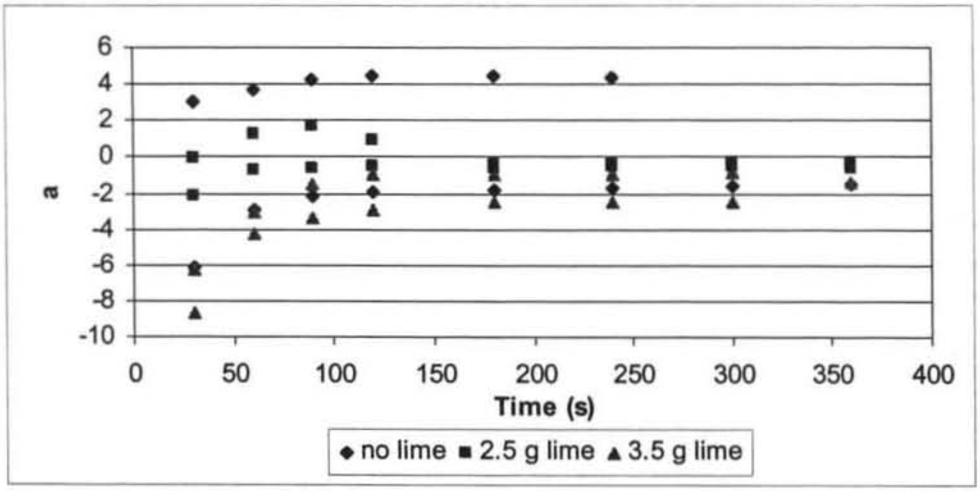

Figure 5.13. Graph of colour value 'a' vs. time for tests done at different lime conditions using white patch normalisation

The results above resemble the copper grade trends in an inverse manner. However the results for the one 'no lime' test do not follow this trend.

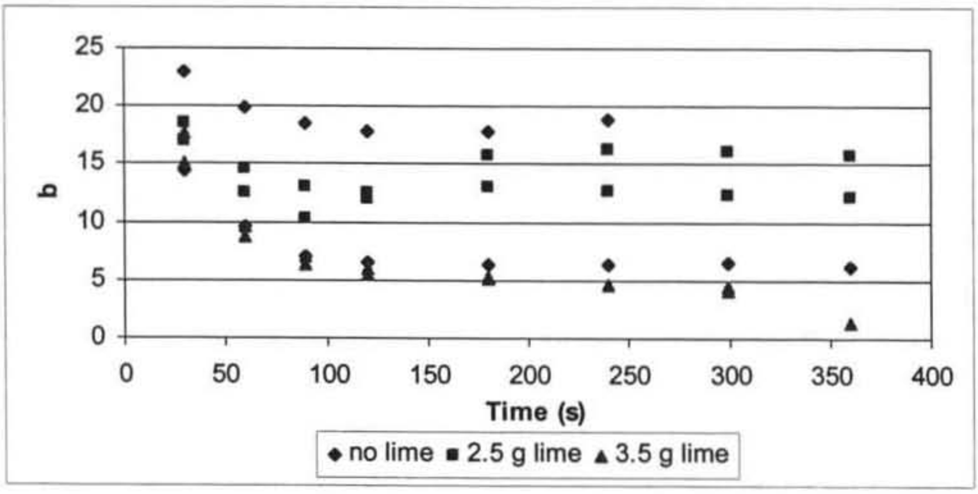

Figure 5.14. Graph of colour value 'b' vs. time for tests done at different lime conditions using white patch normalisation

The values for 'b' show grouping for each testing condition except the 'no lime' tests where the results are separated.

The colour results were then compared directly to copper grade:

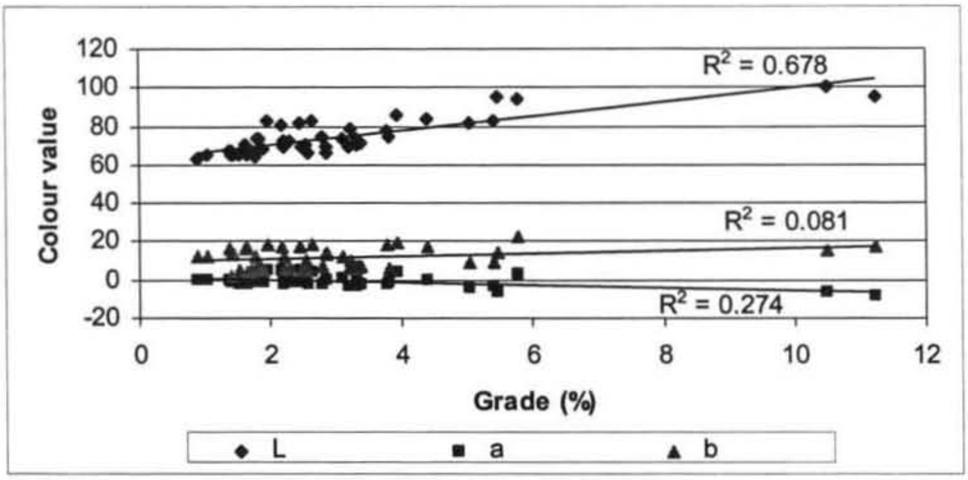

Figure 5.15. Graph of colour values 'L', 'a' and 'b' vs. copper grade for tests done at different lime conditions using white patch normalisation

Table 5.4. Table of correlation coefficients between copper grade and colour values for tests done at different lime conditions using white patch normalisation

| **45 sample data set** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.678 | 0.274 | 0.081 |
| **R** | 0.823 | 0.523 | 0.285 |
| **Pearson's R-crit value (99% confidence interval)** (Table in Appendix D) | 0.372 | 0.372 | 0.372 |

There is a strong correlation between the luminosity component 'L' and copper grade shown by the high correlation coefficient in Table 5.4. above. 'a' also shows a significant relationship with copper grade at the 99% confidence interval. 'b' does not show a significant relationship with copper grade at the 99% confidence interval.

The 'a' component of the 'Lab' colour space represents green-red, the 'b' component represents blue-yellow and the 'L' component represents black-white (see Figure 2.3).

The relationship between 'L' and copper grade could be due to the reflective nature of the minerals present in the froth. Therefore the more mineral present, the more light reflected into the camera and the higher the 'L' value. This could be an indication of solids loading in the froth which is indicated by the grade values.

The relationship between 'a' and copper grade was attributed to the froth colour becoming more green (lower 'a') with higher concentrations of copper (see Figure 2.3). This could be because of the presence of chalcopyrite which is brass-yellow although pyrite may have had a similar visual effect on the froth. The fact that there is a significant correlation between the colour parameter 'a' and copper grade infers that either the camera can distinguish between chalcopyrite and pyrite or the ratios of the two minerals do not change much, only their quantities in the froth relative to other minerals. However this cannot be confirmed without detailed mineralogy.

A multi-variable linear least squares regression was then done to reproduce the copper grades from colour parameters:

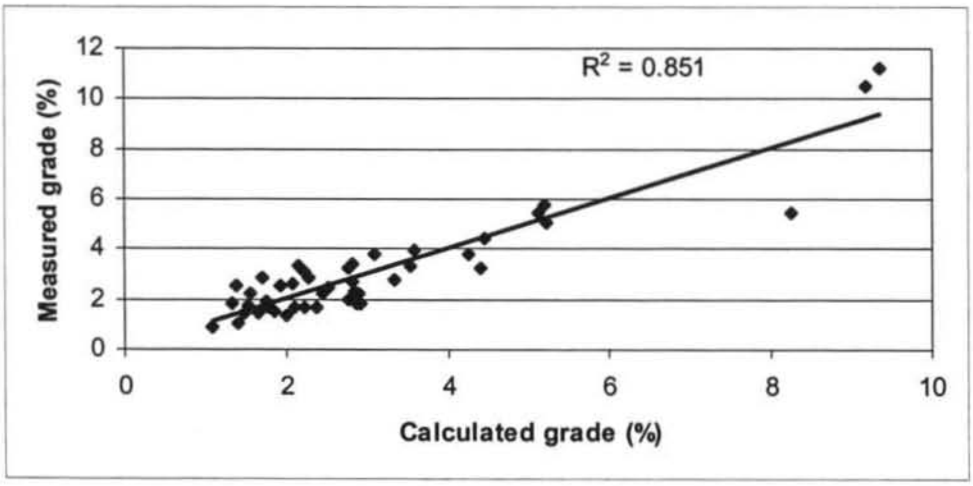

Figure 5.16. Graph of Calculated grade vs. measured grade for tests done at different lime conditions using white patch normalisation

The following model was used to calculated copper grade from the colour parameters 'L', 'a' and 'b':

$$Calculated\ \ grade = 0.00160 \times L_N - 0.00354 \times a_N + 0.00039 \times b_N - 0.09591$$

The $R^2$-value for the model was significantly higher than the individual value of the correlation coefficient between 'L' and copper grade. It must be noted that the model has also been vastly improved by using white patch normalisation.

### *Machine Vision Results (calibrated with grey patch)*

The following colour results have been calibrated using the grey patch on the small calibration board as the white patch became saturated in some of the tests. The results for the grey patch in the same test when the white patch was saturated is shown below:

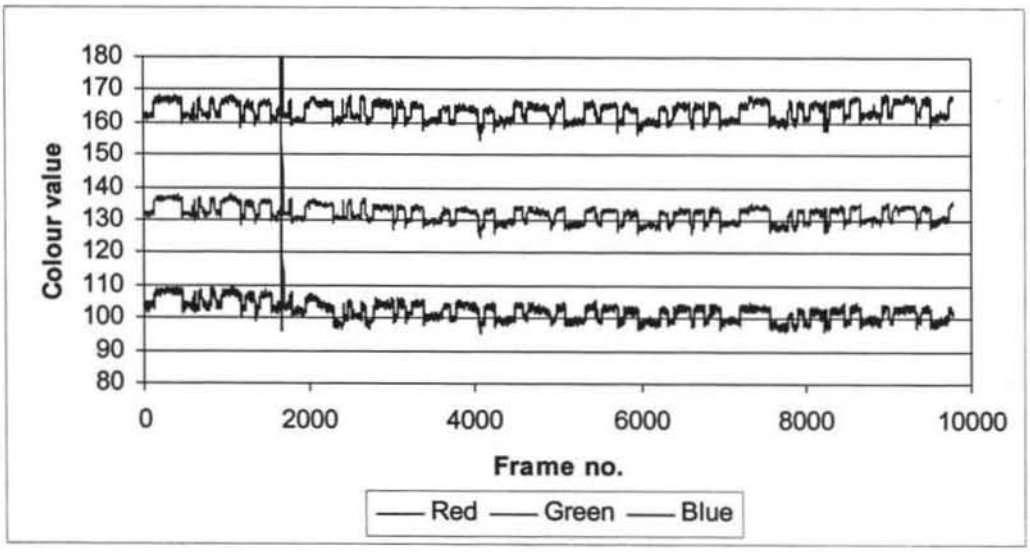

Figure 5.17. Colour values of grey patch in a test when white patch saturation occurs

The values for all three colour channels shown above do not reach values near 255 and it can therefore be said that they grey patch was not saturated and can be used for calibration.

The following results were obtained after calibration was done using the grey patch:

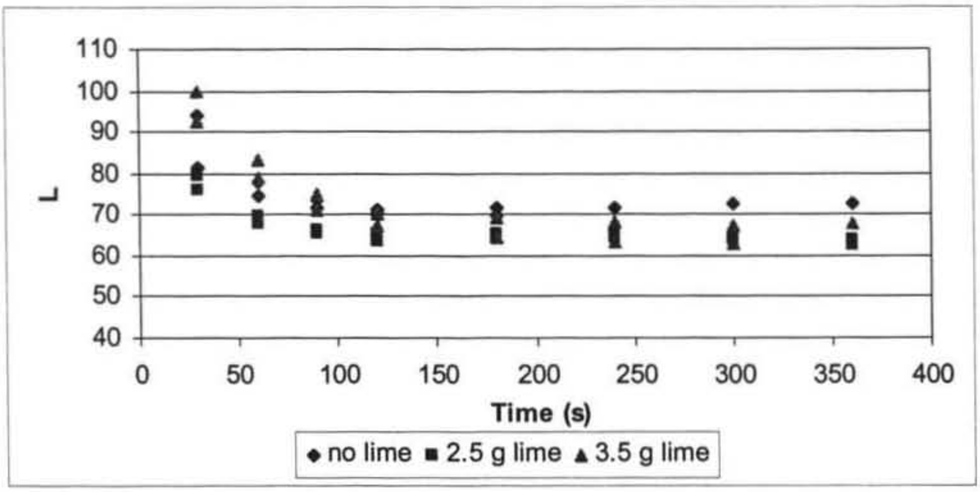

Figure 5.18. Graph of colour value 'L' vs. time for tests done at different lime conditions using grey patch normalisation

The outlying 'no lime' test has now been corrected for and the trends in 'L' with time resemble those of the copper grade with time even more closely than for the results obtained using white patch normalisation.

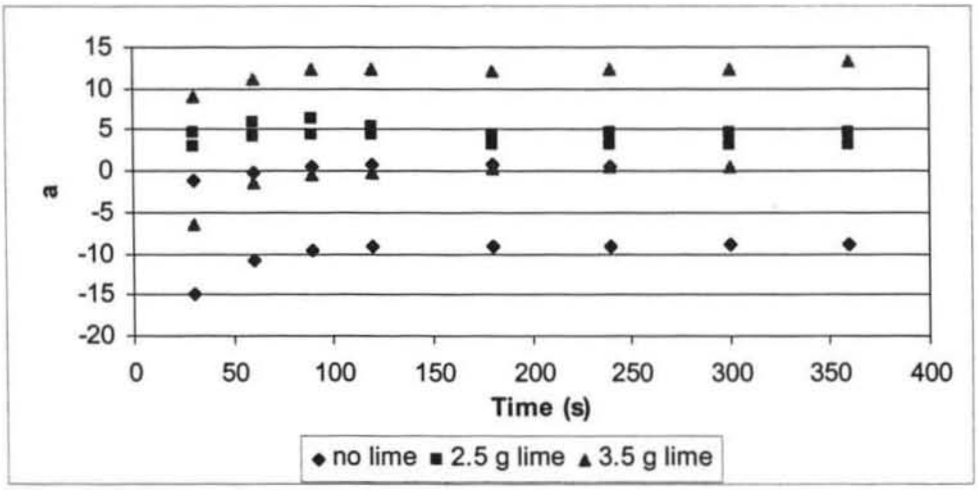

Figure 5.19. Graph of colour value 'a' vs. time for tests done at different lime conditions using grey patch normalisation

The results for the colour parameter 'a' using grey patch normalisation are different to the results using white patch normalisation in the way that there is no grouping between tests done at the same lime condition except for the 2.5 g tests. The different testing conditions are also separated from one another and do not tend toward similar end values.

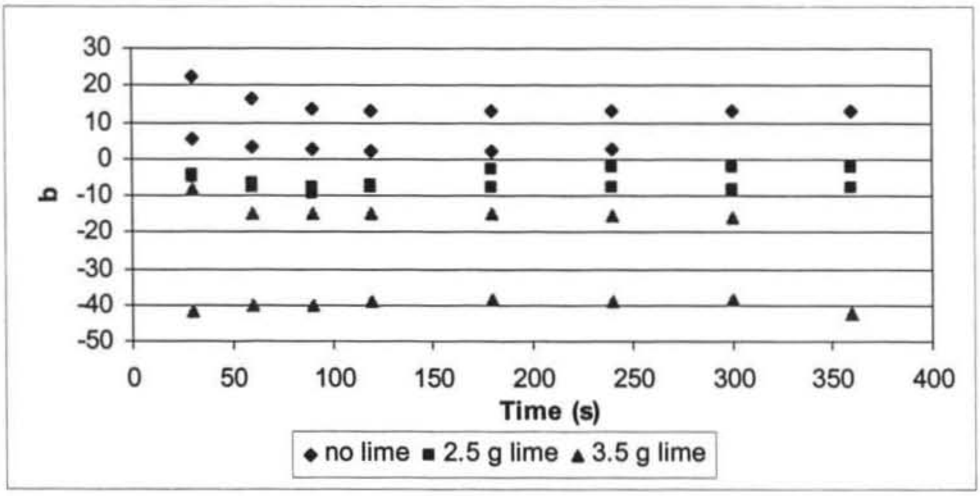

Figure 5.20. Graph of colour value 'b' vs. time for tests done at different lime conditions using grey patch normalisation

The values for 'b' do not follow any obvious trends in relation to copper grade. The tests are grouped according to the lime condition but this grouping in not in the same order as for the grade results.

The direct relationship between colour parameters and grade was then examined:

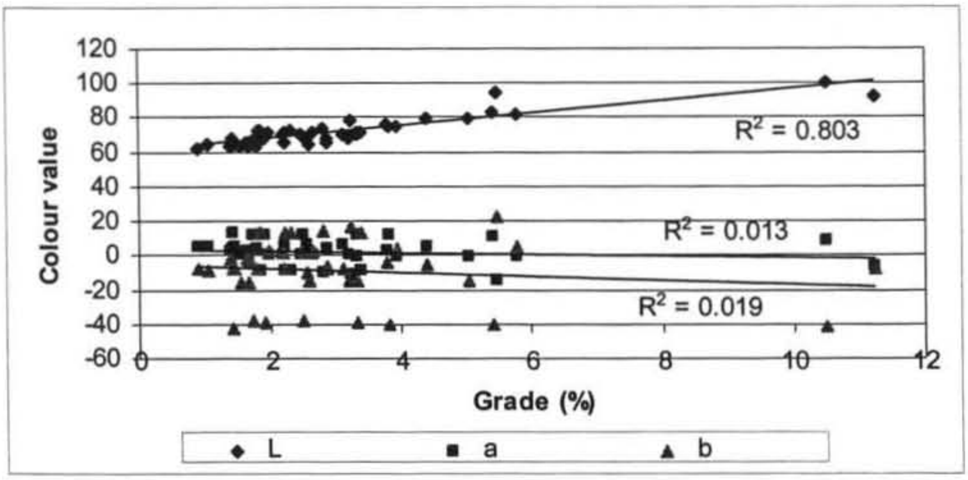

Figure 5.21. Graph of colour values 'L', 'a' and 'b' vs. copper grade for tests done at different lime conditions using grey patch normalisation

Table 5.5. Table of correlation coefficients between copper grade and colour values for tests done at different lime conditions using grey patch normalisation

| **45 sample data set** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.803 | 0.013 | 0.019 |
| **R** | 0.896 | 0.114 | 0.138 |
| **Pearson's R-crit value (99% confidence interval)** (Table in Appendix D) | 0.372 | 0.372 | 0.372 |

A very high correlation coefficient was obtained between 'L' and copper grade. The other colour parameters 'a' and 'b' did not show significant correlations with copper grade at the 99% confidence interval.

The reason for the correlation between 'L' and copper grade improving using grey patch normalisation could be due to the saturation of the white patch during some of the tests and therefore the inadequate calibration of luminosity during those tests. The reason for the correlation between the colour parameters 'a' and 'b' decreasing when using grey patch normalisation could be because the 'grey' patch might no have been a "pure enough" grey. In other words the values for red, green and blue for the patch were unequal and therefore a slight colour shift would be imposed on the data. This highlights the importance of using calibration objects of known colour values.

The colour parameters were then combined in a multi-variable linear least squares regression model to reproduce copper grade:

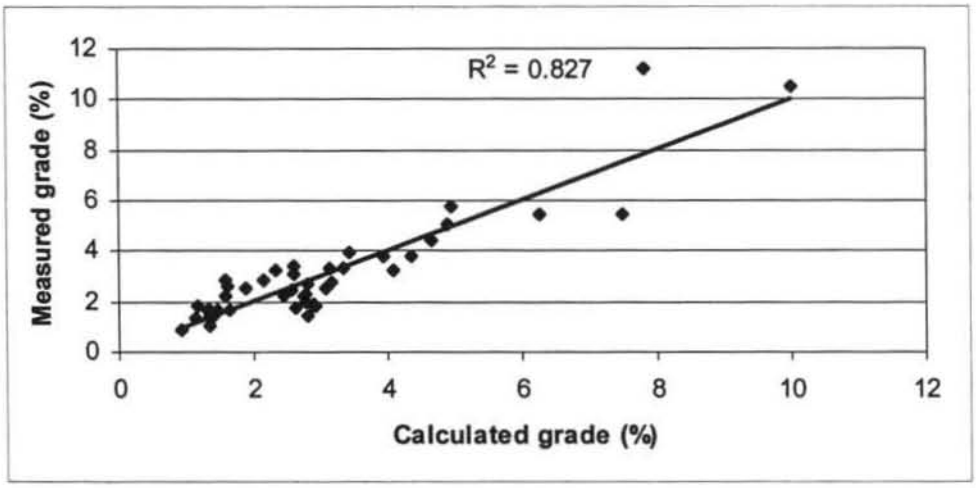

Figure 5.22. Graph of Calculated grade vs. measured grade for tests done at different lime conditions using grey patch normalisation

The following model was used to calculated copper grade from the colour parameters 'L', 'a' and 'b':

$$Calculated\ \ grade = 0.00221 \times L_N - 0.00013 \times a_N - 0.00023 \times b_N - 0.12906$$

The $R^2$-value for the model is a slight improvement on the correlation coefficient between 'L' and copper grade alone. The $R^2$-value is slightly lower using grey patch normalisation as opposed to white patch normalisation.

### *Summary of results for batch tests done on Kennecott ore*

Table 5.6. Summary of results for batch tests done on Kennecott ore

|  | **45 sample data set** | **L** | **a** | **b** | **Model** |
|---|---|---|---|---|---|
| **Without calibration** | **$R^2$** | 0.046 | 0.008 | 0.107 | 0.431 |
|  | **R** | 0.214 | 0.089 | 0.327 | 0.657 |
|  | **Pearson's R-crit value**<br>**(99% confidence interval)**<br>(Table in Appendix D) | 0.372 | 0.372 | 0.372 | 0.372 |
| **Using White patch** | **$R^2$** | 0.678 | 0.274 | 0.081 | 0.851 |
|  | **R** | 0.823 | 0.523 | 0.285 | 0.922 |
|  | **Pearson's R-crit value**<br>**(99% confidence interval)**<br>(Table in Appendix D) | 0.372 | 0.372 | 0.372 | 0.372 |
| **Using Grey patch** | **$R^2$** | 0.803 | 0.013 | 0.019 | 0.827 |
|  | **R** | 0.896 | 0.114 | 0.138 | 0.909 |
|  | **Pearson's R-crit value**<br>**(99% confidence interval)**<br>(Table in Appendix D) | 0.372 | 0.372 | 0.372 | 0.372 |

Using white patch normalisation dramatically improved the correlation between 'L' and 'a' with copper grade. The regression model has also been vastly improved by using white patch normalisation.

Using grey patch normalisation improved the correlation coefficient between 'L' and copper grade further, but it decreased the correlation between 'a' and 'b' with copper grade. The regression model using grey patch normalisation had a slightly lower $R^2$-value as opposed to white patch normalisation.

### 5.1.4. Conclusions for the batch flotation tests done on Kennecott Copper ore

- There was a high correlation between various froth colour parameters and copper grade for individual batch flotation as there was enough range in grade over a single batch test for relationships between colour and grade to be seen.

- The metallurgical copper grade was affected by the addition of lime. The tests where 3.5 g of lime was added showed the highest grades followed by the tests done with no lime and then the tests done with 2.5 g lime.

- This difference in grade was best reflected in the 'Lab' colour space.

- Using white patch normalisation dramatically increased the correlation between froth colour and concentrate grade with 'L' showing a very high correlation with copper grade. The correlation between 'a' and copper grade was also significant at the 99% confidence interval.

- Using grey patch normalisation improved the correlation between 'L' and copper grade further as it accounted for the tests when the white patch was saturated. However it decreased the correlation of the colour parameters 'a' and 'b' with copper grade.

- The increase in 'L' with copper grade could have been a result of increased solid loading in the froth which in turn caused more light to be reflected to the camera and resulted in higher 'L' values. However this was not measured.

- The relationship between 'a' and copper grade was attributed to the froth colour becoming more green (lower 'a') with higher concentrations of copper in the form of the brass-yellow mineral chalcopyrite although pyrite may have produced similar visual effects on the froth. The fact that there is a significant correlation between the colour parameter 'a' and copper grade infers that either the camera can distinguish between chalcopyrite and pyrite or the ratios of the two minerals do not change much, only their quantities in the froth relative to other minerals. However this could not be confirmed without detailed mineralogy.

## 5.2. BATCH TESTS DONE ON NORTH PARKES UNDERGROUND SULPHIDE ORE

### 5.2.1. Introduction

This experimental campaign was done in the laboratory at North Parkes Mine in Parkes, Australia. The ore used was their underground sulphide ore. This ore was made up of approximately 1.0% bornite with less than 0.2% chalcopyrite.

The purpose of this work was to investigate the relationship between froth colour and metallurgical grade for North Parkes underground sulphide ore using batch flotation tests. This was done by establishing stable froth conditions yielding significant metallurgical results and then changing collector dosage to affect grade. These results were then used to try correlate colour parameters to copper grade.

Calibration objects were used in this campaign and only the white patch was used for data calibration as the auto-iris was set on the calibration board consistently which ensured that the white patch was never saturated. Tap water was used instead of plant water for the sake of consistency as the plant water may vary significantly between days.

### 5.2.2. Results for individual tests

The results from each individual batch test were analysed and the relationship between froth colour and copper concentrate was evaluated in the colour spaces discussed in Section 2.2 of the literature review. The results from a single test are shown below:

Figure 5.23 below shows the trends of copper grade with time for an individual batch flotation test using North Parkes copper ore.

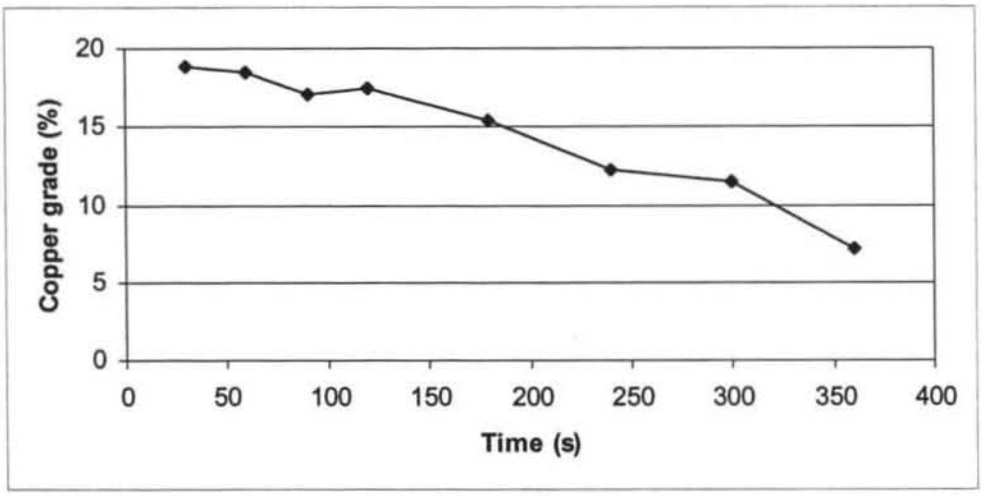

Figure 5.23. Graph of grade vs. time for an individual batch flotation test with 2,0 ml SIBX using North Parkes underground sulphide ore

It can be seen above that the grade curve does not follow the typical first order exponential decay as seen in Figure 5.1. This could possibly be due to the addition of NaHS to the cell and the interaction between NaHS and SIBX.

Table 5.7. Table of correlation coefficients for an individual batch flotation test done with 2,0 ml SIBX using North Parkes copper ore using white patch calibration

| Colour parameter | R-value | Colour parameter | R-value |
|---|---|---|---|
| **Red (R)** | 0.773 | **Normalized blue** | 0.087 |
| **Green (G)** | 0.793 | **L** | 0.778 |
| **Blue (B)** | 0.607 | **a** | -0.778 |
| **grey** | 0.742 | **b** | 0.908 |
| **Relative red** | -0.562 | **Hue** | 0.928 |
| **Relative green** | 0.941 | **Sat** | -0.272 |
| **Relative blue** | 0.087 | **Val** | 0.773 |
| **Normalized red** | -0.562 | **RGB angle** | 0.799 |
| **Normalized green** | 0.941 | **'Lab' angle** | -0.796 |
| **Pearson's R-crit value for 99% confidence interval (Table in Appendix D) for 8 sample data set** | | | **0.765** |

High correlation coefficients were observed for different colour parameters when looking at a single batch flotation test using this ore. The R-values for Relative green, Normalised green, 'b' and 'Hue' are well above the value indicated in the Pearson Table of Product Moment Coefficients for a significant relationship within a 99% confidence interval. This indicates that a strong relationship exists between froth colour and copper grade within a single batch test for the tests done on this ore. (Raw RGB data has been rejected on the basis that the colour space has no separation between colour and luminosity).

The following colour graphs were chosen for comparison with Figure 5.23 as they showed the highest correlation coefficients with copper grade. Relative green was not shown as the trends were the same as Normalised green shown below:

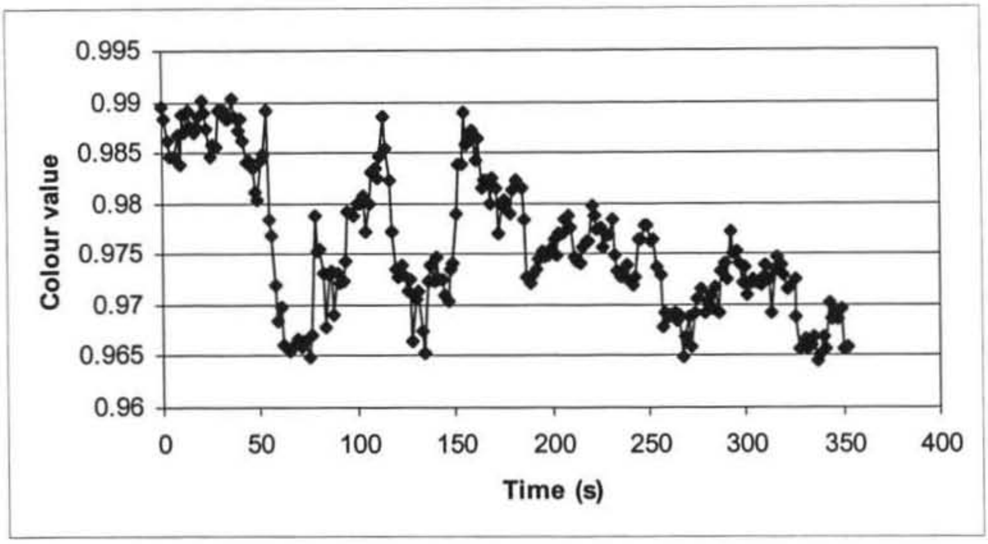

Figure 5.24. Graph of the unaveraged Normalised green vs. time for an individual batch flotation test

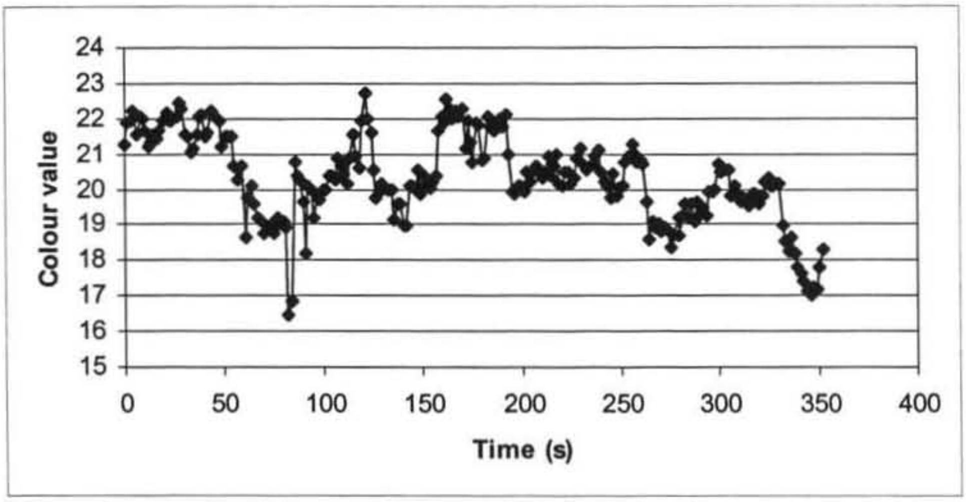

Figure 5.25. Graph of the unaveraged colour parameter 'b' vs. time for an individual batch flotation test

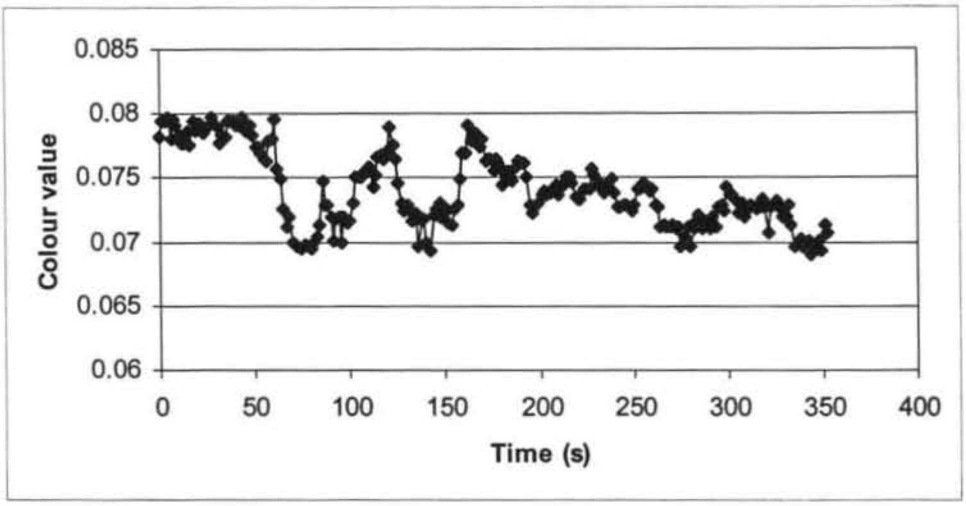

Figure 5.26. Graph of the unaveraged colour parameter 'Hue' vs. time for an individual batch flotation test

The trends of the colour parameters shown above resemble those of the copper grade trends shown in Figure 5.23. This shows that a significant relationship exists between different froth colour parameters and copper grade for an individual batch flotation test using North Parkes copper ore (see Table 5.7).

The overall relationship between froth colour and copper grade was then examined for all the tests performed under different reagent conditions:

### 5.2.3. Overall results for test performed under different reagent conditions

*Metallurgical results*

Tests were run at collector dosages of: 0.5 ml, 1 ml and 2 ml of SIBX with the intention of obtaining different grades to compare with froth colour under the different reagent conditions:

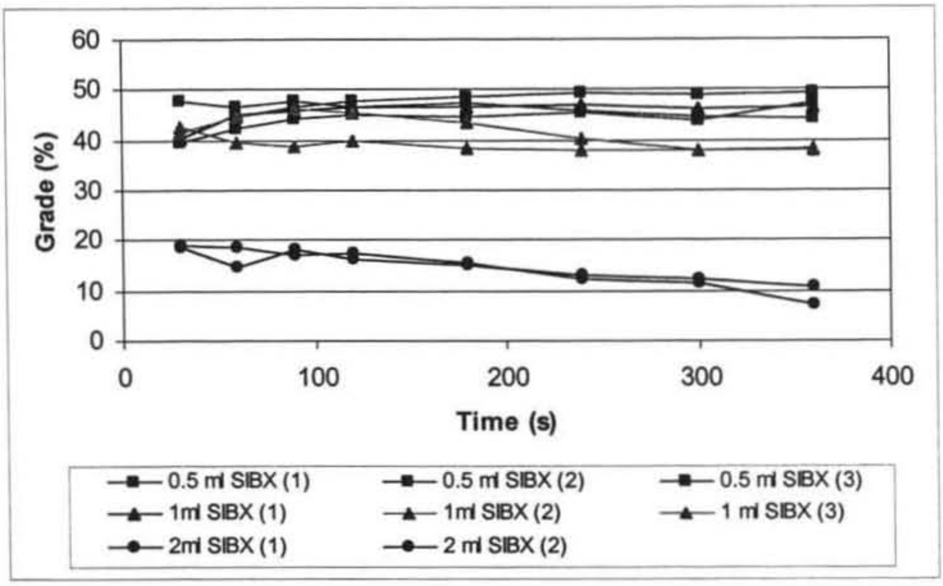

Figure 5.27. Graph of copper grade vs. time for tests conducted under different collector dosages

Figure 5.27. above shows that the grade results obtained for the tests done at 0.5 ml and 1 ml SIBX were similar but the results from the tests done at 2 ml SIBX were significantly different. Using 2 ml of SIBX had a detrimental effect on the stability of the froth, which had to be counteracted by increasing the air flowrate. It also resulted in a completely different froth colour (gold, rather than purple-blue) suggesting the presence of a different mineral such as chalcopyrite or pyrite. This agrees with the drop in measured grade but as iron assays were not done, this cannot be confirmed.

Table 5.8. Table of correlation coefficients between copper grade and colour values for tests done at different SIBX dosages for North Parkes copper ore using white patch calibration

| Colour parameter | R-value | Colour parameter | R-value |
|---|---|---|---|
| Red (R) | -0.889 | Normalized blue | 0.821 |
| Green (G) | -0.860 | L | -0.869 |
| Blue (B) | -0.709 | a | -0.870 |
| grey | -0.867 | b | -0.914 |
| Relative red | -0.356 | Hue | -0.598 |
| Relative green | 0.271 | Sat | -0.851 |
| Relative blue | 0.821 | Val | -0.897 |
| Normalized red | -0.356 | RGB angle | 0.579 |
| Normalized green | 0.271 | 'Lab' angle | -0.203 |
| Pearson's R-crit value for 99% confidence interval (Table in Appendix D) for 64 sample data set | | | 0.325 |

It can be seen above that the 'Lab' colour space again had the highest correlation coefficients overall for any colour space. It was chosen for further analysis of the colour-grade relationship for the batch tests done on North Parkes copper ore.

***Machine Vision Results (without calibration)***

After looking at the colour results in different colour spaces, the 'Lab' colour space was chosen as yielded the most meaningful results.

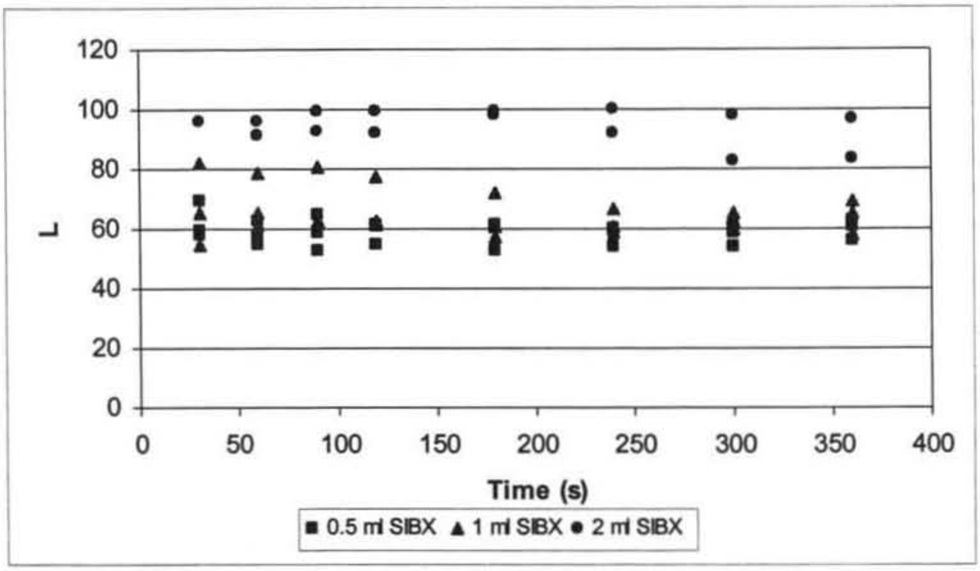

Figure 5.28. Graph of colour value 'L' vs. time

The values obtained for the luminosity component 'L' resemble the metallurgical results for copper grade in the way that the tests done at 0.5 ml and 1 ml SIBX overlap while the results for the tests done at 2 ml SIBX are separate.

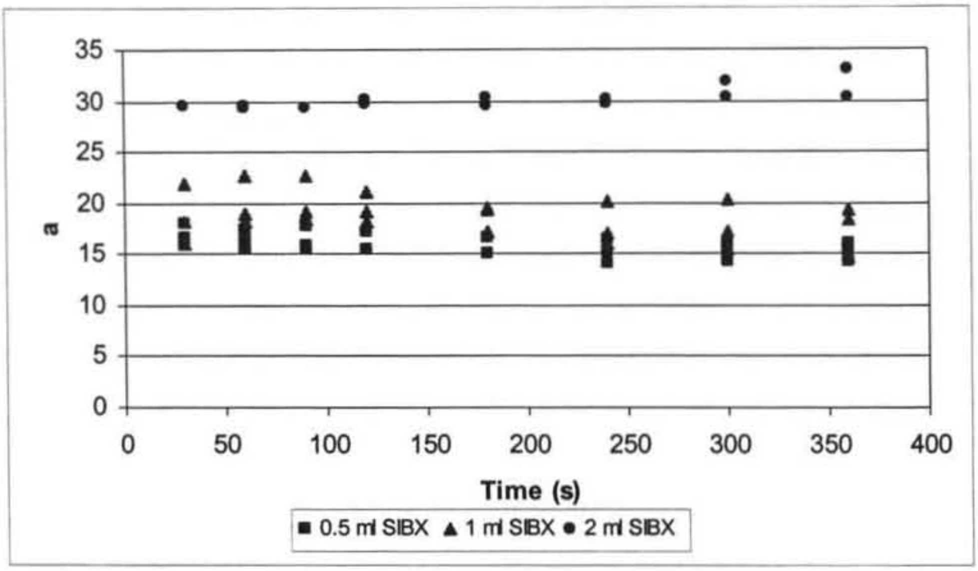

Figure 5.29. Graph of colour value 'a' vs. time

As can be seen above the colour values for 'a' show similar results for the tests run at 0.5 ml and 1 ml SIBX. The results for the tests run at 2 ml SIBX differ considerably. It must be noted that these trends resemble the trends in metallurgical copper grade shown above in Figure 5.27.

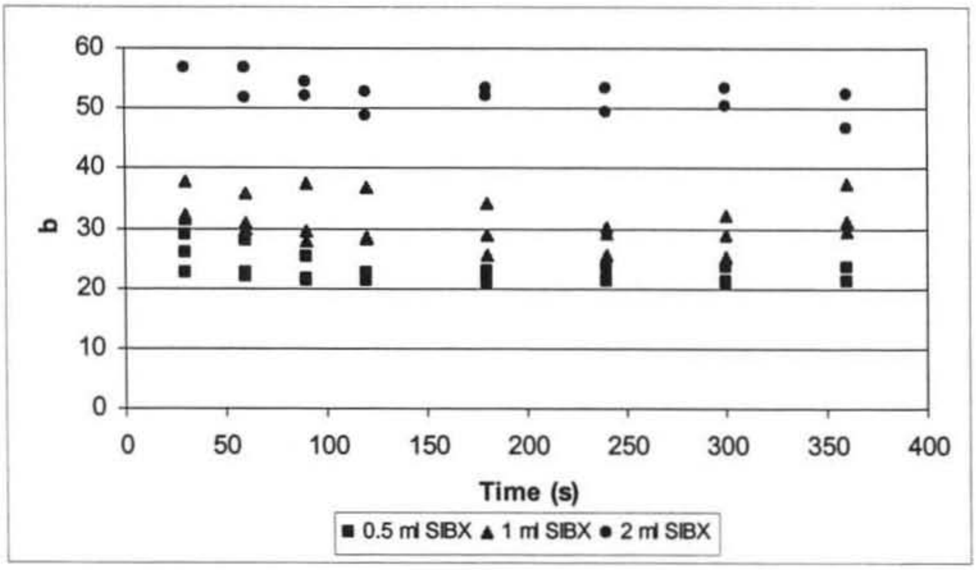

Figure 5.30. Graph of colour value 'b' vs. time

The values for the colour parameter 'b' again show the same grouping as the metallurgical copper grade results.

From this the relationship between the colour parameters and copper concentrate grade was evaluated:

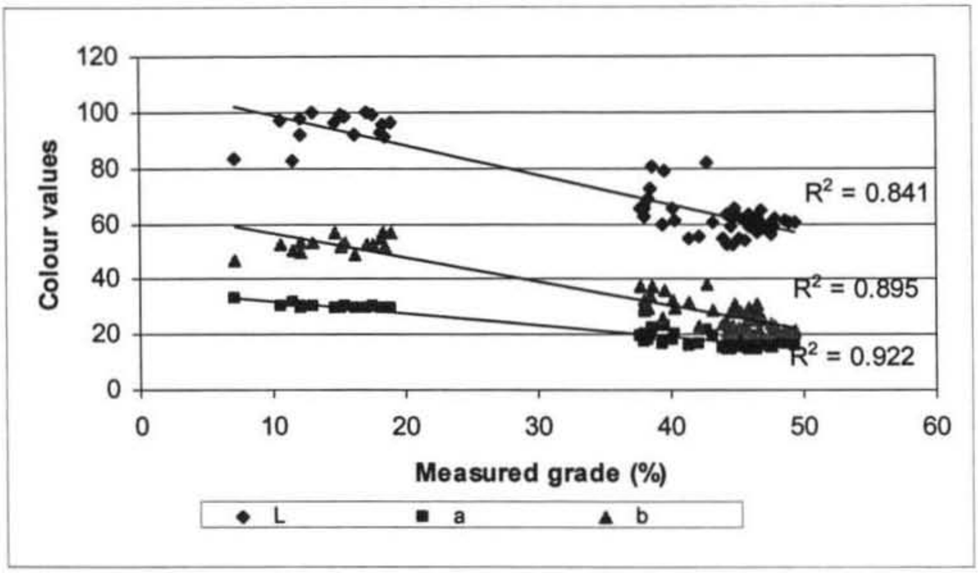

Figure 5.31. Graph of 'a' and 'b' vs. copper grade

Table 5.9. Table of correlation coefficients between copper grade and colour values without using calibration

| 64 sample data set | L | a | b |
|---|---|---|---|
| $R^2$ | 0.841 | 0.922 | 0.895 |
| R | 0.917 | 0.960 | 0.946 |
| **Pearson's R-crit value (99% confidence interval)** (Table in Appendix D) | 0.325 | 0.325 | 0.325 |

The correlation coefficient for the relationship between the colour parameters 'a' and 'b' and copper grade were noted to be very high. The value for the correlation coefficient for the relationship between the luminosity component 'L' and copper grade was also found to be highly significant at the 99% confidence interval.

The relationship between 'a' and 'b' and copper grade can be attributed to the dramatic change in froth colour from a blue-purple (low 'b', low 'a') colour for the tests done at 0.5 ml and 1 ml SIBX when bornite was the predominant copper mineral to the gold-yellow (high 'b' high 'a') colour of the froth for the tests done at 2 ml

SIBX when chalcopyrite was presumably the predominant copper mineral (see Figure 2.3).

The relationship between the luminosity component 'L' and copper grade was due to the much darker blue-purple froth in the 0.5 ml and 1 ml SIBX tests as opposed to the brighter gold-yellow froth seen in the tests done at 2 ml SIBX.

From this data a correlation model was constructed using a linear least squares regression whereby grade was predicted using the colour parameters: 'L', 'a' and 'b'.

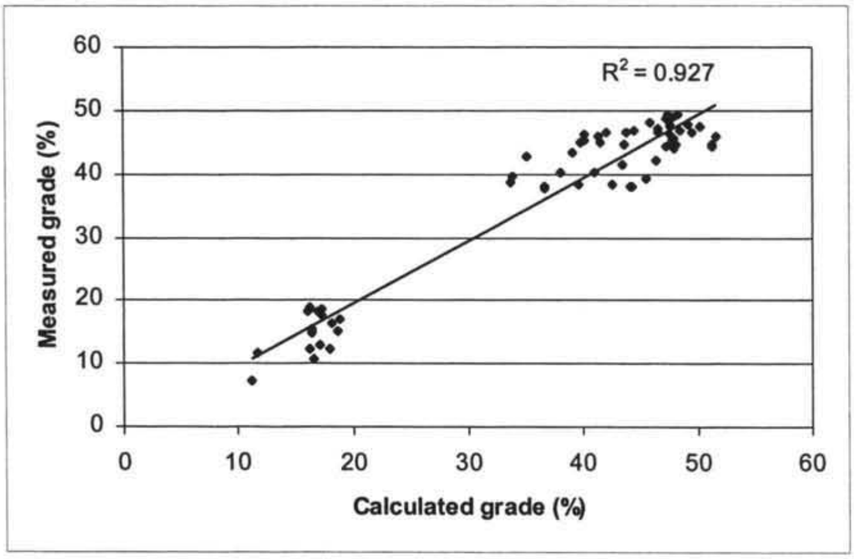

Figure 5.32. Graph of measured grade vs. calculated grade from colour values

The following model was used to calculated copper grade from the colour parameters 'L', 'a' and 'b':

$$Calculated\ grade = 0.00184 \times L_N - 0.01843 \times a_N - 0.00391 \times b_N + 0.75149$$

The $R^2$-value for the correlation between froth colour and copper grade is high as shown in Figure 5.32. above. It is noted that including 'L' and 'b' into the model did not result in a noticeable improvement in the $R^2$-value of the correlation. The colour parameter ‘a’ describes 92.2% of the variation in the metallurgical grade data without the use of the other 2 colour parameters.

The reason for the high correlation coefficient even though there is spread in the data is that the data varies over a large range of grades. Therefore over this range of grades this model can be used to reproduce copper grades from froth colour data using the parameters ‘L’, ‘a’ and ‘b’.

*Machine Vision Results (calibrated with white patch)*

The colour results were calibrated using the white patch on the large calibration board as the small calibration board was observed to be contaminated during the tests done due to froth spitting.

The following colour results were then obtained:

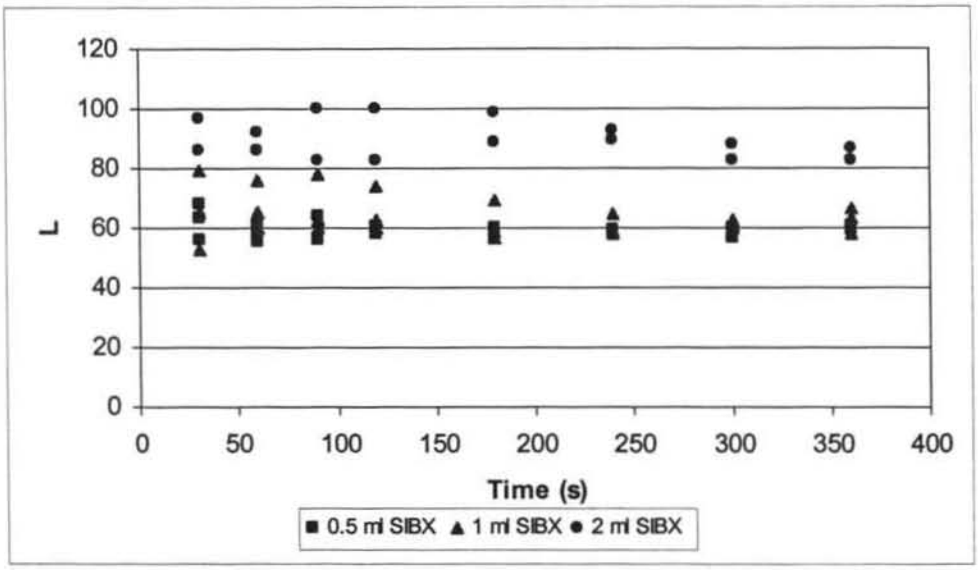

Figure 5.33. Graph of colour value 'L' vs. time

The values obtained for 'L' are similar to those without calibration. The values resemble the trends seen in the copper grade results shown in Figure 5.27.

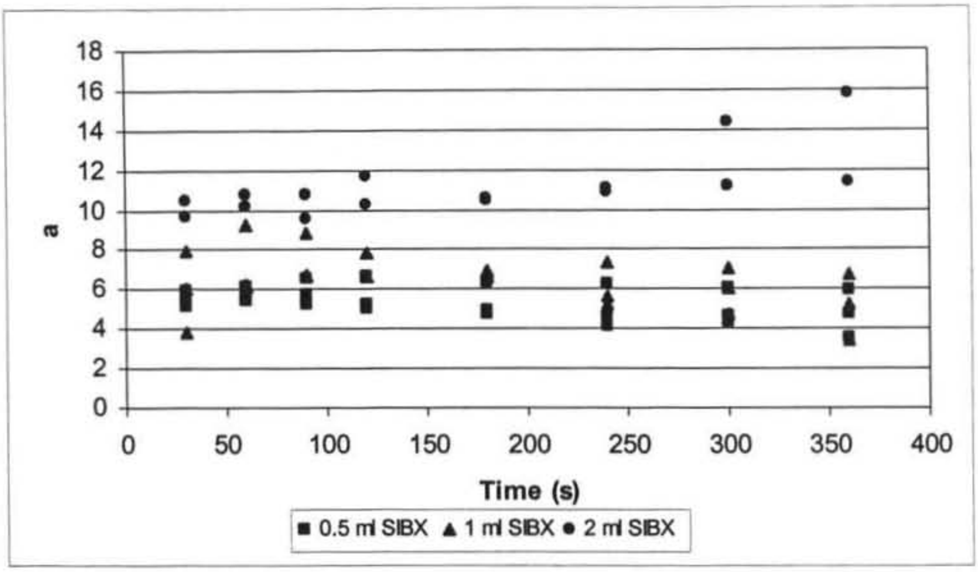

Figure 5.34. Graph of colour value 'a' vs. time

The values obtained for the colour parameter 'a' are similar to those obtained without the calibration objects except for the increase in the deviation seen in the graph above for the 2 ml SIBX data at 300 and 360 seconds. The results for the tests done at 2 ml SIBX also lie closer to the results of the tests done at 0.5 and 1 ml SIBX than for the results without calibration.

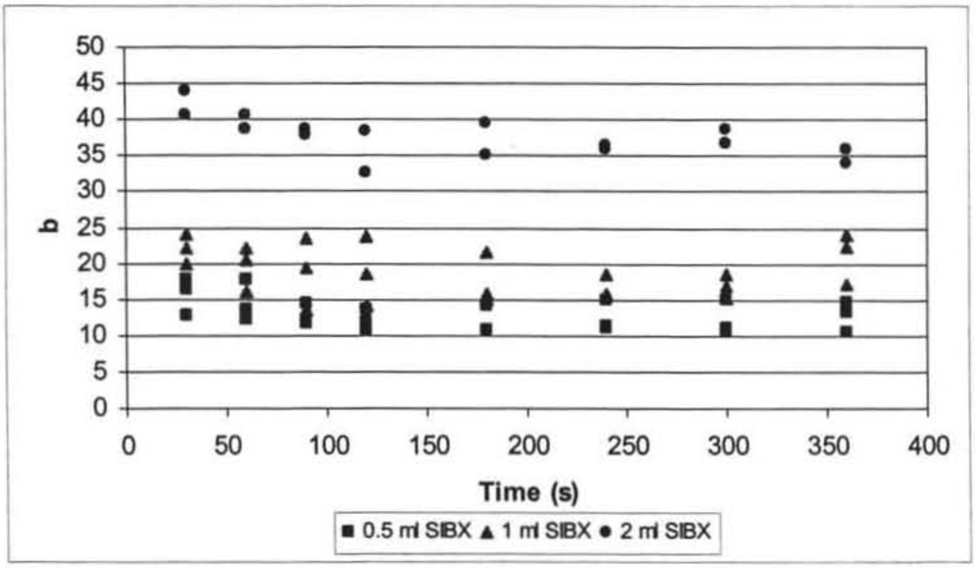

Figure 5.35. Graph of colour value 'b' vs. time

The values for the colour parameter 'b' again show the same grouping as the metallurgical copper grade results.

From this the relationship between the colour parameters and copper concentrate grade was evaluated:

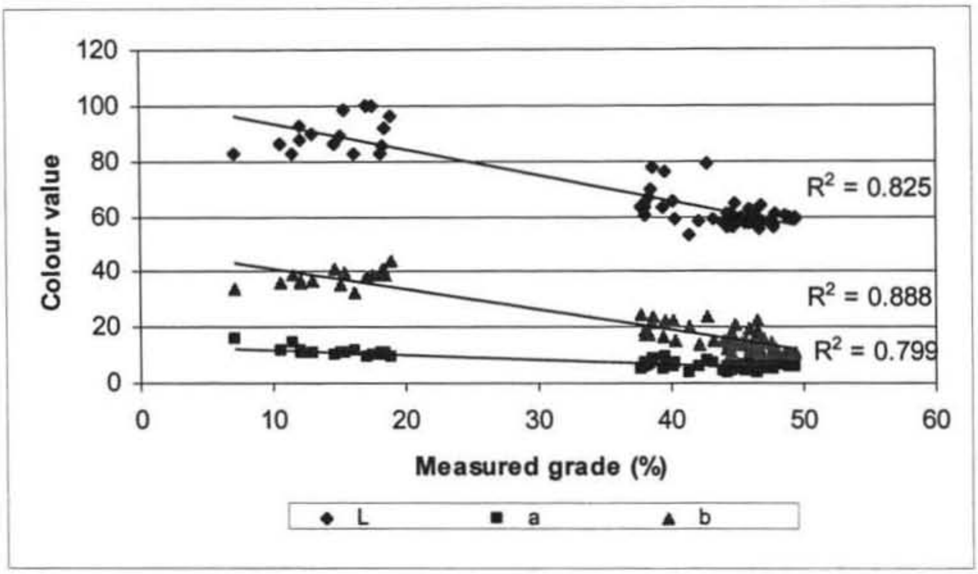

Figure 5.36. Graph of 'a' and 'b' vs. copper grade

Table 5.10. Table of correlation coefficients between copper grade and colour values using calibration

| **64 sample data set** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.825 | 0.799 | 0.888 |
| **R** | 0.908 | 0.894 | 0.942 |
| **Pearson's R-crit value (99% confidence interval)** (Table in Appendix D) | 0.325 | 0.325 | 0.325 |

Significant relationships were observed at the 99% confidence interval between the parameters: 'L', 'a' and 'b' and copper grade after using a calibration object to correct for light changes.

From this data a correlation was constructed using a linear least squares regression model whereby grade was predicted using the parameters: 'L', 'a' and 'b':

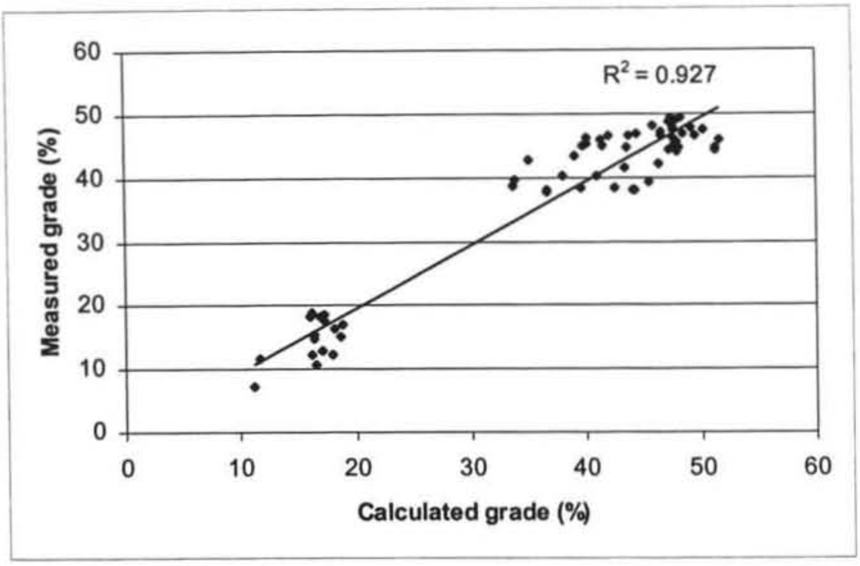

Figure 5.37. Graph of measured grade vs. calculated grade from colour values

The following model was used to calculated copper grade from the colour parameters 'L', 'a' and 'b':

$$Calculated\ \ grade = 0.00079 \times L_N - 0.01877 \times a_N + 0.00908 \times b_N + 0.64781$$

There was a significant increase in the $R^2$-value by including more than 1 of the colour parameters in the model. The colour parameter 'b' accounted for 90% of the variation in copper grade but by including 'L' and 'a' into the model 92.7% of the data could be reproduced.

## ***Summary of results for batch tests done on North Parkes underground sulphide ore***

Table 5.11. Summary of results for batch tests done on North Parkes underground sulphide ore

| | **64 sample data set** | **L** | **a** | **b** | **Model** |
|---|---|---|---|---|---|
| **Without calibration** | **$R^2$** | 0.841 | 0.922 | 0.895 | 0.927 |
| | **R** | 0.917 | 0.96 | 0.946 | 0.963 |
| | **Pearson's R-crit value**<br>**(99% confidence interval)**<br>(Table in Appendix D) | 0.325 | 0.325 | 0.325 | 0.325 |
| **With calibration** | **$R^2$** | 0.825 | 0.799 | 0.888 | 0.927 |
| | **R** | 0.908 | 0.894 | 0.942 | 0.963 |
| | **Pearson's R-crit value**<br>**(99% confidence interval)**<br>(Table in Appendix D) | 0.325 | 0.325 | 0.325 | 0.325 |

The correlation coefficients for the relationship between the parameters 'L', 'a' and 'b' and copper grade were found to be similar with and without the use of calibration except for the noticeable decrease in the correlation coefficient for 'a' when using calibration.

The fact that only small changes in the correlation coefficients were seen when the tests were calibrated for light shows that the lighting conditions were mostly constant in this experimental campaign. This was due to the auto-iris being set on the calibration object consistently before the tests began and also due to the controlled light conditions of the testing environment.

The $R^2$-value obtained from the multi-variable linear least squares regression was the same for both data sets even though the correlation coefficient between 'a' and copper grade decreased when the calibration was done.

### 5.2.4. Conclusions for the batch flotation tests done on North Parkes underground sulphide ore

- There was a significant correlation between froth colour parameters and copper grade for individual batch flotation tests.

- The grade results obtained for the tests done at 0.5 ml and 1 ml SIBX were similar but the results from the tests done at 2 ml SIBX were significantly increased.

- This metallurgical difference was best reflected in the parameters 'L', 'a' and 'b' describing the froth surface.

- The relationship between 'a' and 'b' and copper grade could be attributed to the dramatic change in froth colour from a blue-purple (low 'b', low 'a') colour for the tests done at 0.5 ml and 1 ml SIBX when bornite was the predominant copper mineral to the gold-yellow (high 'b' high 'a') colour of the froth for the tests done at 2 ml SIBX when the chalcopyrite is presumably the predominant copper mineral.

- The relationship between 'L' and copper grade was explained by the much darker blue-purple froth in the 0.5 ml and 1 ml SIBX tests as opposed to the brighter gold-yellow froth seen in the tests done at 2 ml SIBX.

- Using calibration objects in this campaign did not have much effect on the colour results as the lighting conditions were well controlled throughout the testing campaign.

## 5.3. CONCLUSIONS FOR BATCH TESTS

- The batch flotation tests done on both Kennecott and North Parkes ore revealed that the 'Lab' colour space yielded the highest overall correlations with copper grade. The 'Lab' colour space has already been proved to be suitable for colour analysis in the textile industry due to its entirely separate luminosity and colour components. Therefore it was decided that the 'Lab' colour space was suitable for the analysis of flotation froths, and would be used to develop the relationships between froth colour and metallurgical parameters on plant.

- Significant relationship were developed for both Kennecott and North Parkes copper ores. The Kennecott campaign only yielded significant correlations after a calibration was done, while the North Parkes campaign yielded significant relationships between froth colour and copper grade both with and with the use of calibration. This was due to the more consistent lighting conditions and consistent setting of the autoiris on the calibration board during the North Parkes campaign.

# CHAPTER 6 THE RELATIONSHIP BETWEEN FROTH COLOUR AND METALLURGY IN INDUSTRIAL FLOTATION CELLS

## 6.1. INTRODUCTION

The relationship between froth colour and copper grade has been tested and evaluated in the laboratory environment. The 'Lab' colour space was shown to be the most suitable for this analysis as its components are luminosity independent and it gave high correlations between the colour parameters and copper grade.

This warranted the launch of a plant testing campaign where this relationship could be tested on industrial sized flotation cells and evaluated with the possibility of reagent addition control in mind.

This campaign was run during a reagent testing period at Kennecott Copperton Concentrator. New collectors were being trialed, which in turn produced grade changes in the concentrate. Portable digital video cameras were setup on two different flotation cells to monitor the colour changes during the reagent trialing.

The relationship between froth colour and copper grade as well as % solids were tested on two different flotation cells. Both top of froth and concentrate samples were taken initially to determine the most suitable sample to use to develop the relationship.

As with the batch tests performed the reproducibility of metallurgical parameters was not required to do accurate correlations with colour parameters, rather a wide range of metallurgy was required to increase the range of the colour-grade relationship. The reliability of the colour parameters was again improved by using calibration objects.

## 6.2. RELATIONSHIP BETWEEN TOP OF FROTH AND CONCENTRATE GRADES

Initially both top of froth and concentrate samples were taken from both cells being tested. This was done in order to determine which sample would be better for grade-colour correlations if there was a significant difference between the results.

There was concern that if the top of froth grade remained constant while the concentrate grade changed then the camera would not be able to pick up changes in colour, as it could only detect the surface of the froth.

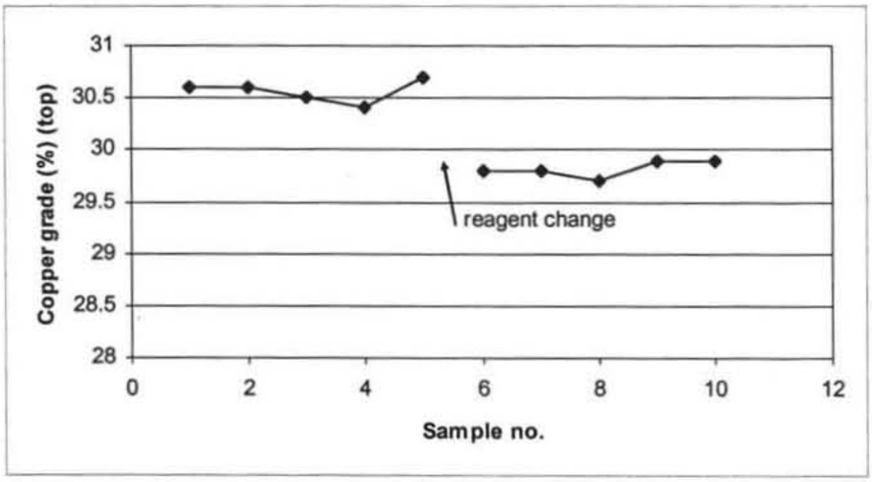

Figure 6.1. The effect of reagent changes on top of froth grade for cell 2, reagent test 2

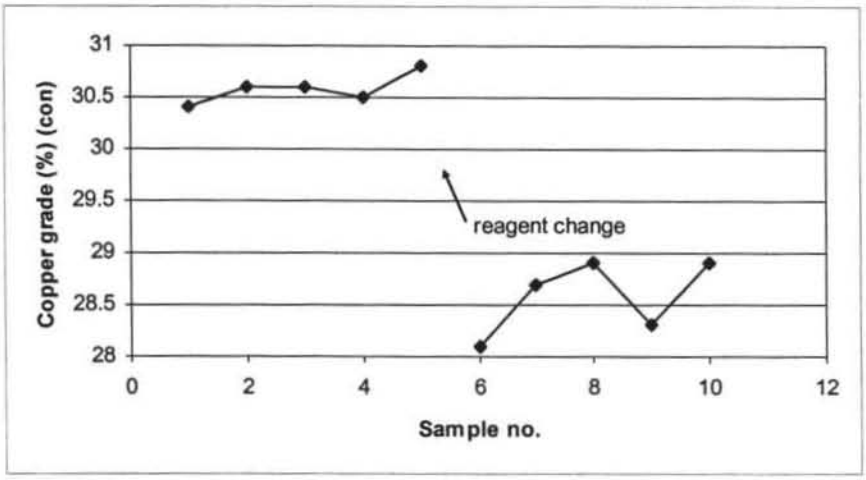

Figure 6.2. The effect of reagent changes on concentrate grade for cell 2, reagent test 2

It can be seen above that there was a step change in both the top of froth grade and the concentrate grade although the change in concentrate grade was greater than the change in top of froth grade (as expected). It can also be noted that there was no significant difference between the top of froth grade and concentrate grade before the step change (normal operation conditions) but there was a difference between them after the change was made.

These results suggest that for the first reagent regime there was little variation of grade within the froth with a low mass pull and high grade. After the reagent change was made the froth seemed to be flowing faster (higher mass pull) and therefore it was less selective (lower grade), but there was an increased difference between top of froth and concentrate grade. As no mass pull measurements were taken more information would be needed to verify this observation and explain the reason behind it.

Significant correlations with colour parameters were seen to exist between both top of froth and concentrate grades for each individual test. Due to this and the similarity between these grades it was decided to continue taking only concentrate samples and to focus the colour–grade correlations on concentrate grade rather than top of froth grade. This was also done because concentrate grade was the variable for which a sensor would be most valuable on plant.

## 6.3. RELATIONSHIP BETWEEN COLOUR PARAMETERS AND CONCENTRATE GRADE

The following results were obtained from the reagent tests done on row 4, cell 2 and cell 4 at Kennecott Copperton Concentrator. As 5 samples were taken from the cells in a relatively short period of time before the reagent change was made and the same was done once the plant had stabilised after the reagent change, it was assumed that the grades and % solids were constant during this sampling interval so average values were used. The "noise" in the data was assumed to be assay error or sampling deviance. The previous section shows that the grades do not usually vary much over this period but for the purpose of data analysis the mean was used.

The results were examined both with and without the use of calibration objects to determine their effect.

Due to the success of using the 'Lab' colour space in the batch flotation tests performed using both Kennecott and North Parkes copper ores, it was decided to develop relationships between froth colour and concentrate grade and % solids in the 'Lab' colour space.

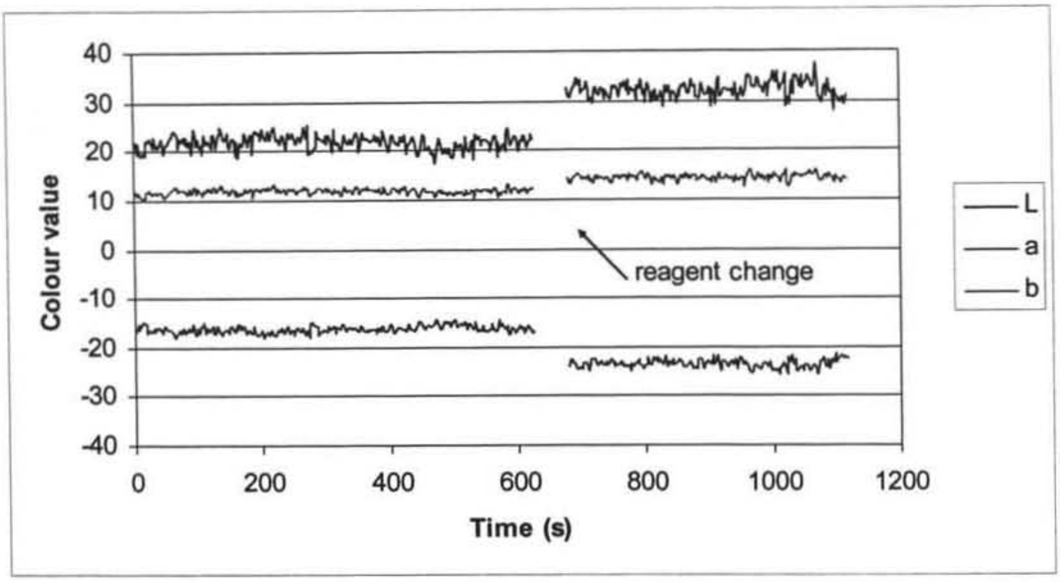

Figure 6.3. Graph of colour parameters 'L', 'a' and 'b' for a reagent test on cell 4

It can be seen above that the mean colour values for 'L', 'a' and 'b' were near constant before and after the reagent change. Therefore the colour values were also averaged over each sampling interval, so as to be directly comparable to the copper grade.

After this averaging was done the following results were seen for the uncalibrated results:

### 6.3.1. Uncalibrated results

*Cell 2*

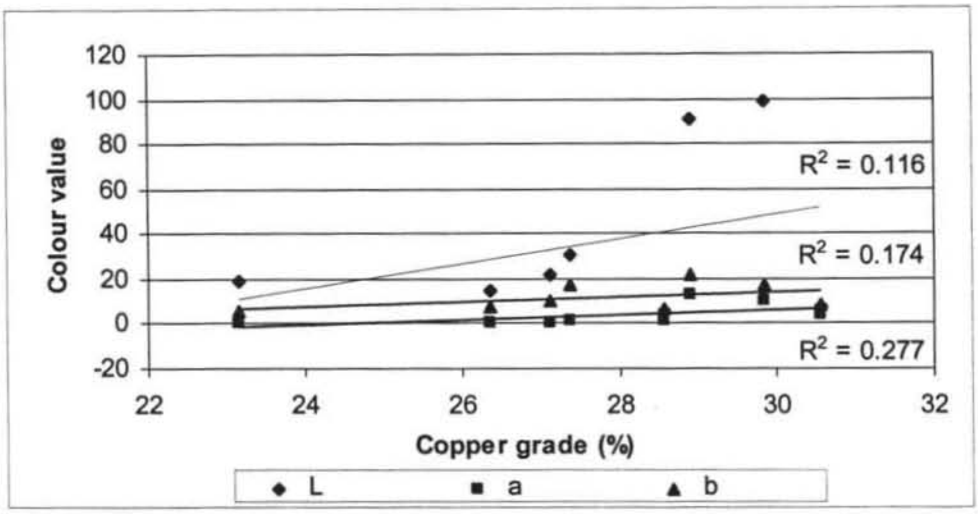

Figure 6.4. Graph of average colour parameters 'L', 'a' and 'b' vs. average copper grade for reagent tests on cell 2 (without calibration)

Table 6.1. Table of Correlation coefficients for froth colour to copper grade relationship on cell 2 (without calibration)

| **Cell 2 data set ( 8 samples)** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.116 | 0.277 | 0.174 |
| **R** | 0.341 | 0.526 | 0.417 |
| **$R_{crit}$ (99% confidence)** | 0.765 | 0.765 | 0.765 |

It can be seen in Table 6.1 above that no significant relationships exist between any of the 'Lab' colour parameters and copper grade for cell 2 at a 99% confidence interval without calibration.

The relationship between % solids and froth colour was also examined for cell 2:

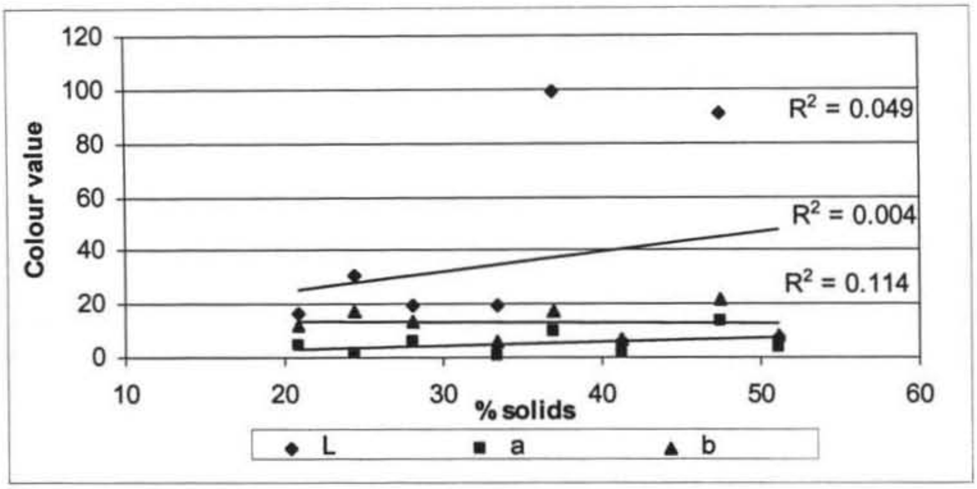

Figure 6.5. Graph of average colour parameters 'L', 'a' and 'b' vs. % solids for reagent tests on cell 2 (without calibration)

Table 6.2. Table of Correlation coefficients for froth colour to % solids relationship on cell 2 (without calibration)

| Cell 2 data set ( 8 samples) | L | a | b |
|---|---|---|---|
| $R^2$ | 0.049 | 0.114 | 0.004 |
| R | 0.221 | 0.338 | 0.063 |
| $R_{crit}$ (99% confidence) | 0.765 | 0.765 | 0.765 |

It can be seen above that no significant relationships exist between any of the 'Lab' colour parameters and % solids at a 99% confidence interval for cell 2 without calibration.

*Cell 4*

The following results were observed for cell 4:

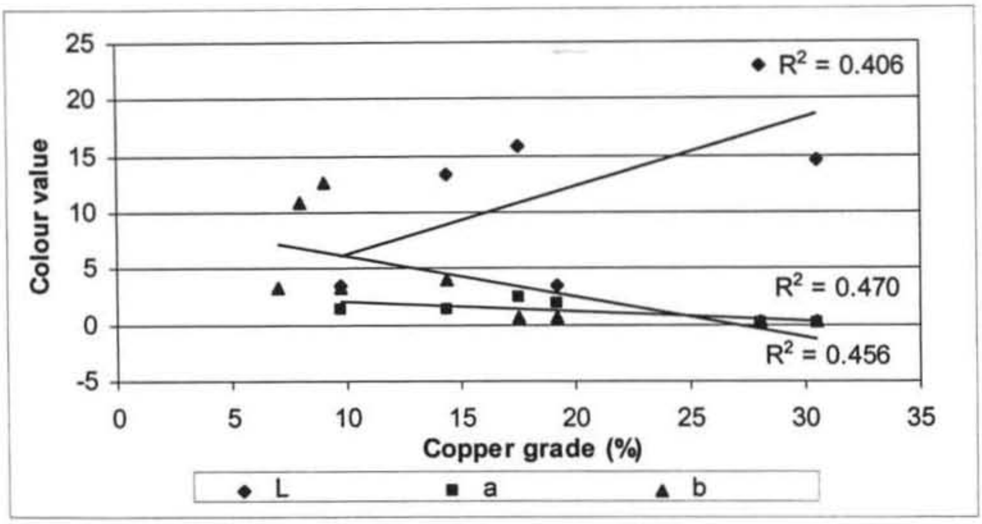

Figure 6.6. Graph of average colour parameters 'L', 'a' and 'b' vs. average copper grade for reagent tests on cell 4 (without calibration)

Table 6.3. Table of Correlation coefficients for froth colour to copper grade relationship on cell 4 (without calibration)

| **Cell 4 data set ( 6 samples)** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.406 | 0.470 | 0.456 |
| **R** | 0.637 | 0.685 | 0.675 |
| **$R_{crit}$ (99% confidence)** | 0.834 | 0.834 | 0.834 |

It can be seen from Table 6.3 that no significant relationship exists at a 99% confidence interval between the 'Lab' colour parameters and copper grade for cell 4 without calibration.

The relationship between froth colour and % solids was also examined for cell 4:

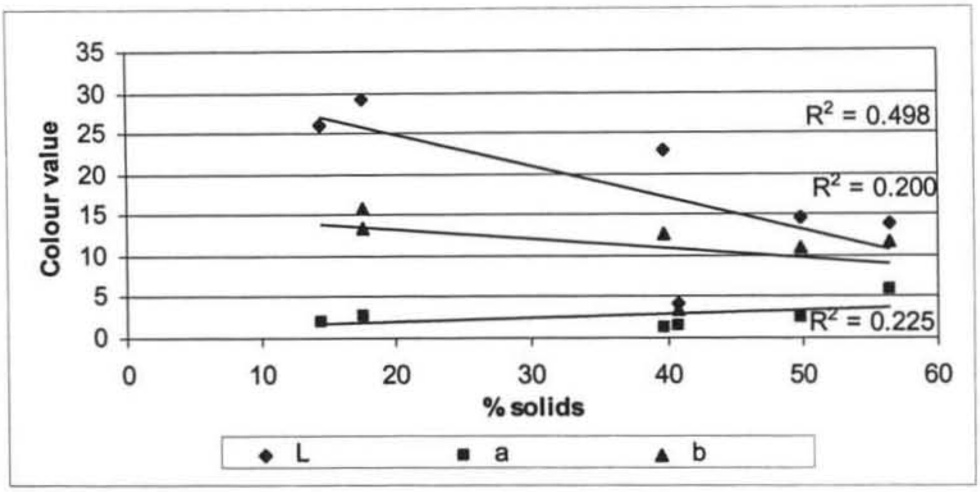

Figure 6.7. Graph of average colour parameters 'L', 'a' and 'b' vs. % solids for reagent tests on cell 4 (without calibration)

Table 6.4. Table of Correlation coefficients for froth colour to % solids relationship on cell 4 (without calibration)

| **Cell 4 data set ( 6 samples)** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.498 | 0.225 | 0.200 |
| **R** | 0.706 | 0.475 | 0.448 |
| **$R_{crit}$ (99% confidence)** | 0.834 | 0.834 | 0.834 |

Once again no significant relationship could be found between froth colour and % solids at a 99% confidence interval for cell 4 without calibration.

The results were then evaluated after calibration was done using white patch normalisation:

### 6.3.2. Calibrated results using white patch normalisation

*Cell 2*

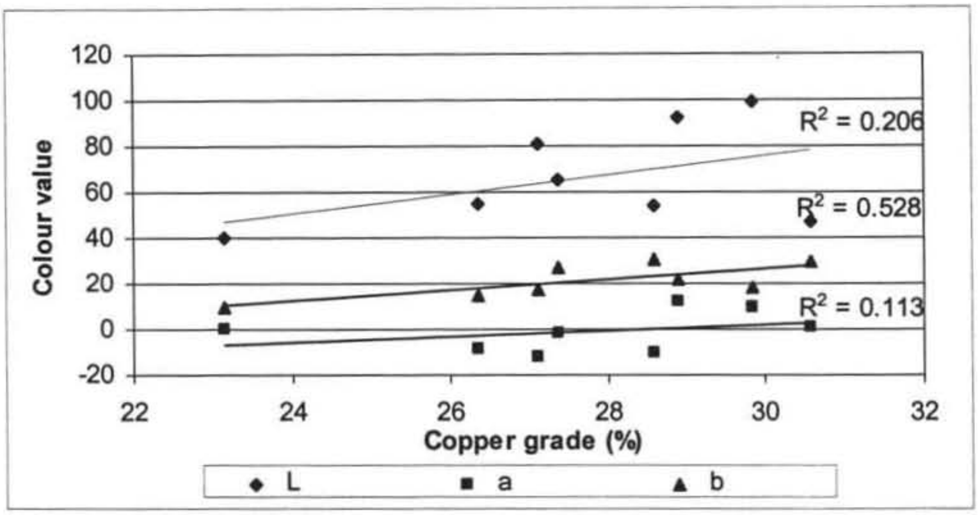

Figure 6.8. Graph of average colour parameters 'L', 'a' and 'b' vs. average copper grade for reagent tests on cell 2 (with calibration)

Table 6.5. Table of Correlation coefficients for froth colour to copper grade relationship on cell 2 (with calibration)

| **Cell 2 data set ( 8 samples)** | **L** | **a** | **b** |
|---|---|---|---|
| $\mathbf{R^2}$ | 0.206 | 0.113 | 0.528 |
| **R** | 0.454 | 0.337 | 0.727 |
| $\mathbf{R_{crit}}$ **(99% confidence)** | 0.765 | 0.765 | 0.765 |
| $\mathbf{R_{crit}}$ **(95% confidence)** | 0.632 | 0.632 | 0.632 |

It can be seen in Table 6.5 above that although no significant relationships exist between any of the 'Lab' colour parameters and copper grade for cell 2 at a 99% confidence interval, there was a significant relationship between the colour parameter 'b' and copper grade in cell 2 at the 95% confidence interval after calibration.

The increase in the colour parameter 'b' (more yellow) with copper grade could be explained by the presence of chalcopyrite in the froth. As this mineral has a yellow-brass colour an increase in the concentration of chalcopyrite in the froth would result in an increase of the colour parameter 'b'.

The relationship between % solids and froth colour was also examined for cell 2:

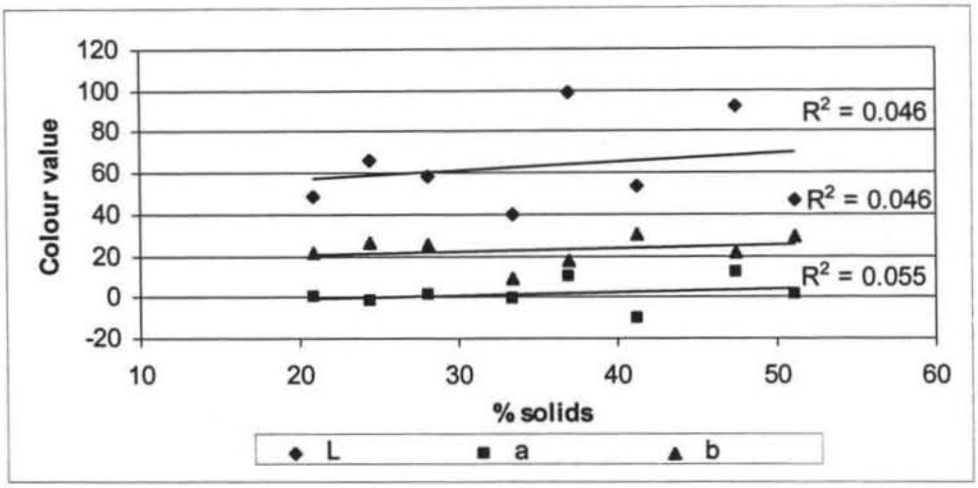

Figure 6.9. Graph of average colour parameters 'L', 'a' and 'b' vs. % solids for reagent tests on cell 2 (using calibration)

Table 6.6. Table of Correlation coefficients for froth colour to % solids relationship on cell 2 (using calibration)

| **Cell 2 data set ( 8 samples)** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.046 | 0.055 | 0.046 |
| **R** | 0.215 | 0.235 | 0.214 |
| **$R_{crit}$ (99% confidence)** | 0.765 | 0.765 | 0.765 |

It can be seen above that no significant relationships exist between any of the 'Lab' colour parameters and % solids at a 99% confidence interval for cell 2 using white patch normalisation.

*Cell 4*

The following results were observed for cell 4:

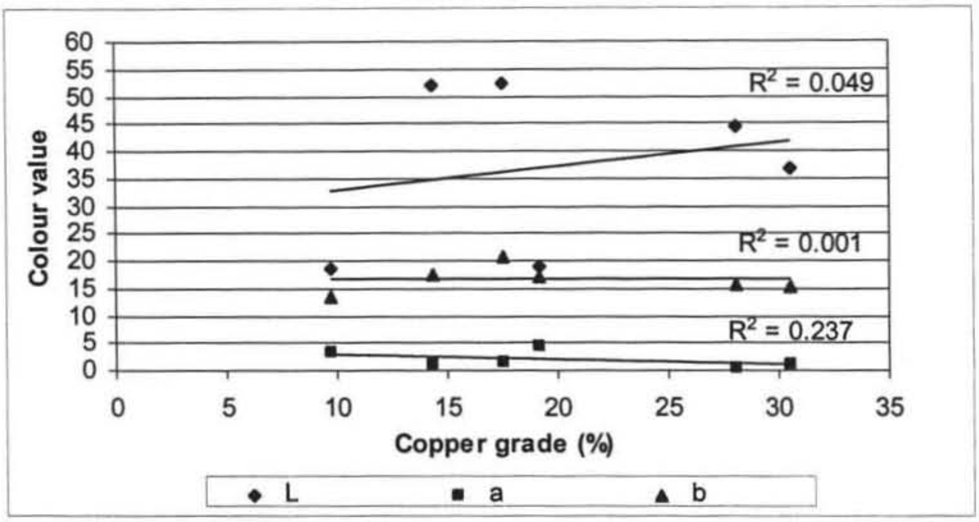

Figure 6.10. Graph of average colour parameters 'L', 'a' and 'b' vs. average copper grade for reagent tests on cell 4 (using calibration)

Table 6.7. Table of Correlation coefficients for froth colour to copper grade relationship on cell 4 (using calibration)

| **Cell 4 data set ( 6 samples)** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.049 | 0.237 | 0.001 |
| **R** | 0.221 | 0.487 | 0.032 |
| **$R_{crit}$ (99% confidence)** | 0.834 | 0.834 | 0.834 |

It can be seen from Table 6.7 that no significant relationship exists at a 99% confidence interval between the 'Lab' colour parameters and copper grade for cell 4 using white patch normalisation.

The relationship between froth colour and % solids was also examined for cell 4:

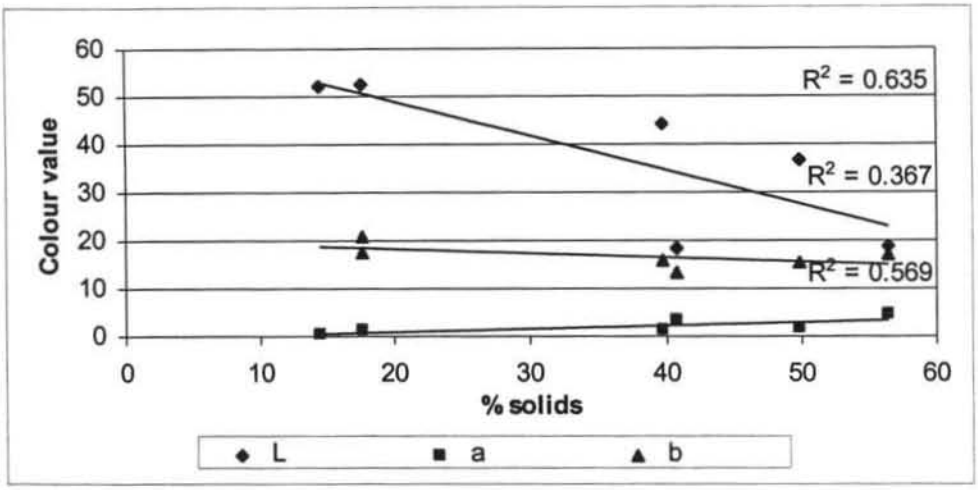

Figure 6.11. Graph of average colour parameters 'L', 'a' and 'b' vs. % solids for reagent tests on cell 4 (using calibration)

Table 6.8. Table of Correlation coefficients for froth colour to % solids relationship on cell 4 (using calibration)

| **Cell 4 data set ( 6 samples)** | **L** | **a** | **b** |
|---|---|---|---|
| **$R^2$** | 0.635 | 0.569 | 0.367 |
| **R** | 0.797 | 0.754 | 0.606 |
| **$R_{crit}$ (99% confidence)** | 0.834 | 0.834 | 0.834 |
| **$R_{crit}$ (95% confidence)** | 0.707 | 0.707 | 0.707 |

Once again no significant relationship could be observed between froth colour and % solids at a 99% confidence interval for cell 4 using white patch normalisation. However a significant relationship was seen to exist between the colour parameters 'L' and 'a' with % solids in cell 4 at a 95% confidence interval when using white patch normalisation.

The froth in cell 4 was grey unlike the gold-yellow froth in cell 2. As solids loading increased in cell 4 the froth became a darker grey. This could explain the relationship between % solids and 'L' as the value of 'L' decreases (becomes darker) as % solids increases.

The relationship between the colour parameter 'a' and % solids can not be properly explained without detailed mineralogy.

A possible reason for a relationship existing between froth colour and copper grade in cell 2 and not cell 4 is due to the rich gold-yellow colour of the froth in cell 2 and the grey froth in cell 4. This could be caused by the different mineralogy in the cells.

This is also a possible reason for a relationship existing between froth colour or luminosity and % solids in cell 4 and not cell 2.

An estimate of the mineralogy was done to determine whether there was in fact a difference in mineralogy in the two cells which caused the difference in froth colour:

*Estimation of mineralogy*

An estimation of the mineralogy was done by assuming that all of the copper from the assays was from chalcopyrite, all the molybdenum was from molybdenite and the pyrite was calculated from a sulphur mass balance from the sulphur assays. From this the following graph was generated:

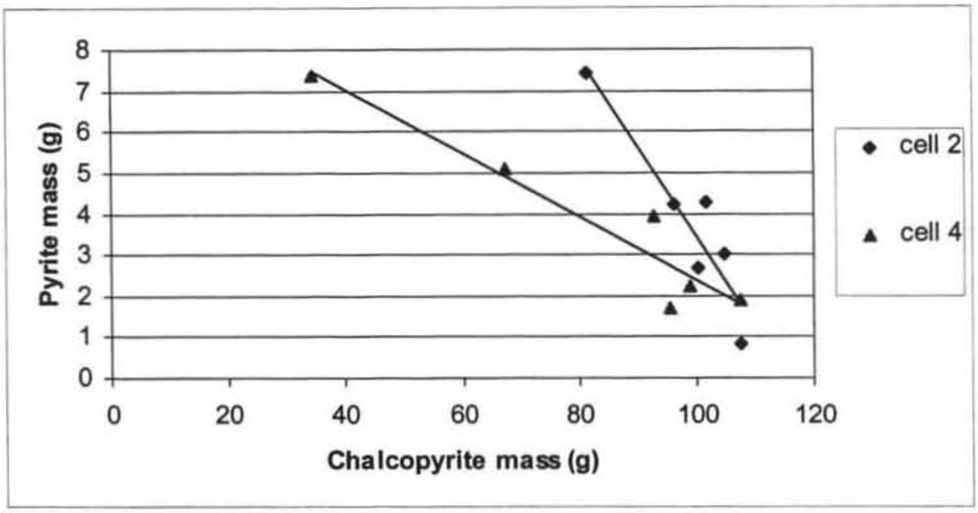

Figure 6.12. Graph of estimated chalcopyrite mass vs. pyrite mass in each sample for a reagent test done on cell 2 and cell 4

It can be seen in Figure 6.12 above that the two flotation cells have distinctly different chalcopyrite to pyrite ratios represented by the different slopes above. This estimation does not take any account of the gangue present in the froth although this would be expected to have a major effect on the colour of the froth. This difference in mineralogy is presumed to be the reason for the different relationships existing between the 'Lab' colour parameters and copper grade and % solids in the 2 flotation cells. However this should be confirmed with a detailed mineralogical analysis.

## 6.4. CONCLUSIONS FOR PLANT TRIAL

- No significant difference was observed between the top of froth grade and the concentrate grade at normal operating conditions. However differences were found after new reagents were added. The top of froth grade showed less variation than the concentrate grade although significant changes were observed in both at the new reagent condition.

- No significant relationships were seen to exist between the 'Lab' colour parameters and copper concentrate grade or % solids in either flotation cell when no calibration was used.

- Significant relationships were observed between the colour parameter 'b' and copper grade in cell 2 after a white patch normalisation was done. This relationship was attributed to the increased concentration of the yellow-brass colour of the mineral chalcopyrite.

- A significant relationship was also found to exist between the colour parameters 'L' and a' and % solids in cell 4 after a white patch normalisation was done. This relationship was attributed to the froth becoming a darker grey as solids loading increased in this cell.

- An estimation of the mineralogy revealed a distinct difference between the two cells. It is presumed that the difference in mineralogy is the reason for the different relationships existing between froth colour and copper grade and % solids in the two cells.

The following concluding remarks were drawn from the work done in this dissertation:

### 7.1. COLOUR SPACES

Although many colour spaces were examined for their use in the colour analysis of flotation froths, only a few proved suitable. This was mainly due to the coupling of luminosity and colour components in some of the colour spaces.

The raw RGB colour results were converted to Relative RGB, Normalised RGB, 'Lab', HSV and RGB angles. These results were then used to develop correlations between froth colour and copper grade. The batch flotation tests done on both Kennecott and North Parkes ore revealed that the 'Lab' colour space yielded the highest overall correlations with copper grade. The 'Lab' colour space has already been proved to be suitable for colour analysis in the textile industry and it has completely separate colour and luminosity components. Therefore it was decided that the 'Lab' colour space was suitable for the analysis of flotation froths, and would be used to develop the relationships between froth colour and metallurgical parameters on plant.

### 7.2. CALIBRATION OBJECTS

Calibration objects were used to correct the RGB values obtained from the cameras for changes in ambient light, as well as changes in the camera settings (auto focus and auto iris).

The use of calibration objects proved invaluable in the laboratory batch flotation tests when there were major changes in light and camera settings between tests and also on plant where light and camera settings changed during the testing campaign. Without the use of calibration objects significant relationships between froth colour and copper grade could not be developed for these tests.

## 7.3. RELATIONSHIPS BETWEEN FROTH COLOUR AND COPPER GRADE

### 7.3.1. Laboratory batch flotation tests

Statistically significant relationships were developed between froth colour and copper grade for laboratory batch flotation tests done using both Kennecott and North Parkes copper ore. These relationship were developed in the 'Lab' colour space after a calibration was done using patches from the calibration board.

A strong correlation was developed between the 'Lab' luminosity component and copper grade in the Kennecott campaign as well as a weaker, yet still significant correlation between the 'Lab' colour parameter 'a' and copper grade.

High correlation coefficients were obtained between all 'Lab' parameters and copper grade using the North Parkes copper ore both before and after calibration. The range of colours obtained in this campaign (blue-purple to yellow-gold) and corresponding range of grades (50% to 5%) contributed to the strength of the relationship between froth colour and copper grade. This change in grade and colour was attributed to a change in the dominant mineral in the froth, going from bornite to chalcopyrite.

### 7.3.2. Kennecott plant trial

Significant correlations with colour parameters were seen to exist between both top of froth and concentrate grades for each individual test. Due to this and the similarity between these grades it was decided to continue taking only concentrate samples and to focus the colour–grade correlations on concentrate grade rather than top of froth grade. This was also done because concentrate grade would be the variable for which a sensor would be most valuable on plant.

After calibration was done on the colour data, significant relationships were observed between froth colour and copper grade in cell 2 and froth colour and % solids in cell 4. An estimation of the mineralogy revealed a distinct mineralogical difference between the two cells. It is presumed that the difference in mineralogy is the reason for the different relationships existing between froth colour and copper grade and % solids in the two cells.

This plant campaign showed that a relationship existed between froth colour and copper grade in cell 2 and froth colour and % solids in cell 4, and significant correlations could be developed with the aid of calibration objects for these relationships. However these relationships were empirical and specific to the cell and ore type that were tested. These relationships could be invaluable to the flotation industry if they could be used in the development of an online sensor or control devise.

The results from the batch tests done both at the UCT and at North Parkes Mines laboratory showed a significant relationship between froth colour and copper grade. They also demonstrated the value of using calibration objects to correct for light changes during testing. These results justified launching a campaign to test the relationship between froth colour and copper grade at Kennecott Copperton Concentrator.

The results from this campaign showed that a significant relationship existed between froth colour and copper grade in cell 2 (a primary rougher), and another significant relationship existed between froth colour and % solids in cell 4 (a rougher scavenger). This work once again showed the importance of using calibration objects to correct for light changes during testing.

The possibility of using froth colour as sensor or a control variable on site should be investigated further in a full scale plant control trial. However in order to use froth colour as a sensor or control variable the colour-grade or % solids relationship would have to be recalibrated whenever an ore change took place, as the relationship between colour and grade or % solids could change with changing ore type.

With this calibration in place, the use of a hood and light calibration object would be unnecessary as the Kennecott Copper flotation plant is entirely indoors and no sunlight could reach the froth surface. Changes in ambient light would be gradual, and would be accounted for by this calibration.

The most effective way of doing this calibration would be to link the grade-colour and % solids sensor/controller to an online analyser so as to prevent the grade–colour and % solids relationship from becoming inaccurate with time. The obvious question arises of why not just using the online analyser independently. The answer is that the online analyser outputs grades infrequently and requires high maintenance to continue operating accurately. Using a Machine Vision System could increase the frequency of the grade outputs and could also yield a % solids estimate for the rougher scavenger cells.

The following scheme is proposed to increase the frequency of the grade outputs obtained from the online analyser using a Machine Vision System:

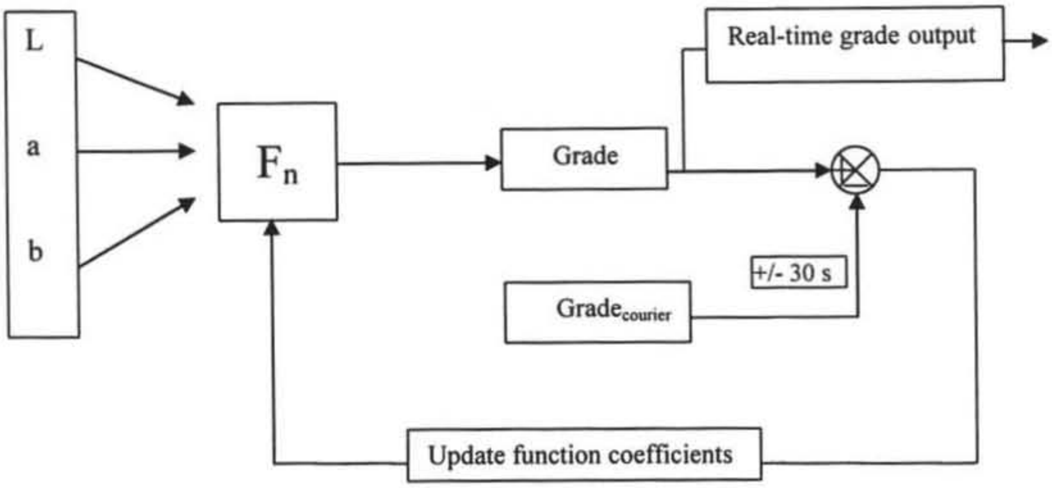

Figure 7.1. Possible auto-calibration scheme for colour-grade relationship using online analyser

This scheme is a simple option proposed to update the correlation coefficients of the grade-colour relationship using the online X-ray analyser (courier). The 'Lab' colour parameters calculated by SmartFroth are the inputs for a colour-grade conversion function that calculates the copper grade based on the 'Lab' colour parameters. This process occurs continuously in real time with a short delay while the outputs are calculated. Whenever an output becomes available from the courier system, the recent (previous few readings) from the conversion function are compared with the courier readings and if a significant difference is observed, the constants in the colour-grade conversion function are updated to minimize this difference. This can be done using multi-variable linear least squares regression or other simple error minimizing tools.

This scheme would have to be tested on plant to determine its accuracy and usefulness as it does not take into account that the concentrate sampled by the courier is a combination of more than one cell and it assumes that changes in the grade-colour relationship are linear between courier readings.

The benefit of this scheme is that it is simple and does not require algorithms to be trained over long periods of time. However if this scheme were to be proved invalid then other more complex options could be used. These other options would require a training period for the conversion algorithm to 'learn' how to interpolate between courier readings by providing it with data at shorter intervals for a prolonged period of time to cover all the possible colour changes that could occur and the resulting grades. This would require a having dedicated online analyser on one cell to reduce the sampling interval and then repeating it on other cells.

Once the usefulness of these schemes has been determined control tests can be initiated to evaluate the potential for using the grade-colour relationship for control purposes.

As there is no way of auto-calibrating the froth colour-% solids relationship directly it would have to be investigated how this relationship would change with ore type to determine whether it would remain valid over time.

Options such as coupling froth colour with other Machine Vision outputs such as froth velocity, bubble size or texture are also possible future routes for research.

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# CHAPTER 10 APPENDICES

**APPENDIX A:** KENNECOTT ORE BATCH TEST DATA

**APPENDIX B:** NORTH PARKES ORE BATCH TEST DATA

**APPENDIX C:** KENNECOTT COPPERTON CONCENTRATOR PLANT DATA

**APPENDIX D:** PEARSON'S TABLE OF PRODUCT MOMENT COEFFICIENTS

**APPENDIX E:** MATLAB SCRIPT FOR LAB COLOUR CONVERSION

# Appendix A: Kennecott ore batch test data

Kennecott ore batch tests (uncalibrated)

| | time | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | Hue | Sat | Val | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| no lime (1) | 30 | 129.3474 | 103.6856 | 77.1135 | 103.3822 | 0.2512 | 0.0029 | -0.2541 | 1.2512 | 1.0029 | 0.7459 | 100.0000 | -40.6097 | 37.8745 | 0.0848 | 0.4038 | 0.5072 | 0.0576 |
| | 60 | 119.5675 | 95.4672 | 71.9815 | 95.6721 | 0.2498 | -0.0021 | -0.2476 | 1.2498 | 0.9979 | 0.7524 | 91.6327 | -37.3510 | 34.2679 | 0.0823 | 0.3980 | 0.4689 | 0.0392 |
| | 90 | 115.8185 | 92.0704 | 69.9584 | 92.6158 | 0.2505 | -0.0059 | -0.2446 | 1.2505 | 0.9941 | 0.7554 | 88.2801 | -35.7445 | 32.7350 | 0.0804 | 0.3960 | 0.4542 | 0.0265 |
| | 120 | 114.2143 | 90.7215 | 69.2796 | 91.4051 | 0.2495 | -0.0075 | -0.2421 | 1.2495 | 0.9925 | 0.7579 | 86.9098 | -35.2403 | 31.9895 | 0.0795 | 0.3934 | 0.4479 | 0.0245 |
| | 180 | 113.5768 | 90.1850 | 68.8704 | 90.8774 | 0.2498 | -0.0076 | -0.2422 | 1.2498 | 0.9924 | 0.7578 | 86.3564 | -35.0103 | 31.8197 | 0.0795 | 0.3936 | 0.4454 | 0.0217 |
| | 240 | 115.8896 | 91.9496 | 69.7268 | 92.5220 | 0.2526 | -0.0062 | -0.2464 | 1.2526 | 0.9938 | 0.7536 | 88.2303 | -35.4628 | 32.8642 | 0.0802 | 0.3983 | 0.4545 | 0.0195 |
| no lime (2) | 30 | 68.4723 | 52.2336 | 37.0870 | 52.5976 | 0.3018 | -0.0069 | -0.2949 | 1.3018 | 0.9931 | 0.7051 | 46.4221 | -17.8941 | 22.1548 | 0.0804 | 0.4584 | 0.2685 | 0.0548 |
| | 60 | 58.5224 | 44.0354 | 32.1526 | 44.9035 | 0.3033 | -0.0193 | -0.2840 | 1.3033 | 0.9807 | 0.7160 | 37.6138 | -14.6735 | 18.2576 | 0.0751 | 0.4506 | 0.2295 | 0.0324 |
| | 90 | 55.5559 | 41.8079 | 31.1149 | 42.8262 | 0.2972 | -0.0238 | -0.2735 | 1.2972 | 0.9762 | 0.7265 | 35.1087 | -14.1019 | 16.8655 | 0.0729 | 0.4399 | 0.2179 | 0.0278 |
| | 120 | 53.8433 | 40.4952 | 30.2398 | 41.5261 | 0.2966 | -0.0248 | -0.2718 | 1.2966 | 0.9752 | 0.7282 | 33.6289 | -13.6786 | 16.2849 | 0.0724 | 0.4384 | 0.2112 | 0.0337 |
| | 180 | 54.2861 | 40.8252 | 30.5496 | 41.8870 | 0.2960 | -0.0253 | -0.2707 | 1.2960 | 0.9747 | 0.7293 | 34.0116 | -13.7918 | 16.3520 | 0.0722 | 0.4372 | 0.2129 | 0.0222 |
| | 240 | 54.3747 | 40.8453 | 30.6061 | 41.9420 | 0.2964 | -0.0261 | -0.2703 | 1.2964 | 0.9739 | 0.7297 | 34.0635 | -13.7479 | 16.3344 | 0.0718 | 0.4371 | 0.2132 | 0.0232 |
| | 300 | 54.9125 | 41.1640 | 30.8221 | 42.2995 | 0.2982 | -0.0268 | -0.2713 | 1.2982 | 0.9732 | 0.7287 | 34.4754 | -13.7359 | 16.4968 | 0.0715 | 0.4387 | 0.2153 | 0.0182 |
| | 360 | 54.9153 | 41.1732 | 30.9073 | 42.3319 | 0.2973 | -0.0274 | -0.2699 | 1.2973 | 0.9726 | 0.7301 | 34.4864 | -13.7635 | 16.4273 | 0.0713 | 0.4372 | 0.2154 | 0.0185 |
| 2,5 g lime (1) | 30 | 52.8693 | 44.1273 | 35.6179 | 44.2048 | 0.1960 | -0.0018 | -0.1943 | 1.1960 | 0.9982 | 0.8057 | 35.5888 | -21.1311 | 13.8553 | 0.0822 | 0.3263 | 0.2073 | 0.0377 |
| | 60 | 47.8217 | 39.7070 | 32.8842 | 40.1376 | 0.1914 | -0.0107 | -0.1807 | 1.1914 | 0.9893 | 0.8193 | 30.9065 | -19.1051 | 11.7438 | 0.0761 | 0.3124 | 0.1875 | 0.0286 |
| | 90 | 46.1114 | 38.3391 | 32.1035 | 38.8513 | 0.1869 | -0.0132 | -0.1737 | 1.1869 | 0.9868 | 0.8263 | 29.3989 | -18.6476 | 10.9806 | 0.0742 | 0.3038 | 0.1808 | 0.0286 |
| | 120 | 44.9542 | 37.3661 | 31.3547 | 37.8917 | 0.1864 | -0.0139 | -0.1725 | 1.1864 | 0.9861 | 0.8275 | 28.3328 | -18.2095 | 10.6536 | 0.0737 | 0.3025 | 0.1763 | 0.0178 |
| | 180 | 45.5829 | 37.8182 | 31.6412 | 38.3474 | 0.1887 | -0.0138 | -0.1749 | 1.1887 | 0.9862 | 0.8251 | 28.8590 | -18.3025 | 10.8921 | 0.0738 | 0.3059 | 0.1788 | 0.0141 |
| | 240 | 45.6274 | 37.8911 | 31.8093 | 38.4426 | 0.1869 | -0.0143 | -0.1726 | 1.1869 | 0.9857 | 0.8274 | 28.9311 | -18.4089 | 10.7883 | 0.0734 | 0.3028 | 0.1789 | 0.0143 |
| | 300 | 45.4441 | 37.7446 | 31.7812 | 38.3233 | 0.1858 | -0.0151 | -0.1707 | 1.1858 | 0.9849 | 0.8293 | 28.7736 | -18.3750 | 10.6473 | 0.0727 | 0.3007 | 0.1782 | 0.0104 |
| | 360 | 44.3688 | 36.8239 | 30.9717 | 37.3881 | 0.1867 | -0.0151 | -0.1716 | 1.1867 | 0.9849 | 0.8284 | 27.7637 | -17.9126 | 10.4489 | 0.0728 | 0.3019 | 0.1740 | 0.0089 |
| 2,5 g lime (2) | 30 | 61.0181 | 50.3790 | 40.8813 | 50.7595 | 0.2021 | -0.0075 | -0.1946 | 1.2021 | 0.9925 | 0.8054 | 42.6471 | -23.2995 | 15.6020 | 0.0786 | 0.3300 | 0.2393 | 0.0438 |
| | 60 | 54.5728 | 44.8365 | 37.4595 | 45.6229 | 0.1962 | -0.0172 | -0.1789 | 1.1962 | 0.9828 | 0.8211 | 36.7848 | -20.8988 | 12.9476 | 0.0718 | 0.3136 | 0.2140 | 0.0309 |
| | 90 | 52.1799 | 42.8580 | 36.4416 | 43.8265 | 0.1906 | -0.0221 | -0.1685 | 1.1906 | 0.9779 | 0.8315 | 34.6620 | -20.1893 | 11.7540 | 0.0679 | 0.3016 | 0.2046 | 0.0256 |
| | 120 | 51.4199 | 42.3302 | 35.2912 | 43.0138 | 0.1954 | -0.0159 | -0.1795 | 1.1954 | 0.9841 | 0.8205 | 33.9802 | -19.8917 | 12.3242 | 0.0727 | 0.3137 | 0.2016 | 0.0221 |
| | 180 | 51.3166 | 42.4064 | 33.8877 | 42.5369 | 0.2064 | -0.0031 | -0.2033 | 1.2064 | 0.9969 | 0.7967 | 33.8815 | -19.7561 | 13.8101 | 0.0815 | 0.3396 | 0.2012 | 0.0166 |
| | 240 | 51.9667 | 42.8782 | 34.1739 | 43.0063 | 0.2084 | -0.0030 | -0.2054 | 1.2084 | 0.9970 | 0.7946 | 34.4237 | -19.8586 | 14.0626 | 0.0815 | 0.3424 | 0.2038 | 0.0164 |
| | 300 | 50.9248 | 41.9941 | 33.4035 | 42.1075 | 0.2094 | -0.0027 | -0.2067 | 1.2094 | 0.9973 | 0.7933 | 33.4596 | -19.4300 | 13.8648 | 0.0817 | 0.3441 | 0.1997 | 0.0167 |
| | 360 | 50.3633 | 41.6052 | 33.1558 | 41.7081 | 0.2075 | -0.0025 | -0.2051 | 1.2075 | 0.9975 | 0.7949 | 33.0012 | -19.3687 | 13.6631 | 0.0818 | 0.3417 | 0.1975 | 0.0137 |
| 3,5 g lime (1) | 30 | 62.7215 | 49.7590 | 36.7305 | 49.7370 | 0.2611 | 0.0004 | -0.2615 | 1.2611 | 1.0004 | 0.7385 | 42.7045 | -19.7761 | 19.4662 | 0.0835 | 0.4144 | 0.2460 | 0.1125 |
| | 60 | 54.5465 | 42.8007 | 33.6047 | 43.6506 | 0.2496 | -0.0195 | -0.2301 | 1.2496 | 0.9805 | 0.7699 | 35.3732 | -17.0324 | 15.1177 | 0.0732 | 0.3839 | 0.2139 | 0.0503 |
| | 90 | 49.7250 | 38.9476 | 30.8959 | 39.8562 | 0.2476 | -0.0228 | -0.2248 | 1.2476 | 0.9772 | 0.7752 | 31.1009 | -15.5820 | 13.5532 | 0.0713 | 0.3787 | 0.1950 | 0.0330 |
| | 120 | 47.4210 | 37.1402 | 29.6570 | 38.0727 | 0.2455 | -0.0245 | -0.2210 | 1.2455 | 0.9755 | 0.7790 | 29.0722 | -14.9481 | 12.7736 | 0.0702 | 0.3746 | 0.1860 | 0.0320 |
| | 180 | 45.5637 | 35.6243 | 28.6041 | 36.5974 | 0.2450 | -0.0266 | -0.2184 | 1.2450 | 0.9734 | 0.7816 | 27.3960 | -14.3376 | 12.1475 | 0.0690 | 0.3722 | 0.1787 | 0.0259 |
| | 240 | 44.8050 | 35.1092 | 28.3378 | 36.0840 | 0.2417 | -0.0270 | -0.2147 | 1.2417 | 0.9730 | 0.7853 | 26.7788 | -14.2789 | 11.8135 | 0.0685 | 0.3675 | 0.1757 | 0.0152 |
| | 300 | 44.5471 | 34.9674 | 28.3456 | 35.9533 | 0.2390 | -0.0274 | -0.2116 | 1.2390 | 0.9726 | 0.7884 | 26.5941 | -14.3315 | 11.6286 | 0.0681 | 0.3637 | 0.1747 | 0.0166 |
| 3,5 g lime (2) | 30 | 70.1377 | 52.3000 | 35.6353 | 52.6910 | 0.3311 | -0.0074 | -0.3237 | 1.3311 | 0.9926 | 0.6763 | 47.0875 | -16.1844 | 23.7039 | 0.0805 | 0.4919 | 0.2750 | 0.1050 |
| | 60 | 59.6886 | 43.9936 | 30.9646 | 44.8823 | 0.3299 | -0.0198 | -0.3101 | 1.3299 | 0.9802 | 0.6899 | 38.0318 | -13.3058 | 19.4646 | 0.0756 | 0.4812 | 0.2341 | 0.0541 |
| | 90 | 54.2511 | 39.7990 | 28.6608 | 40.9036 | 0.3263 | -0.0270 | -0.2993 | 1.3263 | 0.9730 | 0.7007 | 33.3527 | -12.0017 | 17.2196 | 0.0725 | 0.4717 | 0.2127 | 0.0382 |
| | 120 | 51.4578 | 37.6464 | 27.2998 | 38.8013 | 0.3262 | -0.0298 | -0.2964 | 1.3262 | 0.9702 | 0.7036 | 30.9291 | -11.2993 | 16.2119 | 0.0714 | 0.4695 | 0.2018 | 0.0331 |
| | 180 | 50.5953 | 37.0515 | 26.8975 | 38.1814 | 0.3251 | -0.0296 | -0.2955 | 1.3251 | 0.9704 | 0.7045 | 30.2163 | -11.1840 | 15.9379 | 0.0714 | 0.4684 | 0.1984 | 0.0249 |
| | 240 | 49.9412 | 36.6383 | 26.7399 | 37.7732 | 0.3221 | -0.0300 | -0.2921 | 1.3221 | 0.9700 | 0.7079 | 29.7031 | -11.1786 | 15.6302 | 0.0711 | 0.4646 | 0.1958 | 0.0190 |
| | 300 | 49.2862 | 36.1223 | 26.3903 | 37.2663 | 0.3225 | -0.0307 | -0.2918 | 1.3225 | 0.9693 | 0.7082 | 29.1249 | -10.9916 | 15.4104 | 0.0708 | 0.4645 | 0.1933 | 0.0172 |
| | 360 | 48.5594 | 36.2913 | 27.1764 | 37.3424 | 0.3004 | -0.0281 | -0.2722 | 1.3004 | 0.9719 | 0.7278 | 28.9398 | -12.0727 | 14.6941 | 0.0710 | 0.4403 | 0.1904 | 0.0141 |

**Kennecott ore batch tests (calibrated white patch)**

| | time | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | Hue | Sat | Val | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| no lime (1) | 30 | 65.6057 | 60.3579 | 51.7211 | 59.2282 | 0.1077 | 0.0191 | -0.1267 | 1.1077 | 1.0191 | 0.8733 | 93.8702 | 3.0229 | 22.8968 | 0.0555 | 0.4651 | 0.2814 | 0.0576 |
| | 60 | 60.6452 | 55.5738 | 48.2790 | 54.8327 | 0.1060 | 0.0135 | -0.1195 | 1.1060 | 1.0135 | 0.8805 | 85.8818 | 3.6522 | 19.8714 | 0.0533 | 0.4599 | 0.2601 | 0.0392 |
| | 90 | 58.7437 | 53.5964 | 46.9221 | 53.0874 | 0.1065 | 0.0096 | -0.1161 | 1.1065 | 1.0096 | 0.8839 | 82.6378 | 4.2344 | 18.5621 | 0.0518 | 0.4581 | 0.2520 | 0.0265 |
| | 120 | 57.9300 | 52.8112 | 46.4668 | 52.4027 | 0.1055 | 0.0078 | -0.1133 | 1.1055 | 1.0078 | 0.8867 | 81.3302 | 4.4105 | 17.8117 | 0.0510 | 0.4558 | 0.2485 | 0.0245 |
| | 180 | 57.6067 | 52.4989 | 46.1924 | 52.0993 | 0.1057 | 0.0077 | -0.1134 | 1.1057 | 1.0077 | 0.8866 | 80.8013 | 4.4220 | 17.7255 | 0.0510 | 0.4560 | 0.2471 | 0.0217 |
| | 240 | 58.7798 | 53.5261 | 46.7667 | 53.0242 | 0.1085 | 0.0095 | -0.1180 | 1.1085 | 1.0095 | 0.8820 | 82.5573 | 4.3808 | 18.8277 | 0.0518 | 0.4602 | 0.2521 | 0.0195 |
| no lime (2) | 30 | 61.4589 | 62.0916 | 55.6380 | 59.7295 | 0.0290 | 0.0395 | -0.0685 | 1.0290 | 1.0395 | 0.9315 | 94.6431 | -6.1613 | 14.3266 | 0.0616 | 0.3856 | 0.2636 | 0.0548 |
| | 60 | 52.5282 | 52.3462 | 48.2354 | 51.0366 | 0.0292 | 0.0257 | -0.0549 | 1.0292 | 1.0257 | 0.9451 | 78.7537 | -2.9923 | 9.5908 | 0.0549 | 0.3768 | 0.2253 | 0.0324 |
| | 90 | 49.8655 | 49.6983 | 46.6787 | 48.7475 | 0.0229 | 0.0195 | -0.0424 | 1.0229 | 1.0195 | 0.9576 | 74.3652 | -2.1796 | 7.0958 | 0.0513 | 0.3648 | 0.2139 | 0.0278 |
| | 120 | 48.3283 | 48.1378 | 45.3658 | 47.2773 | 0.0222 | 0.0182 | -0.0404 | 1.0222 | 1.0182 | 0.9596 | 71.7419 | -1.9458 | 6.5512 | 0.0505 | 0.3631 | 0.2073 | 0.0337 |
| | 180 | 48.7257 | 48.5302 | 45.8306 | 47.6955 | 0.0216 | 0.0175 | -0.0391 | 1.0216 | 1.0175 | 0.9609 | 72.4209 | -1.8796 | 6.3829 | 0.0501 | 0.3618 | 0.2090 | 0.0222 |
| | 240 | 48.8052 | 48.5540 | 45.9153 | 47.7582 | 0.0219 | 0.0167 | -0.0386 | 1.0219 | 1.0167 | 0.9614 | 72.4897 | -1.7342 | 6.2754 | 0.0497 | 0.3617 | 0.2093 | 0.0232 |
| | 300 | 49.2879 | 48.9328 | 46.2393 | 48.1534 | 0.0236 | 0.0162 | -0.0397 | 1.0236 | 1.0162 | 0.9603 | 73.1693 | -1.5949 | 6.4616 | 0.0495 | 0.3635 | 0.2114 | 0.0182 |
| | 360 | 49.2905 | 48.9437 | 46.3672 | 48.2005 | 0.0226 | 0.0154 | -0.0380 | 1.0226 | 1.0154 | 0.9620 | 73.1976 | -1.5176 | 6.1859 | 0.0490 | 0.3617 | 0.2114 | 0.0185 |
| 2,5 g lime (1) | 30 | 53.3748 | 51.3943 | 43.8789 | 49.5493 | 0.0772 | 0.0372 | -0.1144 | 1.0772 | 1.0372 | 0.8856 | 77.5113 | -2.1352 | 18.4778 | 0.0819 | 0.3257 | 0.2073 | 0.0377 |
| | 60 | 48.2789 | 46.2461 | 40.5112 | 45.0121 | 0.0726 | 0.0274 | -0.1000 | 1.0726 | 1.0274 | 0.9000 | 68.9370 | -0.7843 | 14.5488 | 0.0761 | 0.3123 | 0.1875 | 0.0286 |
| | 90 | 46.5523 | 44.6529 | 39.5494 | 43.5849 | 0.0681 | 0.0245 | -0.0926 | 1.0681 | 1.0245 | 0.9074 | 66.2189 | -0.5790 | 13.0411 | 0.0742 | 0.3038 | 0.1808 | 0.0286 |
| | 120 | 45.3840 | 43.5197 | 38.6269 | 42.5102 | 0.0676 | 0.0237 | -0.0913 | 1.0676 | 1.0237 | 0.9087 | 64.2831 | -0.4845 | 12.5527 | 0.0736 | 0.3025 | 0.1763 | 0.0178 |
| | 180 | 46.0188 | 44.0462 | 38.9798 | 43.0149 | 0.0698 | 0.0240 | -0.0938 | 1.0698 | 1.0240 | 0.9062 | 65.2131 | -0.4111 | 13.0128 | 0.0738 | 0.3059 | 0.1788 | 0.0141 |
| | 240 | 46.0636 | 44.1311 | 39.1869 | 43.1272 | 0.0681 | 0.0233 | -0.0914 | 1.0681 | 1.0233 | 0.9086 | 65.3542 | -0.4016 | 12.7039 | 0.0734 | 0.3029 | 0.1789 | 0.0143 |
| | 300 | 45.8786 | 43.9605 | 39.1523 | 42.9972 | 0.0670 | 0.0224 | -0.0894 | 1.0670 | 1.0224 | 0.9106 | 65.0694 | -0.3317 | 12.3837 | 0.0727 | 0.3007 | 0.1782 | 0.0104 |
| | 360 | 44.7930 | 42.8882 | 38.1551 | 41.9454 | 0.0679 | 0.0225 | -0.0904 | 1.0679 | 1.0225 | 0.9096 | 63.2317 | -0.2916 | 12.2203 | 0.0728 | 0.3019 | 0.1740 | 0.0089 |
| 2,5 g lime (2) | 30 | 57.6085 | 54.8124 | 48.1711 | 53.5307 | 0.0762 | 0.0239 | -0.1001 | 1.0762 | 1.0239 | 0.8999 | 83.7077 | -0.1075 | 16.9381 | 0.0785 | 0.3301 | 0.2393 | 0.0438 |
| | 60 | 51.5234 | 48.7821 | 44.1391 | 48.1482 | 0.0701 | 0.0132 | -0.0833 | 1.0701 | 1.0132 | 0.9167 | 73.6585 | 1.2358 | 12.4454 | 0.0717 | 0.3135 | 0.2140 | 0.0309 |
| | 90 | 49.2642 | 46.6295 | 42.9397 | 46.2778 | 0.0645 | 0.0076 | -0.0721 | 1.0645 | 1.0076 | 0.9279 | 70.0428 | 1.7409 | 10.2132 | 0.0679 | 0.3017 | 0.2046 | 0.0256 |
| | 120 | 48.5467 | 46.0553 | 41.5842 | 45.3954 | 0.0694 | 0.0145 | -0.0840 | 1.0694 | 1.0145 | 0.9160 | 68.9233 | 0.9325 | 11.9353 | 0.0727 | 0.3137 | 0.2016 | 0.0221 |
| | 180 | 48.4492 | 46.1382 | 39.9304 | 44.8392 | 0.0805 | 0.0290 | -0.1095 | 1.0805 | 1.0290 | 0.8905 | 68.8220 | -0.5831 | 15.8115 | 0.0814 | 0.3396 | 0.2012 | 0.0166 |
| | 240 | 49.0629 | 46.6515 | 40.2677 | 45.3274 | 0.0824 | 0.0292 | -0.1116 | 1.0824 | 1.0292 | 0.8884 | 69.7234 | -0.5207 | 16.2680 | 0.0815 | 0.3424 | 0.2038 | 0.0164 |
| | 300 | 48.0793 | 45.6895 | 39.3599 | 44.3762 | 0.0834 | 0.0296 | -0.1130 | 1.0834 | 1.0296 | 0.8870 | 68.0768 | -0.5091 | 16.1499 | 0.0817 | 0.3442 | 0.1997 | 0.0167 |
| | 360 | 47.5491 | 45.2664 | 39.0680 | 43.9611 | 0.0816 | 0.0297 | -0.1113 | 1.0816 | 1.0297 | 0.8887 | 67.3215 | -0.6155 | 15.7897 | 0.0818 | 0.3418 | 0.1975 | 0.0137 |
| 3,5 g lime (1) | 30 | 61.3674 | 62.7412 | 54.6563 | 59.5883 | 0.0299 | 0.0529 | -0.0828 | 1.0299 | 1.0529 | 0.9172 | 95.2993 | -8.6412 | 17.5725 | 0.0683 | 0.3956 | 0.2632 | 0.1125 |
| | 60 | 53.3689 | 53.9676 | 50.0050 | 52.4471 | 0.0176 | 0.0290 | -0.0466 | 1.0176 | 1.0290 | 0.9534 | 81.2224 | -4.2449 | 8.7718 | 0.0560 | 0.3641 | 0.2289 | 0.0503 |
| | 90 | 48.6515 | 49.1092 | 45.9742 | 47.9116 | 0.0154 | 0.0250 | -0.0404 | 1.0154 | 1.0250 | 0.9596 | 73.1120 | -3.3652 | 6.9962 | 0.0538 | 0.3587 | 0.2087 | 0.0330 |
| | 120 | 46.3972 | 46.8301 | 44.1307 | 45.7860 | 0.0133 | 0.0228 | -0.0362 | 1.0133 | 1.0228 | 0.9638 | 69.2794 | -2.9824 | 6.0222 | 0.0523 | 0.3546 | 0.1990 | 0.0320 |
| | 180 | 44.5800 | 44.9188 | 42.5640 | 44.0209 | 0.0127 | 0.0204 | -0.0331 | 1.0127 | 1.0204 | 0.9669 | 66.0815 | -2.5463 | 5.2922 | 0.0510 | 0.3521 | 0.1912 | 0.0259 |
| | 240 | 43.8377 | 44.2694 | 42.1677 | 43.4249 | 0.0095 | 0.0194 | -0.0290 | 1.0095 | 1.0194 | 0.9710 | 64.9610 | -2.5052 | 4.6520 | 0.0502 | 0.3473 | 0.1880 | 0.0152 |
| | 300 | 43.5853 | 44.0905 | 42.1792 | 43.2850 | 0.0069 | 0.0186 | -0.0255 | 1.0069 | 1.0186 | 0.9745 | 64.6480 | -2.4781 | 4.1655 | 0.0495 | 0.3434 | 0.1869 | 0.0166 |
| 3,5 g lime (2) | 30 | 64.7404 | 65.2950 | 58.4800 | 62.8385 | 0.0303 | 0.0391 | -0.0694 | 1.0303 | 1.0391 | 0.9306 | 100.0000 | -6.2844 | 15.1432 | 0.0614 | 0.3873 | 0.2777 | 0.1050 |
| | 60 | 55.0954 | 54.9247 | 50.8152 | 53.6117 | 0.0277 | 0.0245 | -0.0522 | 1.0277 | 1.0245 | 0.9478 | 83.1166 | -3.0107 | 9.5522 | 0.0540 | 0.3737 | 0.2363 | 0.0541 |
| | 90 | 50.0762 | 49.6878 | 47.0345 | 48.9329 | 0.0234 | 0.0154 | -0.0388 | 1.0234 | 1.0154 | 0.9612 | 74.4724 | -1.5050 | 6.3825 | 0.0490 | 0.3625 | 0.2148 | 0.0382 |
| | 120 | 47.4979 | 47.0004 | 44.8010 | 46.4331 | 0.0229 | 0.0122 | -0.0351 | 1.0229 | 1.0122 | 0.9649 | 69.9818 | -0.9548 | 5.4180 | 0.0472 | 0.3600 | 0.2037 | 0.0331 |
| | 180 | 46.7017 | 46.2576 | 44.1407 | 45.7000 | 0.0219 | 0.0122 | -0.0341 | 1.0219 | 1.0122 | 0.9659 | 68.7007 | -0.9828 | 5.1995 | 0.0471 | 0.3587 | 0.2003 | 0.0249 |
| | 240 | 46.0980 | 45.7419 | 43.8822 | 45.2407 | 0.0190 | 0.0111 | -0.0300 | 1.0190 | 1.0111 | 0.9700 | 67.8132 | -0.9309 | 4.5513 | 0.0462 | 0.3541 | 0.1977 | 0.0190 |
| | 300 | 45.4934 | 45.0976 | 43.3084 | 44.6331 | 0.0193 | 0.0104 | -0.0297 | 1.0193 | 1.0104 | 0.9703 | 66.7332 | -0.8048 | 4.4154 | 0.0459 | 0.3542 | 0.1951 | 0.0172 |
| | 360 | 44.8226 | 45.3086 | 44.5984 | 44.9099 | -0.0019 | 0.0089 | -0.0069 | 0.9981 | 1.0089 | 0.9931 | 66.8845 | -1.4374 | 1.3687 | 0.1264 | 0.3283 | 0.1923 | 0.0141 |

**Kennecott ore batch tests (calibrated grey patch)**

| | time | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | Hue | Sat | Val | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| no lime (1) | 30 | 101.1552 | 100.5172 | 96.5376 | 99.4033 | 0.0176 | 0.0112 | -0.0288 | 1.0176 | 1.0112 | 0.9712 | 81.4082 | -1.1703 | 5.1127 | 0.0555 | 0.4651 | 0.2814 | 0.0576 |
| | 60 | 93.5069 | 92.5499 | 90.1128 | 92.0566 | 0.0158 | 0.0054 | -0.0211 | 1.0158 | 1.0054 | 0.9789 | 74.3335 | -0.2104 | 3.3322 | 0.0533 | 0.4599 | 0.2601 | 0.0392 |
| | 90 | 90.5750 | 89.2569 | 87.5802 | 89.1374 | 0.0161 | 0.0013 | -0.0175 | 1.0161 | 1.0013 | 0.9825 | 71.4537 | 0.4575 | 2.5127 | 0.0518 | 0.4581 | 0.2520 | 0.0265 |
| | 120 | 89.3204 | 87.9492 | 86.7304 | 88.0000 | 0.0150 | -0.0006 | -0.0144 | 1.0150 | 0.9994 | 0.9856 | 70.2996 | 0.7090 | 1.9625 | 0.0510 | 0.4558 | 0.2485 | 0.0245 |
| | 180 | 88.8219 | 87.4292 | 86.2181 | 87.4897 | 0.0152 | -0.0007 | -0.0145 | 1.0152 | 0.9993 | 0.9855 | 69.8294 | 0.7328 | 1.9607 | 0.0510 | 0.4560 | 0.2471 | 0.0217 |
| | 240 | 90.6306 | 89.1399 | 87.2902 | 89.0202 | 0.0181 | 0.0013 | -0.0194 | 1.0181 | 1.0013 | 0.9806 | 71.3719 | 0.5417 | 2.7845 | 0.0518 | 0.4602 | 0.2521 | 0.0195 |
| no lime (2) | 30 | 109.6814 | 117.0653 | 96.9897 | 107.9121 | 0.0164 | 0.0848 | -0.1012 | 1.0164 | 1.0848 | 0.8988 | 93.8959 | -15.0384 | 22.0936 | 0.0616 | 0.3856 | 0.2636 | 0.0548 |
| | 60 | 93.7433 | 98.6917 | 84.0852 | 92.1734 | 0.0170 | 0.0707 | -0.0878 | 1.0170 | 1.0707 | 0.9122 | 78.0637 | -10.7299 | 16.4081 | 0.0549 | 0.3768 | 0.2253 | 0.0324 |
| | 90 | 88.9915 | 93.6994 | 81.3716 | 88.0208 | 0.0110 | 0.0645 | -0.0755 | 1.0110 | 1.0645 | 0.9245 | 73.6923 | -9.6280 | 13.7519 | 0.0513 | 0.3648 | 0.2139 | 0.0278 |
| | 120 | 86.2482 | 90.7573 | 79.0828 | 85.3628 | 0.0104 | 0.0632 | -0.0736 | 1.0104 | 1.0632 | 0.9264 | 71.0848 | -9.1912 | 13.0377 | 0.0505 | 0.3631 | 0.2073 | 0.0337 |
| | 180 | 86.9573 | 91.4970 | 79.8932 | 86.1158 | 0.0098 | 0.0625 | -0.0723 | 1.0098 | 1.0625 | 0.9277 | 71.7569 | -9.1888 | 12.9357 | 0.0501 | 0.3618 | 0.2090 | 0.0222 |
| | 240 | 87.0993 | 91.5420 | 80.0408 | 86.2274 | 0.0101 | 0.0616 | -0.0717 | 1.0101 | 1.0616 | 0.9283 | 71.8219 | -9.0561 | 12.8384 | 0.0497 | 0.3617 | 0.2093 | 0.0232 |
| | 300 | 87.9608 | 92.2562 | 80.6056 | 86.9409 | 0.0117 | 0.0611 | -0.0729 | 1.0117 | 1.0611 | 0.9271 | 72.4930 | -8.9743 | 13.0590 | 0.0495 | 0.3635 | 0.2114 | 0.0182 |
| | 360 | 87.9654 | 92.2768 | 80.8285 | 87.0236 | 0.0108 | 0.0604 | -0.0712 | 1.0108 | 1.0604 | 0.9288 | 72.5193 | -8.9082 | 12.8064 | 0.0490 | 0.3617 | 0.2114 | 0.0185 |
| 2,5 g lime (1) | 30 | 95.1283 | 93.9694 | 97.9332 | 95.6770 | -0.0057 | -0.0178 | 0.0236 | 0.9943 | 0.9822 | 1.0236 | 76.0856 | 2.8851 | -4.5502 | 0.0819 | 0.3257 | 0.2073 | 0.0377 |
| | 60 | 86.0461 | 84.5565 | 90.4169 | 87.0065 | -0.0110 | -0.0282 | 0.0392 | 0.9890 | 0.9718 | 1.0392 | 67.7015 | 4.1234 | -6.8485 | 0.0761 | 0.3123 | 0.1875 | 0.0286 |
| | 90 | 82.9687 | 81.6435 | 88.2702 | 84.2941 | -0.0157 | -0.0314 | 0.0472 | 0.9843 | 0.9686 | 1.0472 | 65.0547 | 4.3709 | -7.8805 | 0.0742 | 0.3038 | 0.1808 | 0.0286 |
| | 120 | 80.8866 | 79.5714 | 86.2113 | 82.2231 | -0.0163 | -0.0322 | 0.0485 | 0.9837 | 0.9678 | 1.0485 | 63.1515 | 4.3788 | -7.9139 | 0.0736 | 0.3025 | 0.1763 | 0.0178 |
| | 180 | 82.0179 | 80.5342 | 86.9989 | 83.1837 | -0.0140 | -0.0319 | 0.0459 | 0.9860 | 0.9681 | 1.0459 | 64.0575 | 4.4351 | -7.6320 | 0.0738 | 0.3059 | 0.1788 | 0.0141 |
| | 240 | 82.0978 | 80.6895 | 87.4612 | 83.4162 | -0.0158 | -0.0327 | 0.0485 | 0.9842 | 0.9673 | 1.0485 | 64.2073 | 4.5213 | -8.0414 | 0.0734 | 0.3029 | 0.1789 | 0.0143 |
| | 300 | 81.7681 | 80.3775 | 87.3839 | 83.1765 | -0.0169 | -0.0337 | 0.0506 | 0.9831 | 0.9663 | 1.0506 | 63.9347 | 4.6251 | -8.3442 | 0.0727 | 0.3007 | 0.1782 | 0.0104 |
| | 360 | 79.8332 | 78.4168 | 85.1583 | 81.1361 | -0.0161 | -0.0335 | 0.0496 | 0.9839 | 0.9665 | 1.0496 | 62.1187 | 4.5249 | -8.0161 | 0.0728 | 0.3019 | 0.1740 | 0.0089 |
| 2,5 g lime (2) | 30 | 99.7473 | 97.1375 | 101.9954 | 99.6267 | 0.0012 | -0.0250 | 0.0238 | 1.0012 | 0.9750 | 1.0238 | 79.3230 | 4.5907 | -5.1752 | 0.0785 | 0.3301 | 0.2393 | 0.0438 |
| | 60 | 89.2111 | 86.4506 | 93.4582 | 89.7067 | -0.0055 | -0.0363 | 0.0418 | 0.9945 | 0.9637 | 1.0418 | 69.7814 | 5.8004 | -7.8520 | 0.0717 | 0.3135 | 0.2140 | 0.0309 |
| | 90 | 85.2994 | 82.6360 | 90.9187 | 86.2847 | -0.0114 | -0.0423 | 0.0537 | 0.9886 | 0.9577 | 1.0537 | 66.3666 | 6.3688 | -9.5069 | 0.0679 | 0.3017 | 0.2046 | 0.0256 |
| | 120 | 84.0570 | 81.6183 | 88.0485 | 84.5746 | -0.0061 | -0.0350 | 0.0411 | 0.9939 | 0.9650 | 1.0411 | 65.2488 | 5.2574 | -7.2646 | 0.0727 | 0.3137 | 0.2016 | 0.0221 |
| | 180 | 83.8881 | 81.7652 | 84.5468 | 83.4001 | 0.0059 | -0.0196 | 0.0138 | 1.0059 | 0.9804 | 1.0138 | 65.0585 | 3.2254 | -2.7908 | 0.0814 | 0.3396 | 0.2012 | 0.0166 |
| | 240 | 84.9508 | 82.6749 | 85.2609 | 84.2956 | 0.0078 | -0.0192 | 0.0115 | 1.0078 | 0.9808 | 1.0115 | 65.9117 | 3.2709 | -2.4927 | 0.0815 | 0.3424 | 0.2038 | 0.0164 |
| | 300 | 83.2477 | 80.9701 | 83.3389 | 82.5189 | 0.0088 | -0.0188 | 0.0099 | 1.0088 | 0.9812 | 1.0099 | 64.3332 | 3.1762 | -2.2227 | 0.0817 | 0.3442 | 0.1997 | 0.0167 |
| | 360 | 82.3296 | 80.2203 | 82.7207 | 81.7569 | 0.0070 | -0.0188 | 0.0118 | 1.0070 | 0.9812 | 1.0118 | 63.6181 | 3.0859 | -2.4456 | 0.0818 | 0.3418 | 0.1975 | 0.0137 |
| 3,5 g lime (1) | 30 | 104.5519 | 114.5525 | 118.9165 | 112.6736 | -0.0721 | 0.0167 | 0.0554 | 0.9279 | 1.0167 | 1.0554 | 92.6074 | -6.4929 | -8.3089 | 0.0683 | 0.3956 | 0.2632 | 0.1125 |
| | 60 | 90.9248 | 98.5336 | 108.7966 | 99.4183 | -0.0854 | -0.0089 | 0.0943 | 0.9146 | 0.9911 | 1.0943 | 79.0249 | -1.3115 | -14.9989 | 0.0560 | 0.3641 | 0.2289 | 0.0503 |
| | 90 | 82.8877 | 89.6632 | 100.0268 | 90.8592 | -0.0877 | -0.0132 | 0.1009 | 0.9123 | 0.9868 | 1.1009 | 71.1239 | -0.5043 | -14.9680 | 0.0538 | 0.3587 | 0.2087 | 0.0330 |
| | 120 | 79.0471 | 85.5022 | 96.0157 | 86.8550 | -0.0899 | -0.0156 | 0.1055 | 0.9101 | 0.9844 | 1.1055 | 67.3964 | -0.1179 | -15.1047 | 0.0523 | 0.3546 | 0.1990 | 0.0320 |
| | 180 | 75.9512 | 82.0125 | 92.6071 | 83.5236 | -0.0907 | -0.0181 | 0.1088 | 0.9093 | 0.9819 | 1.1088 | 64.2803 | 0.2846 | -15.1297 | 0.0510 | 0.3521 | 0.1912 | 0.0259 |
| | 240 | 74.6865 | 80.8267 | 91.7448 | 82.4193 | -0.0938 | -0.0193 | 0.1131 | 0.9062 | 0.9807 | 1.1131 | 63.2060 | 0.4237 | -15.5705 | 0.0502 | 0.3473 | 0.1880 | 0.0152 |
| | 300 | 74.2565 | 80.5002 | 91.7699 | 82.1755 | -0.0964 | -0.0204 | 0.1168 | 0.9036 | 0.9796 | 1.1168 | 62.9175 | 0.5510 | -16.0443 | 0.0495 | 0.3434 | 0.1869 | 0.0166 |
| 3,5 g lime (2) | 30 | 109.9875 | 120.3495 | 151.9830 | 127.4400 | -0.1369 | -0.0556 | 0.1926 | 0.8631 | 0.9444 | 1.1926 | 100.0000 | 8.9820 | -41.5848 | 0.0614 | 0.3873 | 0.2777 | 0.1050 |
| | 60 | 93.6016 | 101.2355 | 132.0628 | 108.9666 | -0.1410 | -0.0709 | 0.2120 | 0.8590 | 0.9291 | 1.2120 | 83.3119 | 11.1455 | -40.2280 | 0.0540 | 0.3737 | 0.2363 | 0.0541 |
| | 90 | 85.0745 | 91.5830 | 122.2374 | 99.6316 | -0.1461 | -0.0808 | 0.2269 | 0.8539 | 0.9192 | 1.2269 | 74.8016 | 12.2700 | -39.9062 | 0.0490 | 0.3625 | 0.2148 | 0.0382 |
| | 120 | 80.6943 | 86.6296 | 116.4327 | 94.5855 | -0.1469 | -0.0841 | 0.2310 | 0.8531 | 0.9159 | 1.2310 | 70.3338 | 12.3457 | -38.8133 | 0.0472 | 0.3600 | 0.2037 | 0.0331 |
| | 180 | 79.3416 | 85.2606 | 114.7168 | 93.1063 | -0.1478 | -0.0843 | 0.2321 | 0.8522 | 0.9157 | 1.2321 | 69.0598 | 12.1952 | -38.4142 | 0.0471 | 0.3587 | 0.2003 | 0.0249 |
| | 240 | 78.3160 | 84.3099 | 114.0448 | 92.2236 | -0.1508 | -0.0858 | 0.2366 | 0.8492 | 0.9142 | 1.2366 | 68.2157 | 12.3871 | -38.7975 | 0.0462 | 0.3541 | 0.1977 | 0.0190 |
| | 300 | 77.2888 | 83.1224 | 112.5536 | 90.9883 | -0.1506 | -0.0864 | 0.2370 | 0.8494 | 0.9136 | 1.2370 | 67.1337 | 12.3541 | -38.4070 | 0.0459 | 0.3542 | 0.1951 | 0.0172 |
| | 360 | 76.1491 | 83.5114 | 115.9062 | 91.8556 | -0.1710 | -0.0908 | 0.2618 | 0.8290 | 0.9092 | 1.2618 | 67.5572 | 13.3885 | -42.4429 | 0.1264 | 0.3283 | 0.1923 | 0.0141 |

**Uncalibrated results for North Parkes underground sulphide ore**

| | time | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | Hue | Sat | Val | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 ml SIBX (1) | 30 | 47.9694 | 37.2445 | 29.8042 | 38.3393 | 2.2512 | 1.9714 | 1.7774 | 1.2512 | 0.9714 | 0.7774 | 69.2968 | 17.9842 | 28.9984 | 0.0683 | 0.3787 | 0.1881 | 0.5884 |
| | 60 | 44.1308 | 33.8886 | 26.7814 | 34.9336 | 2.2633 | 1.9701 | 1.7666 | 1.2633 | 0.9701 | 0.7666 | 62.3794 | 17.4196 | 27.8965 | 0.0683 | 0.3931 | 0.1731 | 0.4462 |
| | 90 | 45.2282 | 35.0097 | 28.8751 | 36.3710 | 2.2435 | 1.9626 | 1.7939 | 1.2435 | 0.9626 | 0.7939 | 64.6720 | 17.7426 | 25.2344 | 0.0625 | 0.3616 | 0.1774 | 0.4676 |
| | 120 | 43.3374 | 33.6020 | 28.2864 | 35.0753 | 2.2356 | 1.9580 | 1.8064 | 1.2356 | 0.9580 | 0.8064 | 61.6477 | 17.2231 | 22.6923 | 0.0589 | 0.3473 | 0.1700 | 0.4791 |
| | 180 | 42.7966 | 33.4179 | 28.4511 | 34.8885 | 2.2267 | 1.9578 | 1.8155 | 1.2267 | 0.9578 | 0.8155 | 61.0908 | 16.6210 | 21.4316 | 0.0577 | 0.3352 | 0.1678 | 0.4865 |
| | 240 | 42.2302 | 32.9328 | 27.9310 | 34.3647 | 2.2289 | 1.9583 | 1.8128 | 1.2289 | 0.9583 | 0.8128 | 60.0698 | 16.4604 | 21.4806 | 0.0583 | 0.3386 | 0.1656 | 0.4940 |
| | 300 | 42.3621 | 33.1663 | 28.2496 | 34.5927 | 2.2246 | 1.9588 | 1.8166 | 1.2246 | 0.9588 | 0.8166 | 60.4802 | 16.2547 | 21.1405 | 0.0581 | 0.3331 | 0.1661 | 0.4899 |
| | 360 | 42.3633 | 33.2341 | 28.3199 | 34.6391 | 2.2230 | 1.9594 | 1.8176 | 1.2230 | 0.9594 | 0.8176 | 60.5742 | 16.0974 | 21.0664 | 0.0583 | 0.3315 | 0.1661 | 0.4944 |
| 0.5 ml SIBX (2) | 30 | 42.2987 | 32.6451 | 26.1855 | 33.7098 | 2.2548 | 1.9684 | 1.7768 | 1.2548 | 0.9684 | 0.7768 | 59.5889 | 16.5227 | 25.7188 | 0.0668 | 0.3809 | 0.1659 | 0.3942 |
| | 60 | 39.6197 | 30.4362 | 25.0018 | 31.6859 | 2.2504 | 1.9606 | 1.7891 | 1.2504 | 0.9606 | 0.7891 | 54.9732 | 16.2110 | 22.7027 | 0.0620 | 0.3690 | 0.1554 | 0.4211 |
| | 90 | 38.1359 | 29.2839 | 24.3651 | 30.5949 | 2.2465 | 1.9571 | 1.7964 | 1.2465 | 0.9571 | 0.7964 | 52.5007 | 15.8418 | 21.0842 | 0.0595 | 0.3611 | 0.1496 | 0.4428 |
| | 120 | 39.2371 | 30.3419 | 24.8830 | 31.4873 | 2.2461 | 1.9636 | 1.7903 | 1.2461 | 0.9636 | 0.7903 | 54.5984 | 15.5384 | 22.4974 | 0.0634 | 0.3658 | 0.1539 | 0.4518 |
| | 180 | 38.1818 | 29.4906 | 23.8995 | 30.5239 | 2.2509 | 1.9661 | 1.7830 | 1.2509 | 0.9661 | 0.7830 | 52.7514 | 15.0856 | 22.7135 | 0.0652 | 0.3741 | 0.1497 | 0.4465 |
| | 240 | 38.9600 | 30.1341 | 24.2272 | 31.1071 | 2.2524 | 1.9687 | 1.7788 | 1.2524 | 0.9687 | 0.7788 | 54.0987 | 15.1633 | 23.6382 | 0.0668 | 0.3782 | 0.1528 | 0.4558 |
| | 300 | 39.0574 | 30.2369 | 24.3698 | 31.2214 | 2.2510 | 1.9685 | 1.7805 | 1.2510 | 0.9685 | 0.7805 | 54.3044 | 15.1600 | 23.5202 | 0.0666 | 0.3761 | 0.1532 | 0.4401 |
| | 360 | 39.8677 | 30.8981 | 25.0618 | 31.9425 | 2.2481 | 1.9673 | 1.7846 | 1.2481 | 0.9673 | 0.7846 | 55.7244 | 15.4508 | 23.5356 | 0.0657 | 0.3714 | 0.1563 | 0.4756 |
| 0.5 ml SIBX (3) | 30 | 41.2464 | 32.1052 | 26.6649 | 33.3388 | 2.2372 | 1.9630 | 1.7998 | 1.2372 | 0.9630 | 0.7998 | 58.2797 | 15.9359 | 22.5616 | 0.0622 | 0.3535 | 0.1618 | 0.4768 |
| | 60 | 40.7296 | 31.8222 | 26.5770 | 33.0429 | 2.2326 | 1.9631 | 1.8043 | 1.2326 | 0.9631 | 0.8043 | 57.5859 | 15.5325 | 21.8369 | 0.0618 | 0.3475 | 0.1597 | 0.4673 |
| | 90 | 41.2335 | 32.3837 | 27.2388 | 33.6187 | 2.2265 | 1.9633 | 1.8102 | 1.2265 | 0.9633 | 0.8102 | 58.6812 | 15.4027 | 21.4770 | 0.0613 | 0.3394 | 0.1617 | 0.4767 |
| | 120 | 42.3862 | 33.4736 | 28.4710 | 34.7769 | 2.2188 | 1.9625 | 1.8187 | 1.2188 | 0.9625 | 0.8187 | 60.9094 | 15.5288 | 21.0849 | 0.0599 | 0.3283 | 0.1662 | 0.4663 |
| | 180 | 41.8038 | 33.1042 | 28.1431 | 34.3504 | 2.2170 | 1.9637 | 1.8193 | 1.2170 | 0.9637 | 0.8193 | 60.0450 | 15.0979 | 20.7970 | 0.0605 | 0.3268 | 0.1639 | 0.4751 |
| | 240 | 41.0989 | 32.7585 | 27.5617 | 33.8064 | 2.2157 | 1.9690 | 1.8153 | 1.2157 | 0.9690 | 0.8153 | 59.1114 | 14.1666 | 21.1161 | 0.0640 | 0.3294 | 0.1612 | 0.4590 |
| | 300 | 40.9605 | 32.5792 | 27.4453 | 33.6616 | 2.2168 | 1.9678 | 1.8153 | 1.2168 | 0.9678 | 0.8153 | 58.7838 | 14.3134 | 20.9962 | 0.0633 | 0.3300 | 0.1606 | 0.4447 |
| | 360 | 43.2431 | 34.6076 | 28.5869 | 35.4792 | 2.2188 | 1.9754 | 1.8057 | 1.2188 | 0.9754 | 0.8057 | 62.9046 | 14.2035 | 23.4786 | 0.0685 | 0.3389 | 0.1696 | 0.4418 |
| 1 ml SIBX (1) | 30 | 46.2459 | 35.2827 | 26.7334 | 36.0874 | 2.2815 | 1.9777 | 1.7408 | 1.2815 | 0.9777 | 0.7408 | 65.4843 | 18.2383 | 32.2286 | 0.0730 | 0.4219 | 0.1814 | 0.4015 |
| | 60 | 46.0499 | 35.2004 | 27.1697 | 36.1400 | 2.2742 | 1.9740 | 1.7518 | 1.2742 | 0.9740 | 0.7518 | 65.2893 | 18.2247 | 30.7891 | 0.0709 | 0.4100 | 0.1806 | 0.4482 |
| | 90 | 44.7870 | 34.0519 | 26.5661 | 35.1350 | 2.2747 | 1.9692 | 1.7561 | 1.2747 | 0.9692 | 0.7561 | 62.9880 | 18.3619 | 29.3450 | 0.0685 | 0.4068 | 0.1756 | 0.4583 |
| | 120 | 44.5942 | 34.0014 | 26.7704 | 35.1220 | 2.2697 | 1.9681 | 1.7622 | 1.2697 | 0.9681 | 0.7622 | 62.8171 | 18.1601 | 28.5478 | 0.0676 | 0.3997 | 0.1749 | 0.4653 |
| | 180 | 41.1327 | 31.2799 | 25.0559 | 32.4895 | 2.2660 | 1.9628 | 1.7712 | 1.2660 | 0.9628 | 0.7712 | 57.0187 | 17.2632 | 25.3857 | 0.0645 | 0.3909 | 0.1613 | 0.4654 |
| | 240 | 41.5489 | 32.1719 | 25.7506 | 33.1571 | 2.2531 | 1.9703 | 1.7766 | 1.2531 | 0.9703 | 0.7766 | 58.4743 | 15.9524 | 25.3869 | 0.0677 | 0.3802 | 0.1629 | 0.4701 |
| | 300 | 42.2163 | 32.9857 | 26.5593 | 33.9205 | 2.2446 | 1.9724 | 1.7830 | 1.2446 | 0.9724 | 0.7830 | 60.0033 | 15.5197 | 25.2078 | 0.0684 | 0.3709 | 0.1656 | 0.4617 |
| | 360 | 41.4183 | 32.1398 | 23.5211 | 32.3597 | 2.2799 | 1.9932 | 1.7269 | 1.2799 | 0.9932 | 0.7269 | 58.1723 | 14.6698 | 31.0039 | 0.0803 | 0.4321 | 0.1624 | 0.4647 |

**Calibrated results for North Parkes underground sulphide ore**

| | time | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | Hue | Sat | Val | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 ml SIBX (1) | 30 | 42.4667 | 37.6854 | 32.6038 | 38.3394 | 0.1078 | -0.0171 | -0.1498 | 1.1078 | 0.9829 | 0.8502 | 68.3017 | 5.9313 | 17.7687 | 0.0682 | 0.3788 | 0.1881 | 0.5884 |
| | 60 | 39.0684 | 34.2899 | 29.2971 | 34.9336 | 0.1188 | -0.0184 | -0.1619 | 1.1188 | 0.9816 | 0.8381 | 61.3852 | 6.1499 | 17.6421 | 0.0682 | 0.3936 | 0.1731 | 0.4462 |
| | 90 | 40.0399 | 35.4242 | 31.5875 | 36.3710 | 0.1010 | -0.0261 | -0.1316 | 1.1010 | 0.9739 | 0.8684 | 63.7412 | 6.5664 | 14.2871 | 0.0625 | 0.3616 | 0.1774 | 0.4676 |
| | 120 | 38.3660 | 33.9999 | 30.9435 | 35.0753 | 0.0941 | -0.0306 | -0.1181 | 1.0941 | 0.9694 | 0.8819 | 60.7827 | 6.6551 | 11.9615 | 0.0589 | 0.3477 | 0.1700 | 0.4791 |
| | 180 | 37.8872 | 33.8136 | 31.1237 | 34.8885 | 0.0860 | -0.0308 | -0.1080 | 1.0860 | 0.9692 | 0.8920 | 60.2868 | 6.2957 | 10.7032 | 0.0577 | 0.3353 | 0.1678 | 0.4865 |
| | 240 | 37.3859 | 33.3227 | 30.5547 | 34.3647 | 0.0880 | -0.0303 | -0.1111 | 1.0880 | 0.9697 | 0.8889 | 59.2647 | 6.2258 | 10.9249 | 0.0583 | 0.3388 | 0.1656 | 0.4940 |
| | 300 | 37.5026 | 33.5590 | 30.9033 | 34.5927 | 0.0842 | -0.0299 | -0.1068 | 1.0842 | 0.9701 | 0.8932 | 59.6990 | 6.0409 | 10.5064 | 0.0581 | 0.3333 | 0.1661 | 0.4899 |
| | 360 | 37.5037 | 33.6276 | 30.9802 | 34.6391 | 0.0829 | -0.0292 | -0.1059 | 1.0829 | 0.9708 | 0.8941 | 59.8047 | 5.8948 | 10.4254 | 0.0583 | 0.3317 | 0.1661 | 0.4944 |
| 0.5 ml SIBX (2) | 30 | 39.5211 | 35.2764 | 30.5676 | 33.7097 | 0.1725 | 0.0464 | -0.0933 | 1.1725 | 1.0464 | 0.9067 | 63.1416 | 5.0852 | 16.3830 | 0.0667 | 0.3810 | 0.1659 | 0.3942 |
| | 60 | 37.0181 | 32.8895 | 29.1858 | 31.6859 | 0.1686 | 0.0380 | -0.0793 | 1.1686 | 1.0380 | 0.9207 | 58.3013 | 5.6639 | 13.5913 | 0.0620 | 0.3693 | 0.1554 | 0.4211 |
| | 90 | 35.6317 | 31.6443 | 28.4425 | 30.5950 | 0.1649 | 0.0344 | -0.0707 | 1.1649 | 1.0344 | 0.9293 | 55.7224 | 5.7739 | 12.1174 | 0.0595 | 0.3614 | 0.1496 | 0.4428 |
| | 120 | 36.6606 | 32.7877 | 29.0471 | 31.4873 | 0.1643 | 0.0413 | -0.0776 | 1.1643 | 1.0413 | 0.9224 | 57.9498 | 5.0596 | 13.4831 | 0.0634 | 0.3659 | 0.1539 | 0.4518 |
| | 180 | 35.6746 | 31.8677 | 27.8989 | 30.5240 | 0.1687 | 0.0440 | -0.0859 | 1.1687 | 1.0440 | 0.9141 | 55.9968 | 4.7728 | 14.0889 | 0.0652 | 0.3740 | 0.1497 | 0.4465 |
| | 240 | 36.4017 | 32.5631 | 28.2815 | 31.1071 | 0.1703 | 0.0469 | -0.0911 | 1.1703 | 1.0469 | 0.9089 | 57.4093 | 4.5850 | 14.9581 | 0.0668 | 0.3784 | 0.1528 | 0.4558 |
| | 300 | 36.4927 | 32.6742 | 28.4480 | 31.2214 | 0.1691 | 0.0466 | -0.0892 | 1.1691 | 1.0466 | 0.9108 | 57.6328 | 4.5757 | 14.7847 | 0.0666 | 0.3764 | 0.1532 | 0.4401 |
| | 360 | 37.2498 | 33.3886 | 29.2558 | 31.9425 | 0.1666 | 0.0454 | -0.0848 | 1.1666 | 1.0454 | 0.9152 | 59.1331 | 4.7143 | 14.5399 | 0.0657 | 0.3720 | 0.1563 | 0.4756 |
| 0.5 ml SIBX (3) | 30 | 35.9364 | 31.9286 | 28.5133 | 33.3388 | 0.0781 | -0.0424 | -0.1449 | 1.0781 | 0.9576 | 0.8551 | 56.2939 | 5.6457 | 12.7197 | 0.0621 | 0.3537 | 0.1618 | 0.4768 |
| | 60 | 35.4861 | 31.6472 | 28.4192 | 33.0429 | 0.0740 | -0.0422 | -0.1400 | 1.0740 | 0.9578 | 0.8600 | 55.6447 | 5.4173 | 12.0655 | 0.0618 | 0.3475 | 0.1597 | 0.4673 |
| | 90 | 35.9252 | 32.2056 | 29.1269 | 33.6186 | 0.0688 | -0.0420 | -0.1339 | 1.0688 | 0.9580 | 0.8661 | 56.7474 | 5.2451 | 11.5343 | 0.0613 | 0.3396 | 0.1617 | 0.4767 |
| | 120 | 36.9295 | 33.2895 | 30.4445 | 34.7769 | 0.0620 | -0.0428 | -0.1247 | 1.0620 | 0.9572 | 0.8753 | 58.9610 | 5.2187 | 10.7887 | 0.0599 | 0.3284 | 0.1662 | 0.4663 |
| | 180 | 36.4220 | 32.9222 | 30.0939 | 34.3504 | 0.0604 | -0.0416 | -0.1240 | 1.0604 | 0.9584 | 0.8760 | 58.1339 | 4.9296 | 10.6360 | 0.0605 | 0.3269 | 0.1639 | 0.4751 |
| | 240 | 35.8079 | 32.5784 | 29.4722 | 33.8063 | 0.0594 | -0.0364 | -0.1284 | 1.0594 | 0.9636 | 0.8716 | 57.2507 | 4.1107 | 11.1971 | 0.0639 | 0.3296 | 0.1612 | 0.4590 |
| | 300 | 35.6873 | 32.4000 | 29.3477 | 33.6616 | 0.0603 | -0.0374 | -0.1283 | 1.0603 | 0.9626 | 0.8717 | 56.9205 | 4.2884 | 11.0989 | 0.0633 | 0.3301 | 0.1606 | 0.4447 |
| | 360 | 37.6761 | 34.4173 | 30.5685 | 35.4792 | 0.0620 | -0.0298 | -0.1386 | 1.0620 | 0.9702 | 0.8614 | 60.9563 | 3.5356 | 13.2326 | 0.0685 | 0.3391 | 0.1696 | 0.4418 |
| 1 ml SIBX (1) | 30 | 41.3143 | 36.1095 | 29.5687 | 36.0873 | 0.1449 | 0.0006 | -0.1806 | 1.1449 | 1.0006 | 0.8194 | 65.1766 | 5.9895 | 22.1451 | 0.0730 | 0.4219 | 0.1814 | 0.4015 |
| | 60 | 41.1392 | 36.0253 | 30.0513 | 36.1400 | 0.1384 | -0.0032 | -0.1685 | 1.1384 | 0.9968 | 0.8315 | 65.0110 | 6.1575 | 20.5369 | 0.0708 | 0.4099 | 0.1806 | 0.4482 |
| | 90 | 40.0110 | 34.8498 | 29.3837 | 35.1350 | 0.1389 | -0.0081 | -0.1639 | 1.1389 | 0.9919 | 0.8361 | 62.6919 | 6.6756 | 19.2397 | 0.0684 | 0.4068 | 0.1756 | 0.4583 |
| | 120 | 39.8387 | 34.7981 | 29.6096 | 35.1220 | 0.1342 | -0.0092 | -0.1569 | 1.1342 | 0.9908 | 0.8431 | 62.5481 | 6.5900 | 18.3812 | 0.0676 | 0.3995 | 0.1749 | 0.4653 |
| | 180 | 36.7463 | 32.0129 | 27.7133 | 32.4895 | 0.1311 | -0.0147 | -0.1471 | 1.1311 | 0.9853 | 0.8529 | 56.7683 | 6.6506 | 15.7819 | 0.0643 | 0.3908 | 0.1613 | 0.4654 |
| | 240 | 37.1181 | 32.9258 | 28.4816 | 33.1571 | 0.1196 | -0.0073 | -0.1408 | 1.1196 | 0.9927 | 0.8592 | 58.3282 | 5.2600 | 15.6894 | 0.0671 | 0.3800 | 0.1629 | 0.4701 |
| | 300 | 37.7144 | 33.7587 | 29.3762 | 33.9205 | 0.1121 | -0.0047 | -0.1343 | 1.1121 | 0.9953 | 0.8657 | 59.9152 | 4.7292 | 15.2951 | 0.0683 | 0.3711 | 0.1656 | 0.4617 |
| | 360 | 37.0015 | 32.8929 | 26.0158 | 32.3597 | 0.1437 | 0.0165 | -0.1965 | 1.1437 | 1.0165 | 0.8035 | 57.9694 | 3.4157 | 22.2544 | 0.0803 | 0.4325 | 0.1624 | 0.4647 |

**Calibrated results for North Parkes underground sulphide ore (continued)**

| | time | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | Hue | Sat | Val | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 ml SIBX (2) | 30 | 34.3771 | 30.4099 | 24.3614 | 30.5524 | 0.1251 | -0.0047 | -0.2026 | 1.1251 | 0.9953 | 0.7974 | 52.8668 | 3.7715 | 19.9841 | 0.0784 | 0.4590 | 0.1564 | 0.4136 |
| | 60 | 38.1178 | 33.4877 | 29.0282 | 34.3956 | 0.1086 | -0.0261 | -0.1568 | 1.1086 | 0.9739 | 0.8432 | 59.7185 | 6.2261 | 16.0810 | 0.0677 | 0.4192 | 0.1734 | 0.4477 |
| | 90 | 38.1426 | 33.5759 | 29.9873 | 34.7176 | 0.0987 | -0.0328 | -0.1363 | 1.0987 | 0.9672 | 0.8637 | 59.9614 | 6.7168 | 13.6195 | 0.0638 | 0.3999 | 0.1736 | 0.4609 |
| | 120 | 38.0303 | 33.4535 | 29.7081 | 34.5512 | 0.1007 | -0.0318 | -0.1402 | 1.1007 | 0.9682 | 0.8598 | 59.6982 | 6.6276 | 14.0660 | 0.0646 | 0.4037 | 0.1730 | 0.4526 |
| | 180 | 37.6730 | 32.8672 | 28.8636 | 33.9697 | 0.1089 | -0.0324 | -0.1502 | 1.1089 | 0.9676 | 0.8498 | 58.5939 | 6.9865 | 14.9951 | 0.0649 | 0.4150 | 0.1714 | 0.4325 |
| | 240 | 38.0091 | 33.0140 | 28.9360 | 34.1696 | 0.1124 | -0.0338 | -0.1532 | 1.1124 | 0.9662 | 0.8468 | 58.9923 | 7.3589 | 15.3580 | 0.0645 | 0.4189 | 0.1729 | 0.4025 |
| | 300 | 38.9244 | 33.7272 | 28.5614 | 34.6491 | 0.1238 | -0.0262 | -0.1766 | 1.1238 | 0.9738 | 0.8234 | 60.4495 | 7.0270 | 18.4942 | 0.0684 | 0.4403 | 0.1771 | 0.3808 |
| | 360 | 40.2467 | 35.1877 | 27.8733 | 35.4406 | 0.1370 | -0.0067 | -0.2159 | 1.1370 | 0.9933 | 0.7841 | 63.1443 | 5.2210 | 24.1388 | 0.0772 | 0.4728 | 0.1831 | 0.3771 |
| 1 ml SIBX (3) | 30 | 49.0164 | 42.6606 | 35.7081 | 44.0640 | 0.1124 | -0.0318 | -0.1897 | 1.1124 | 0.9682 | 0.8103 | 79.0335 | 7.9754 | 23.9709 | 0.0720 | 0.4149 | 0.2206 | 0.4275 |
| | 60 | 47.6412 | 41.0039 | 34.9010 | 42.7330 | 0.1149 | -0.0405 | -0.1832 | 1.1149 | 0.9595 | 0.8168 | 75.9362 | 9.2790 | 21.9849 | 0.0677 | 0.4114 | 0.2144 | 0.3947 |
| | 90 | 48.6261 | 41.9876 | 35.2827 | 43.5577 | 0.1163 | -0.0361 | -0.1898 | 1.1163 | 0.9639 | 0.8102 | 77.8591 | 8.8243 | 23.5700 | 0.0700 | 0.4169 | 0.2189 | 0.3865 |
| | 120 | 46.5006 | 40.2914 | 33.3796 | 41.5896 | 0.1185 | -0.0310 | -0.1982 | 1.1185 | 0.9690 | 0.8018 | 74.1783 | 7.8091 | 23.8303 | 0.0724 | 0.4239 | 0.2093 | 0.5417 |
| | 180 | 43.7201 | 38.1771 | 31.9265 | 39.3687 | 0.1106 | -0.0303 | -0.1891 | 1.1106 | 0.9697 | 0.8109 | 69.5947 | 6.8379 | 21.5664 | 0.0727 | 0.4134 | 0.1968 | 0.3842 |
| | 240 | 40.5756 | 35.8876 | 30.5386 | 36.9697 | 0.0977 | -0.0293 | -0.1742 | 1.0977 | 0.9707 | 0.8258 | 64.5610 | 5.6127 | 18.4831 | 0.0726 | 0.3956 | 0.1826 | 0.3806 |
| | 300 | 39.7447 | 35.0617 | 30.2696 | 36.2916 | 0.0952 | -0.0339 | -0.1660 | 1.0952 | 0.9661 | 0.8340 | 62.9316 | 6.0347 | 16.9840 | 0.0700 | 0.3883 | 0.1789 | 0.3805 |
| | 360 | 41.8482 | 36.8512 | 32.1211 | 38.2667 | 0.0937 | -0.0370 | -0.1608 | 1.0937 | 0.9630 | 0.8392 | 66.7593 | 6.7117 | 17.0158 | 0.0682 | 0.3836 | 0.1884 | 0.3827 |
| 2 ml SIBX (1) | 30 | 54.4572 | 45.5675 | 33.0006 | 49.4609 | 0.1011 | -0.0787 | -0.3329 | 1.1011 | 0.9213 | 0.6671 | 85.7994 | 10.4171 | 40.7103 | 0.0787 | 0.5108 | 0.2621 | 0.1836 |
| | 60 | 54.5830 | 45.7752 | 33.2023 | 49.6531 | 0.0994 | -0.0781 | -0.3314 | 1.0994 | 0.9219 | 0.6686 | 86.1655 | 10.1974 | 40.6481 | 0.0789 | 0.5090 | 0.2627 | 0.1463 |
| | 90 | 52.8471 | 44.0619 | 32.3172 | 48.0385 | 0.1005 | -0.0828 | -0.3277 | 1.1005 | 0.9172 | 0.6723 | 82.7977 | 10.7456 | 38.5778 | 0.0770 | 0.5066 | 0.2544 | 0.1823 |
| | 120 | 52.5471 | 43.8753 | 34.4086 | 48.5400 | 0.0835 | -0.0963 | -0.2921 | 1.0835 | 0.9037 | 0.7079 | 82.5458 | 11.7042 | 32.5811 | 0.0708 | 0.4723 | 0.2529 | 0.1620 |
| | 180 | 55.6266 | 47.1139 | 36.5487 | 51.6639 | 0.0768 | -0.0881 | -0.2927 | 1.0768 | 0.9119 | 0.7073 | 88.8268 | 10.4303 | 35.1754 | 0.0741 | 0.4695 | 0.2678 | 0.1514 |
| | 240 | 56.2531 | 47.4692 | 36.5273 | 52.0401 | 0.0810 | -0.0879 | -0.2980 | 1.0810 | 0.9121 | 0.7020 | 89.6569 | 10.8207 | 36.3716 | 0.0743 | 0.4756 | 0.2708 | 0.1299 |
| | 300 | 55.4232 | 46.4882 | 35.4356 | 50.9895 | 0.0872 | -0.0884 | -0.3052 | 1.0872 | 0.9116 | 0.6948 | 87.7802 | 11.2054 | 36.8291 | 0.0744 | 0.4839 | 0.2668 | 0.1212 |
| | 360 | 54.7587 | 45.8642 | 35.1685 | 50.4064 | 0.0864 | -0.0902 | -0.3023 | 1.0864 | 0.9098 | 0.6977 | 86.5424 | 11.3629 | 35.8948 | 0.0736 | 0.4815 | 0.2636 | 0.1060 |
| 2 ml SIBX (2) | 30 | 59.9313 | 50.8697 | 37.0083 | 49.5506 | 0.2096 | 0.0266 | -0.2532 | 1.2096 | 1.0266 | 0.7468 | 96.3347 | 9.6043 | 43.9626 | 0.0788 | 0.5099 | 0.2624 | 0.1891 |
| | 60 | 57.4605 | 48.4624 | 36.6682 | 47.7586 | 0.2037 | 0.0146 | -0.2328 | 1.2037 | 1.0146 | 0.7672 | 91.6844 | 10.7664 | 38.7180 | 0.0741 | 0.4938 | 0.2516 | 0.1842 |
| | 90 | 61.3706 | 52.7547 | 41.1078 | 51.9019 | 0.1826 | 0.0164 | -0.2081 | 1.1826 | 1.0164 | 0.7919 | 100.0000 | 9.5850 | 37.8474 | 0.0742 | 0.4684 | 0.2687 | 0.1705 |
| | 120 | 61.5557 | 52.6003 | 40.8179 | 51.8356 | 0.1875 | 0.0146 | -0.2124 | 1.1875 | 1.0146 | 0.7876 | 99.8711 | 10.3026 | 38.4881 | 0.0737 | 0.4735 | 0.2695 | 0.1751 |
| | 180 | 60.9832 | 51.8617 | 39.7397 | 51.0672 | 0.1943 | 0.0155 | -0.2219 | 1.1943 | 1.0155 | 0.7781 | 98.4726 | 10.5614 | 39.5337 | 0.0743 | 0.4828 | 0.2670 | 0.1540 |
| | 240 | 57.7203 | 48.8280 | 38.1251 | 48.4030 | 0.1926 | 0.0087 | -0.2123 | 1.1926 | 1.0087 | 0.7877 | 92.4428 | 11.0840 | 35.7862 | 0.0716 | 0.4757 | 0.2527 | 0.1217 |
| | 300 | 53.6107 | 43.4288 | 32.1211 | 43.3684 | 0.2403 | 0.0012 | -0.2643 | 1.2403 | 1.0012 | 0.7357 | 82.3962 | 14.3356 | 38.7126 | 0.0706 | 0.5284 | 0.2347 | 0.1147 |
| | 360 | 53.9157 | 43.5113 | 34.0828 | 44.0880 | 0.2238 | -0.0128 | -0.2283 | 1.2238 | 0.9872 | 0.7717 | 82.8472 | 15.8018 | 34.0383 | 0.0646 | 0.4991 | 0.2361 | 0.0712 |

**Data for reagent test 1 (calibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 1, cell 2 | -1.3250 | -1.4958 | 2.3537 | 65.6991 | 56.6729 | 50.1159 | 57.4960 | 0.1427 | -0.0143 | -0.1284 | 1.1427 | 0.9857 | 0.8716 | 90.4299 | 11.5342 | 21.0561 | 45.4875 |
| | -1.1608 | -1.6948 | 2.4294 | 66.8135 | 57.5484 | 50.6894 | 58.3504 | 0.1450 | -0.0137 | -0.1313 | 1.1450 | 0.9863 | 0.8687 | 91.9915 | 11.7694 | 21.8877 | 47.6469 |
| | -1.4381 | -1.9600 | 2.6398 | 67.7094 | 58.0872 | 51.2558 | 59.0175 | 0.1473 | -0.0158 | -0.1315 | 1.1473 | 0.9842 | 0.8685 | 93.0692 | 12.4358 | 22.0640 | 47.8350 |
| | -0.8224 | -1.3596 | 2.2454 | 67.8391 | 58.2115 | 51.3270 | 59.1259 | 0.1474 | -0.0155 | -0.1319 | 1.1474 | 0.9845 | 0.8681 | 93.2765 | 12.4093 | 22.1848 | 48.6525 |
| | -1.1491 | -2.2050 | 2.7491 | 67.9366 | 58.0185 | 51.1085 | 59.0212 | 0.1511 | -0.0170 | -0.1341 | 1.1511 | 0.9830 | 0.8659 | 93.0849 | 12.9512 | 22.4583 | 47.5190 |
| | -1.0474 | -1.8739 | 2.4249 | 70.3114 | 62.6622 | 57.1156 | 63.3631 | 0.1097 | -0.0111 | -0.0986 | 1.1097 | 0.9889 | 0.9014 | 100.0000 | 9.3920 | 17.6269 | 31.3674 |
| | -1.0175 | -1.5127 | 2.1985 | 69.8616 | 62.1620 | 56.5656 | 62.8631 | 0.1113 | -0.0112 | -0.1002 | 1.1113 | 0.9888 | 0.8998 | 99.1756 | 9.4666 | 17.7865 | 40.2683 |
| | -0.5499 | -0.6968 | 1.2616 | 69.2850 | 61.5660 | 55.7914 | 62.2141 | 0.1137 | -0.0104 | -0.1032 | 1.1137 | 0.9896 | 0.8968 | 98.1636 | 9.4052 | 18.2205 | 36.6314 |
| | -0.3865 | -0.3512 | 1.0234 | 69.5962 | 61.7665 | 56.1140 | 62.4922 | 0.1137 | -0.0116 | -0.1021 | 1.1137 | 0.9884 | 0.8979 | 98.5622 | 9.6816 | 18.0135 | 34.4828 |
| | -0.1797 | -0.1176 | 1.4118 | 70.1635 | 62.2608 | 56.5891 | 63.0045 | 0.1136 | -0.0118 | -0.1018 | 1.1136 | 0.9882 | 0.8982 | 99.4248 | 9.7898 | 18.0957 | 41.7925 |
| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
| reagent test 1, cell 2 | 0.0701 | 0.2372 | 0.2576 | 6.2047 | 4.1946 | 55.9398 | 24.0083 | 29.0000 | 28.4000 | 1.4100 | 34.2000 | 8.5900 | 26.5000 | 27.6000 | 1.7200 | 33.7000 | 10.0400 |
| | 0.0709 | 0.2413 | 0.2620 | 6.3817 | 4.3617 | 55.6486 | 24.8513 | 28.8000 | 28.3000 | 1.4600 | 34.0000 | 8.8200 | 27.1000 | 27.6000 | 1.6400 | 33.2000 | 10.3300 |
| | 0.0692 | 0.2430 | 0.2655 | 6.5985 | 4.4023 | 56.2901 | 25.3272 | 28.9000 | 28.4000 | 1.4200 | 34.1000 | 8.6100 | 27.1000 | 27.6000 | 1.6500 | 33.4000 | 10.1100 |
| | 0.0695 | 0.2434 | 0.2660 | 6.6071 | 4.4263 | 56.1806 | 25.4196 | 28.9000 | 28.4000 | 1.3600 | 34.1000 | 8.4000 | 27.9000 | 28.1000 | 1.4700 | 33.7000 | 9.5700 |
| | 0.0684 | 0.2477 | 0.2664 | 6.7883 | 4.4803 | 56.5752 | 25.9250 | 28.9000 | 28.4000 | 1.2900 | 34.5000 | 8.3700 | 27.7000 | 27.6000 | 1.5400 | 33.2000 | 10.1800 |
| | 0.0701 | 0.1877 | 0.2757 | 5.2571 | 3.5503 | 55.9676 | 19.9729 | 29.9000 | 28.4000 | 0.9400 | 33.5000 | 9.1100 | 27.5000 | 26.2000 | 1.1300 | 31.3000 | 13.5500 |
| | 0.0702 | 0.1903 | 0.2740 | 5.2930 | 3.5794 | 55.9313 | 20.1488 | 29.8000 | 28.4000 | 0.9300 | 33.4000 | 9.3400 | 27.8000 | 26.7000 | 1.2400 | 31.7000 | 12.5000 |
| | 0.0713 | 0.1948 | 0.2717 | 5.3228 | 3.6602 | 55.4858 | 20.5048 | 29.9000 | 28.5000 | 0.9600 | 33.4000 | 8.9900 | 27.6000 | 26.7000 | 1.1700 | 31.6000 | 12.7900 |
| | 0.0699 | 0.1937 | 0.2729 | 5.3786 | 3.6232 | 56.0347 | 20.4504 | 30.0000 | 28.7000 | 0.8700 | 33.8000 | 8.5300 | 27.1000 | 25.8000 | 1.1500 | 30.3000 | 15.1500 |
| | 0.0696 | 0.1935 | 0.2752 | 5.4254 | 3.6423 | 56.1250 | 20.5741 | 29.6000 | 28.4000 | 1.0000 | 34.0000 | 8.7600 | 28.4000 | 27.4000 | 1.2300 | 32.6000 | 11.0500 |

**Data for reagent test 2 (calibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 2 | 0.43 | -1.67 | 2.45 | 37.21 | 33.10 | 21.72 | 30.67 | 0.21 | 0.08 | -0.29 | 1.21 | 1.08 | 0.71 | 47.30 | 0.79 | 29.03 | 53.37 |
| | 0.34 | -1.63 | 2.11 | 37.03 | 32.93 | 21.27 | 30.41 | 0.22 | 0.08 | -0.30 | 1.22 | 1.08 | 0.70 | 46.99 | 0.68 | 29.63 | 49.08 |
| | 0.26 | -1.44 | 2.49 | 37.09 | 32.97 | 21.12 | 30.40 | 0.22 | 0.08 | -0.31 | 1.22 | 1.08 | 0.69 | 47.06 | 0.63 | 30.04 | 48.74 |
| | 0.09 | -1.31 | 2.81 | 36.76 | 32.65 | 21.11 | 30.17 | 0.22 | 0.08 | -0.30 | 1.22 | 1.08 | 0.70 | 46.51 | 0.78 | 29.39 | 47.20 |
| | 0.50 | -1.44 | 2.30 | 36.38 | 32.23 | 21.28 | 29.96 | 0.21 | 0.08 | -0.29 | 1.21 | 1.08 | 0.71 | 45.83 | 1.12 | 28.15 | 57.61 |
| | 0.13 | -0.67 | 2.39 | 37.18 | 37.93 | 24.97 | 33.36 | 0.11 | 0.14 | -0.25 | 1.11 | 1.14 | 0.75 | 53.54 | -10.23 | 29.38 | 39.28 |
| | 0.18 | -1.16 | 2.42 | 37.18 | 37.94 | 24.60 | 33.24 | 0.12 | 0.14 | -0.26 | 1.12 | 1.14 | 0.74 | 53.53 | -10.41 | 30.18 | 41.25 |
| | 0.12 | -1.35 | 2.84 | 37.45 | 38.14 | 24.43 | 33.34 | 0.12 | 0.14 | -0.27 | 1.12 | 1.14 | 0.73 | 53.88 | -10.46 | 31.00 | 42.81 |
| | -0.18 | -0.91 | 2.13 | 36.77 | 37.49 | 23.75 | 32.67 | 0.13 | 0.15 | -0.27 | 1.13 | 1.15 | 0.73 | 52.75 | -10.51 | 31.04 | 41.41 |
| | 0.47 | -0.97 | 2.71 | 37.61 | 38.31 | 24.31 | 33.41 | 0.13 | 0.15 | -0.27 | 1.13 | 1.15 | 0.73 | 54.16 | -10.64 | 31.61 | 41.45 |
| | **Hue** | **Sat** | **Val** | **Cr** | **Cb** | **RGB angle** | **Length** | **Cu (con)** | **Fe** | **MoS2** | **S** | **Insol** | **Cu (top)** | **Fe** | **MoS2** | **S** | **Insol** |
| reagent test 2, cell 2 | 0.12 | 0.42 | 0.15 | 3.66 | 5.58 | 33.31 | 29.04 | 30.40 | 28.30 | 1.59 | 32.30 | 8.86 | 30.60 | 28.60 | 1.47 | 33.80 | 8.19 |
| | 0.12 | 0.43 | 0.15 | 3.69 | 5.70 | 32.90 | 29.64 | 30.60 | 28.40 | 1.56 | 32.80 | 8.32 | 30.60 | 28.60 | 1.48 | 33.50 | 8.38 |
| | 0.12 | 0.43 | 0.15 | 3.71 | 5.78 | 32.72 | 30.04 | 30.60 | 28.40 | 1.66 | 32.90 | 8.51 | 30.50 | 28.50 | 1.51 | 33.50 | 8.28 |
| | 0.12 | 0.43 | 0.14 | 3.68 | 5.65 | 33.11 | 29.40 | 30.50 | 28.50 | 1.73 | 33.10 | 8.30 | 30.40 | 28.40 | 1.53 | 33.00 | 8.26 |
| | 0.12 | 0.41 | 0.14 | 3.64 | 5.39 | 34.03 | 28.17 | 30.80 | 26.10 | 1.28 | 31.40 | 12.77 | 30.70 | 28.60 | 1.47 | 33.50 | 8.37 |
| | 0.18 | 0.34 | 0.15 | 0.83 | 5.55 | 8.54 | 31.11 | 28.10 | 28.60 | 1.46 | 33.20 | 8.41 | 29.80 | 27.80 | 1.24 | 33.40 | 9.54 |
| | 0.18 | 0.35 | 0.15 | 0.87 | 5.72 | 8.64 | 31.92 | 28.70 | 26.80 | 1.36 | 32.30 | 11.10 | 29.80 | 27.80 | 1.22 | 33.60 | 9.54 |
| | 0.18 | 0.36 | 0.15 | 0.95 | 5.89 | 9.15 | 32.72 | 28.90 | 27.00 | 1.30 | 32.10 | 11.24 | 29.70 | 27.80 | 1.23 | 33.60 | 9.53 |
| | 0.18 | 0.37 | 0.15 | 0.93 | 5.90 | 8.95 | 32.77 | 28.30 | 26.40 | 1.38 | 31.50 | 11.98 | 29.90 | 28.10 | 1.20 | 33.50 | 9.33 |
| | 0.18 | 0.37 | 0.15 | 0.97 | 6.01 | 9.13 | 33.35 | 28.90 | 27.00 | 1.32 | 32.20 | 11.00 | 29.90 | 28.00 | 1.18 | 33.60 | 9.33 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 4 | -0.0588 | -0.5203 | 2.3768 | 29.8926 | 27.0392 | 21.5540 | 26.1619 | 0.1426 | 0.0335 | -0.1761 | 1.1426 | 1.0335 | 0.8239 | 36.4442 | 1.4611 | 15.0832 | 0.1096 |
| | -0.1063 | -0.7089 | 2.2757 | 30.6840 | 27.6842 | 21.9645 | 26.7776 | 0.1459 | 0.0339 | -0.1797 | 1.1459 | 1.0339 | 0.8203 | 37.6387 | 1.5937 | 15.7158 | 0.1093 |
| | -0.1677 | -0.5743 | 2.6125 | 30.3733 | 27.3400 | 21.6532 | 26.4555 | 0.1481 | 0.0334 | -0.1815 | 1.1481 | 1.0334 | 0.8185 | 37.0459 | 1.6975 | 15.6726 | 0.1087 |
| | 0.0411 | -0.2896 | 2.7908 | 29.8363 | 26.8770 | 21.2363 | 25.9832 | 0.1483 | 0.0344 | -0.1827 | 1.1483 | 1.0344 | 0.8173 | 36.1923 | 1.5965 | 15.5260 | 0.1093 |
| | -0.0393 | -0.7062 | 2.1518 | 29.5957 | 26.6375 | 21.1438 | 25.7923 | 0.1475 | 0.0328 | -0.1802 | 1.1475 | 1.0328 | 0.8198 | 35.7778 | 1.6888 | 15.1886 | 0.1083 |
| | -0.1688 | -0.5924 | 2.5106 | 32.3975 | 29.3806 | 23.8109 | 28.5297 | 0.1356 | 0.0298 | -0.1654 | 1.1356 | 1.0298 | 0.8346 | 40.6650 | 1.6351 | 15.3293 | 0.1081 |
| | -0.1362 | -0.4415 | 2.7710 | 34.2583 | 31.4452 | 25.4703 | 30.3913 | 0.1272 | 0.0347 | -0.1619 | 1.1272 | 1.0347 | 0.8381 | 44.1832 | 0.9053 | 16.0777 | 0.1133 |
| | 0.0005 | -0.5265 | 2.3647 | 34.4683 | 31.6243 | 25.7001 | 30.5976 | 0.1265 | 0.0336 | -0.1601 | 1.1265 | 1.0336 | 0.8399 | 44.5171 | 0.9895 | 15.9760 | 0.1126 |
| | -0.0686 | -0.7496 | 2.4890 | 35.3208 | 32.3511 | 26.3777 | 31.3499 | 0.1267 | 0.0319 | -0.1586 | 1.1267 | 1.0319 | 0.8414 | 45.8487 | 1.1820 | 16.1573 | 0.1113 |
| | 0.0082 | -0.4290 | 3.0033 | 35.4394 | 32.5237 | 26.7933 | 31.5854 | 0.1220 | 0.0297 | -0.1517 | 1.1220 | 1.0297 | 0.8483 | 46.1489 | 1.2137 | 15.5493 | 0.1105 |
| | **Hue** | **Sat** | **Val** | **Cr** | **Cb** | **RGB angle** | **Length** | **Cu (con)** | **Fe** | **MoS2** | **S** | **Insol** | | | | | |
| reagent test 2, cell 4 | 0.1096 | 0.2790 | 0.1172 | 2.3026 | 2.8165 | 39.2672 | 15.1538 | 30.6000 | 28.1000 | 1.5400 | 33.5000 | 8.2300 | | | | | |
| | 0.1093 | 0.2842 | 0.1203 | 2.4160 | 2.9405 | 39.4077 | 15.7964 | 30.3000 | 27.9000 | 1.6800 | 33.4000 | 8.4700 | | | | | |
| | 0.1087 | 0.2871 | 0.1191 | 2.4333 | 2.9311 | 39.6986 | 15.7642 | 30.8000 | 28.2000 | 1.4600 | 33.5000 | 8.2400 | | | | | |
| | 0.1093 | 0.2882 | 0.1170 | 2.3832 | 2.9001 | 39.4129 | 15.6079 | 30.6000 | 28.2000 | 1.5300 | 33.7000 | 8.1500 | | | | | |
| | 0.1083 | 0.2856 | 0.1161 | 2.3678 | 2.8357 | 39.8623 | 15.2822 | 30.5000 | 28.0000 | 1.5000 | 33.8000 | 8.2500 | | | | | |
| | 0.1081 | 0.2650 | 0.1270 | 2.4116 | 2.8775 | 39.9653 | 15.4163 | 27.3000 | 25.1000 | 1.2500 | 30.5000 | 14.6200 | | | | | |
| | 0.1133 | 0.2565 | 0.1343 | 2.3268 | 3.0245 | 37.5720 | 16.1032 | 28.7000 | 26.6000 | 1.3800 | 32.1000 | 11.4000 | | | | | |
| | 0.1126 | 0.2544 | 0.1352 | 2.3407 | 3.0069 | 37.8987 | 16.0066 | 27.2000 | 25.0000 | 1.2800 | 29.8000 | 15.2100 | | | | | |
| | 0.1113 | 0.2532 | 0.1385 | 2.4229 | 3.0469 | 38.4919 | 16.2005 | 27.9000 | 25.8000 | 1.2800 | 31.0000 | 13.4100 | | | | | |
| | 0.1105 | 0.2440 | 0.1390 | 2.3654 | 2.9328 | 38.8870 | 15.5966 | 29.4000 | 27.3000 | 1.2500 | 33.0000 | 10.0000 | | | | | |

**Data for reagent test 3 (rejected for analysis) (calibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 2 | 0.2615 | -1.8320 | 2.4840 | 45.4530 | 41.3867 | 32.1734 | 39.6710 | 0.1457 | 0.0432 | -0.1890 | 1.1457 | 1.0432 | 0.8110 | 61.8264 | 1.1335 | 24.0888 |
| | 0.2055 | -1.2638 | 2.1799 | 40.6055 | 36.6160 | 27.1551 | 34.7922 | 0.1671 | 0.0524 | -0.2195 | 1.1671 | 1.0524 | 0.7805 | 53.5004 | 1.1204 | 24.7116 |
| | 0.1620 | -1.6065 | 2.5522 | 44.2915 | 39.8507 | 29.4796 | 37.8739 | 0.1694 | 0.0522 | -0.2216 | 1.1694 | 1.0522 | 0.7784 | 59.2542 | 1.3756 | 26.9760 |
| | 0.2420 | -1.5917 | 2.7535 | 40.4450 | 36.6746 | 27.8685 | 34.9960 | 0.1557 | 0.0480 | -0.2037 | 1.1557 | 1.0480 | 0.7963 | 53.5503 | 1.0070 | 23.0883 |
| | 0.4053 | -2.1573 | 2.1329 | 34.8482 | 32.0630 | 23.5963 | 30.1692 | 0.1551 | 0.0628 | -0.2179 | 1.1551 | 1.0628 | 0.7821 | 45.0631 | -0.5469 | 21.7587 |
| | 0.3137 | -1.3455 | 2.2749 | 36.7313 | 33.9558 | 25.9480 | 32.2117 | 0.1403 | 0.0541 | -0.1945 | 1.1403 | 1.0541 | 0.8055 | 48.4141 | -0.4271 | 20.6703 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 2 | 0.1156 | 0.2922 | 0.1782 | 3.4210 | 4.6237 | 36.4972 | 24.1155 | 27.1000 | 28.3000 | 1.3500 | 34.0000 | 8.6300 | 33.0749 |
| | 0.1172 | 0.3312 | 0.1592 | 3.3985 | 4.7206 | 35.7511 | 24.7370 | 28.0000 | 28.2000 | 1.4200 | 34.2000 | 8.6900 | 25.4009 |
| | 0.1167 | 0.3344 | 0.1737 | 3.7670 | 5.1847 | 36.0011 | 27.0111 | 28.7000 | 28.4000 | 1.4300 | 33.9000 | 8.4600 | 25.7276 |
| | 0.1167 | 0.3110 | 0.1586 | 3.1984 | 4.4023 | 35.9991 | 23.1103 | 26.4000 | 27.3000 | 1.4200 | 32.9000 | 11.8400 | 25.6747 |
| | 0.1254 | 0.3229 | 0.1367 | 2.5588 | 4.1088 | 31.9126 | 21.7656 | 26.3000 | 27.1000 | 1.3400 | 32.0000 | 12.7500 | 18.4895 |
| | 0.1238 | 0.2936 | 0.1440 | 2.5069 | 3.9069 | 32.6869 | 20.6748 | 25.3000 | 25.4000 | 1.3200 | 30.5000 | 15.8100 | 18.6158 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 4 | -0.1119 | -0.9629 | 0.3307 | 39.2470 | 36.1778 | 28.3719 | 34.5989 | 0.1343 | 0.0456 | -0.1800 | 1.1343 | 1.0456 | 0.8200 | 52.4463 | 0.1683 | 20.3525 |
| | 0.0069 | -0.2842 | 0.2540 | 41.4985 | 36.4910 | 26.8139 | 34.9345 | 0.1879 | 0.0446 | -0.2325 | 1.1879 | 1.0446 | 0.7675 | 53.7419 | 3.0929 | 25.9049 |
| | -0.0891 | -0.1517 | 0.2573 | 38.2346 | 35.6298 | 29.7163 | 34.5269 | 0.1074 | 0.0319 | -0.1393 | 1.1074 | 1.0319 | 0.8607 | 51.4435 | 0.3918 | 15.6866 |
| | 0.0144 | -0.0606 | 0.2567 | 38.8096 | 36.3766 | 30.8144 | 35.3335 | 0.0984 | 0.0295 | -0.1279 | 1.0984 | 1.0295 | 0.8721 | 52.7066 | 0.2611 | 14.7353 |
| | -0.1225 | -0.2891 | 0.1849 | 38.9056 | 35.8937 | 28.4268 | 34.4087 | 0.1307 | 0.0432 | -0.1738 | 1.1307 | 1.0432 | 0.8262 | 51.9520 | 0.2575 | 19.5450 |
| | -0.0073 | -0.4028 | 0.1862 | 38.6074 | 35.6401 | 28.6606 | 34.3027 | 0.1255 | 0.0390 | -0.1645 | 1.1255 | 1.0390 | 0.8355 | 51.5292 | 0.4598 | 18.4004 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 4 | 0.1196 | 0.2771 | 0.1539 | 2.6673 | 3.8620 | 34.6305 | 20.3532 | 18.1400 | 24.8400 | 1.4900 | 27.7700 | 22.4000 | 18.1400 |
| | 0.1098 | 0.3539 | 0.1627 | 4.0460 | 4.9651 | 39.1759 | 26.0889 | 17.0700 | 23.3100 | 1.5100 | 25.3700 | 26.7900 | 17.0700 |
| | 0.1157 | 0.2228 | 0.1499 | 2.1926 | 2.9669 | 36.4651 | 15.6915 | 17.4500 | 21.5900 | 1.4500 | 22.6400 | 29.0000 | 17.4500 |
| | 0.1159 | 0.2060 | 0.1522 | 2.0519 | 2.7882 | 36.3499 | 14.7376 | 18.8200 | 23.7000 | 1.2000 | 24.4400 | 27.7600 | 18.8200 |
| | 0.1188 | 0.2693 | 0.1526 | 2.5982 | 3.7055 | 35.0366 | 19.5466 | 13.0200 | 16.6300 | 1.0400 | 15.3100 | 43.2800 | 13.0200 |
| | 0.1169 | 0.2576 | 0.1514 | 2.5220 | 3.4860 | 35.8844 | 18.4061 | 11.2900 | 14.5600 | 0.9910 | 13.6000 | 46.6500 | 11.2900 |

**Data for reagent test 4 (calibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green nori | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 4, cell 2 | 0.0934 | -1.3176 | 2.4992 | 45.4603 | 42.6734 | 32.7107 | 40.2815 | 0.1286 | 0.0594 | -0.1879 | 1.1286 | 1.0594 | 0.8121 | 63.43 | -1.86 | 24.90 |
| | 0.1140 | -0.8522 | 2.4034 | 46.5743 | 43.5731 | 33.0450 | 41.0641 | 0.1342 | 0.0611 | -0.1953 | 1.1342 | 1.0611 | 0.8047 | 65.03 | -1.78 | 26.28 |
| | 0.3458 | -0.7879 | 2.1074 | 47.4124 | 44.3809 | 33.6260 | 41.8065 | 0.1341 | 0.0616 | -0.1957 | 1.1341 | 1.0616 | 0.8043 | 66.42 | -1.88 | 26.79 |
| | 0.0201 | -0.9232 | 2.6941 | 47.6079 | 44.5154 | 33.5167 | 41.8800 | 0.1368 | 0.0629 | -0.1997 | 1.1368 | 1.0629 | 0.8003 | 66.66 | -1.89 | 27.37 |
| | -0.0041 | -0.5152 | 3.0059 | 47.4934 | 44.2227 | 33.2156 | 41.6439 | 0.1405 | 0.0619 | -0.2024 | 1.1405 | 1.0619 | 0.7976 | 66.23 | -1.53 | 27.51 |
| | 0.4307 | -2.0478 | 2.2619 | 34.3311 | 32.1719 | 26.6327 | 31.0452 | 0.1058 | 0.0363 | -0.1421 | 1.1058 | 1.0363 | 0.8579 | 45.21 | -0.15 | 14.60 |
| | 0.5371 | -2.3094 | 2.1213 | 28.7616 | 27.6893 | 24.9853 | 27.1454 | 0.0595 | 0.0200 | -0.0796 | 1.0595 | 1.0200 | 0.9204 | 37.07 | -0.24 | 7.24 |
| | 0.7405 | -2.7194 | 2.3223 | 29.7677 | 28.6791 | 25.5691 | 28.0053 | 0.0629 | 0.0241 | -0.0870 | 1.0629 | 1.0241 | 0.9130 | 38.80 | -0.52 | 8.21 |
| | 0.7532 | -2.5075 | 1.9596 | 29.9129 | 28.7249 | 25.6908 | 28.1096 | 0.0642 | 0.0219 | -0.0860 | 1.0642 | 1.0219 | 0.9140 | 38.93 | -0.27 | 8.09 |
| | 0.6095 | -3.0173 | 1.8000 | 29.9221 | 28.7158 | 25.6313 | 28.0897 | 0.0652 | 0.0223 | -0.0875 | 1.0652 | 1.0223 | 0.9125 | 38.92 | -0.27 | 8.23 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 4, cell 2 | 0.1302 | 0.2805 | 0.1783 | 2.7094 | 4.7625 | 29.6358 | 24.9679 | 27.9000 | 27.1000 | 1.3000 | 32.6000 | 11.2800 | 21.1103 |
| | 0.1297 | 0.2905 | 0.1826 | 2.8976 | 5.0410 | 29.8907 | 26.3450 | 27.3000 | 26.5000 | 1.4400 | 32.5000 | 11.4400 | 20.3375 |
| | 0.1300 | 0.2908 | 0.1859 | 2.9389 | 5.1446 | 29.7378 | 26.8592 | 27.4000 | 26.8000 | 1.3100 | 32.7000 | 11.9400 | 32.7280 |
| | 0.1301 | 0.2960 | 0.1867 | 3.0008 | 5.2601 | 29.7044 | 27.4389 | 27.1000 | 26.7000 | 1.3500 | 32.7000 | 12.5600 | 22.8510 |
| | 0.1285 | 0.3006 | 0.1862 | 3.1112 | 5.2900 | 30.4612 | 27.5568 | 27.1000 | 26.8000 | 1.2600 | 32.2000 | 11.9600 | 24.9879 |
| | 0.1199 | 0.2242 | 0.1346 | 1.8812 | 2.7378 | 34.4943 | 14.6001 | 23.1000 | 28.1000 | 1.0300 | 31.6000 | 15.4100 | 26.2063 |
| | 0.1193 | 0.1313 | 0.1128 | 0.9296 | 1.3391 | 34.7665 | 7.2448 | 23.6000 | 28.8000 | 1.0800 | 32.0000 | 14.2200 | 33.9869 |
| | 0.1235 | 0.1410 | 0.1167 | 0.9802 | 1.5189 | 32.8347 | 8.2265 | 22.8000 | 27.8000 | 1.0100 | 31.3000 | 16.2600 | 33.4669 |
| | 0.1198 | 0.1411 | 0.1173 | 1.0337 | 1.5004 | 34.5647 | 8.0971 | 23.0000 | 27.7000 | 1.0600 | 30.8000 | 17.1200 | 34.1277 |
| | 0.1198 | 0.1434 | 0.1173 | 1.0500 | 1.5251 | 34.5452 | 8.2302 | 23.2000 | 27.8000 | 1.1000 | 30.9000 | 16.5200 | 39.1608 |

Data for reagent test 5 (calibrated)

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 2 | 0.2817 | -1.4596 | 1.9921 | 51.5803 | 54.9038 | 47.1725 | 51.2189 | 0.0071 | 0.0719 | -0.0790 | 1.0071 | 1.0719 | 0.9210 | 82.2490 | -11.9486 | 15.9524 | |
| | 0.4935 | -1.6583 | 1.9525 | 50.3274 | 53.4384 | 45.5173 | 49.7610 | 0.0114 | 0.0739 | -0.0853 | 1.0114 | 1.0739 | 0.9147 | 79.8051 | -11.7238 | 16.5285 | |
| | 0.0692 | -1.3837 | 2.1796 | 49.7062 | 52.6834 | 44.9188 | 49.1028 | 0.0123 | 0.0729 | -0.0852 | 1.0123 | 1.0729 | 0.9148 | 78.5774 | -11.3766 | 16.2577 | |
| | 0.3335 | -1.3180 | 1.9656 | 51.1575 | 54.0152 | 45.4659 | 50.2129 | 0.0188 | 0.0757 | -0.0945 | 1.0188 | 1.0757 | 0.9055 | 80.8210 | -11.7231 | 18.0902 | |
| | 0.2995 | -1.6210 | 2.1153 | 51.6163 | 54.5213 | 45.4562 | 50.5313 | 0.0215 | 0.0790 | -0.1004 | 1.0215 | 1.0790 | 0.8996 | 81.6200 | -12.1717 | 19.2279 | |
| | 0.4567 | -1.4660 | 1.9223 | 40.1604 | 42.2503 | 34.5981 | 39.0030 | 0.0297 | 0.0833 | -0.1129 | 1.0297 | 1.0833 | 0.8871 | 60.9473 | -9.7414 | 16.6927 | |
| | 0.3477 | -1.9859 | 2.4705 | 36.6604 | 38.7037 | 32.2872 | 35.8838 | 0.0216 | 0.0786 | -0.1002 | 1.0216 | 1.0786 | 0.8998 | 54.9086 | -8.7920 | 13.9323 | |
| | 0.5336 | -1.7628 | 2.2758 | 35.9333 | 37.7996 | 31.6344 | 35.1224 | 0.0231 | 0.0762 | -0.0993 | 1.0231 | 1.0762 | 0.9007 | 53.4185 | -8.2889 | 13.4653 | |
| | 0.3693 | -2.2462 | 2.4870 | 35.9402 | 37.7347 | 31.5253 | 35.0667 | 0.0249 | 0.0761 | -0.1010 | 1.0249 | 1.0761 | 0.8990 | 53.3274 | -8.1888 | 13.6102 | |
| | 0.5019 | -1.9425 | 2.2942 | 35.3276 | 37.0627 | 30.4661 | 34.2855 | 0.0304 | 0.0810 | -0.1114 | 1.0304 | 1.0810 | 0.8886 | 52.1384 | -8.3561 | 14.5578 | |
| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
| reagent test 5, cell 2 | 0.2383 | 0.1408 | 0.2153 | -1.2702 | 2.8871 | 23.7479 | 2.2137 | 27.3000 | 27.5000 | 0.8400 | | 9.2400 | 31.0000 | 28.4000 | 1.4200 | 34.0000 | 8.07 |
| | 0.2321 | 0.1482 | 0.2096 | -1.1207 | 3.0014 | 20.4748 | 2.1877 | 26.6000 | 27.0000 | 0.8400 | | 10.4700 | 31.0000 | 28.4000 | 1.4300 | 33.9000 | 7.9 |
| | 0.2306 | 0.1474 | 0.2066 | -1.0540 | 2.9527 | 19.6454 | 2.1814 | 27.9000 | 27.9000 | 0.8400 | | 8.6100 | 30.9000 | 28.4000 | 1.4300 | 34.0000 | 7.79 |
| | 0.2224 | 0.1583 | 0.2118 | -0.9021 | 3.3130 | 15.2317 | 2.1458 | 26.6000 | 27.1000 | 0.9000 | | 9.7600 | 31.1000 | 28.6000 | 1.4000 | 34.2000 | 7.58 |
| | 0.2201 | 0.1663 | 0.2138 | -0.8796 | 3.5314 | 13.9866 | 2.1351 | 27.2000 | 27.6000 | 0.8400 | | 8.7000 | 31.1000 | 28.4000 | 1.3900 | 33.8000 | 7.9 |
| | 0.2122 | 0.1811 | 0.1657 | -0.5198 | 3.0344 | 9.7206 | 2.0991 | 26.9000 | 28.5000 | 0.6900 | | 8.6200 | 30.5000 | 28.4000 | 1.0700 | 33.9000 | 8.45 |
| | 0.2197 | 0.1658 | 0.1518 | -0.6147 | 2.5015 | 13.8049 | 2.1337 | 26.3000 | 28.5000 | 0.6500 | | 8.8500 | 30.5000 | 28.4000 | 1.0800 | 33.9000 | 8.31 |
| | 0.2171 | 0.1631 | 0.1482 | -0.5309 | 2.4178 | 12.3848 | 2.1226 | 26.3000 | 28.5000 | 0.6500 | | 9.4200 | 30.5000 | 28.4000 | 1.0700 | 34.1000 | 8.35 |
| | 0.2148 | 0.1646 | 0.1480 | -0.4824 | 2.4477 | 11.1491 | 2.1124 | 26.5000 | 28.6000 | 0.6800 | | 9.0200 | 30.5000 | 28.4000 | 1.0600 | 34.1000 | 8.34 |
| | 0.2105 | 0.1780 | 0.1453 | -0.4072 | 2.6256 | 8.8147 | 2.0919 | 25.8000 | 28.4000 | 0.7300 | | 8.9300 | 30.5000 | 28.4000 | 1.0900 | 34.2000 | 8.25 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 4 | -0.0637 | -0.5880 | 1.3761 | 20.9512 | 16.9919 | 11.3095 | 16.4176 | 0.2761 | 0.0350 | -0.3111 | 1.2761 | 1.0350 | 0.6889 | 18.9495 | 4.5411 | 16.6354 |
| | -0.1270 | -0.2812 | 1.1445 | 20.7302 | 16.8289 | 11.1367 | 16.2319 | 0.2771 | 0.0368 | -0.3139 | 1.2771 | 1.0368 | 0.6861 | 18.6217 | 4.4326 | 16.6132 |
| | 0.0662 | -0.8961 | 1.3387 | 21.1369 | 17.1332 | 11.2843 | 16.5181 | 0.2796 | 0.0372 | -0.3169 | 1.2796 | 1.0372 | 0.6831 | 19.2200 | 4.5577 | 17.0372 |
| | 0.2023 | -0.1925 | 1.0953 | 20.6391 | 16.7395 | 10.8327 | 16.0704 | 0.2843 | 0.0416 | -0.3259 | 1.2843 | 1.0416 | 0.6741 | 18.4466 | 4.3639 | 17.0845 |
| | 0.1356 | -0.8432 | 1.4717 | 21.3456 | 17.2620 | 11.2130 | 16.6069 | 0.2853 | 0.0395 | -0.3248 | 1.2853 | 1.0395 | 0.6752 | 19.4858 | 4.6427 | 17.5393 |
| | 0.0059 | -0.1305 | 1.0616 | 19.7648 | 15.9130 | 10.0359 | 15.2379 | 0.2971 | 0.0443 | -0.3414 | 1.2971 | 1.0443 | 0.6586 | 16.9228 | 4.3918 | 16.9207 |
| | 0.2473 | -0.3225 | 1.3465 | 21.0763 | 16.9153 | 10.7648 | 16.2521 | 0.2968 | 0.0408 | -0.3376 | 1.2968 | 1.0408 | 0.6624 | 18.8964 | 4.8290 | 17.8223 |
| | -0.1590 | -0.7664 | 1.1878 | 19.2055 | 16.9480 | 13.2923 | 16.4819 | 0.1652 | 0.0283 | -0.1935 | 1.1652 | 1.0283 | 0.8065 | 18.1214 | 1.8060 | 10.6220 |
| | 0.1413 | -1.2278 | 1.4999 | 19.5608 | 17.2998 | 13.6270 | 16.8292 | 0.1623 | 0.0280 | -0.1903 | 1.1623 | 1.0280 | 0.8097 | 18.7654 | 1.7824 | 10.6544 |
| | -0.1367 | -0.6237 | 1.0844 | 20.4957 | 17.6612 | 13.8345 | 17.3304 | 0.1826 | 0.0191 | -0.2017 | 1.1826 | 1.0191 | 0.7983 | 19.6991 | 2.8842 | 11.4428 |
| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | % solids | | | |
| reagent test 5, cell 4 | 0.0982 | 0.4602 | 0.0822 | 3.0022 | 3.0657 | 44.4005 | 17.2441 | 20.3000 | 23.6000 | 1.2100 | | 17.2900 | 20.3000 | | | |
| | 0.0989 | 0.4628 | 0.0813 | 2.9675 | 3.0614 | 44.1073 | 17.1943 | 19.0490 | 25.8300 | 0.8060 | | 18.9400 | 19.0490 | | | |
| | 0.0989 | 0.4661 | 0.0829 | 3.0462 | 3.1449 | 44.0860 | 17.6363 | 20.9000 | 24.2000 | 1.2000 | | 16.0200 | 20.9000 | | | |
| | 0.1004 | 0.4751 | 0.0809 | 2.9879 | 3.1549 | 43.4428 | 17.6330 | 14.2940 | 22.2500 | 0.7600 | | 29.6500 | 14.2940 | | | |
| | 0.0995 | 0.4747 | 0.0837 | 3.1153 | 3.2442 | 43.8389 | 18.1434 | 21.4000 | 24.8000 | 1.2700 | | 15.2600 | 21.4000 | | | |
| | 0.1007 | 0.4922 | 0.0775 | 2.9556 | 3.1349 | 43.3133 | 17.4814 | 9.7170 | 16.8500 | 0.6190 | | 42.4700 | 9.7170 | | | |
| | 0.0994 | 0.4892 | 0.0827 | 3.1730 | 3.2999 | 43.8771 | 18.4649 | 10.2370 | 17.5600 | 0.6460 | | 41.5900 | 10.2370 | | | |
| | 0.1030 | 0.3079 | 0.0753 | 1.7533 | 1.9296 | 42.2597 | 10.7744 | 10.8200 | 18.1500 | 0.6260 | | 40.4200 | 10.8200 | | | |
| | 0.1032 | 0.3034 | 0.0767 | 1.7572 | 1.9376 | 42.2053 | 10.8025 | 6.9560 | 14.2600 | 0.5410 | | 47.6900 | 6.9560 | | | |
| | 0.0957 | 0.3250 | 0.0804 | 2.1252 | 2.0893 | 45.4877 | 11.8007 | 11.0960 | 18.1900 | 0.6080 | | 40.1700 | 11.0960 | | | |

**Data for reagent test 1(uncalibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 1, cell 2 | -1.3250 | -1.4958 | 2.3537 | 116.6859 | 99.8635 | 88.6527 | 101.0666 | 0.1546 | -0.0119 | -0.1229 | 1.1546 | 0.9881 | 0.8771 | 47.6087 | -29.0380 | 12.1015 | 45.4875 |
| | -1.1608 | -1.6948 | 2.4294 | 118.6651 | 101.4062 | 89.6672 | 102.5789 | 0.1569 | -0.0114 | -0.1259 | 1.1569 | 0.9886 | 0.8741 | 48.5438 | -29.2979 | 12.5114 | 47.6469 |
| | -1.4381 | -1.9600 | 2.6398 | 120.2563 | 102.3557 | 90.6691 | 103.7588 | 0.1591 | -0.0135 | -0.1262 | 1.1591 | 0.9865 | 0.8738 | 49.2136 | -29.3058 | 12.5913 | 47.8350 |
| | -0.8224 | -1.3596 | 2.2454 | 120.4867 | 102.5748 | 90.7950 | 103.9506 | 0.1591 | -0.0132 | -0.1266 | 1.1591 | 0.9868 | 0.8734 | 49.3348 | -29.3686 | 12.6531 | 48.6525 |
| | -1.1491 | -2.2050 | 2.7491 | 120.6598 | 102.2346 | 90.4086 | 103.7654 | 0.1628 | -0.0147 | -0.1287 | 1.1628 | 0.9853 | 0.8713 | 49.2468 | -28.9382 | 12.7442 | 47.5190 |
| | -1.0474 | -1.8739 | 2.4249 | 126.4252 | 112.6758 | 103.1178 | 113.4098 | 0.1149 | -0.0065 | -0.0908 | 1.1149 | 0.9935 | 0.9092 | 54.3169 | -36.0328 | 10.9617 | 31.3674 |
| | -1.0175 | -1.5127 | 2.1985 | 125.6163 | 111.7764 | 102.1249 | 112.5090 | 0.1166 | -0.0065 | -0.0924 | 1.1166 | 0.9935 | 0.9076 | 53.8225 | -35.6180 | 11.0115 | 40.2683 |
| | -0.5499 | -0.6968 | 1.2616 | 124.5797 | 110.7048 | 100.7270 | 111.3403 | 0.1190 | -0.0057 | -0.0954 | 1.1190 | 0.9943 | 0.9046 | 53.2091 | -35.1297 | 11.1916 | 36.6314 |
| | -0.3865 | -0.3512 | 1.0234 | 125.1391 | 111.0653 | 101.3095 | 111.8408 | 0.1190 | -0.0069 | -0.0943 | 1.1190 | 0.9931 | 0.9057 | 53.4608 | -35.1898 | 11.0920 | 34.4828 |
| | -0.1797 | -0.1176 | 1.4118 | 126.1592 | 111.9541 | 102.1673 | 112.7623 | 0.1189 | -0.0072 | -0.0941 | 1.1189 | 0.9928 | 0.9059 | 53.9854 | -35.4497 | 11.1487 | 41.7925 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 1, cell 2 | 0.0667 | 0.2403 | 0.4576 | 11.4628 | 7.3766 | 57.2356 | 31.4607 | 29.0000 | 28.4000 | 1.4100 | 34.2000 | 8.5900 | 26.5000 | 27.6000 | 1.7200 | 33.7000 | 10.0400 |
| | 0.0675 | 0.2444 | 0.4654 | 11.7840 | 7.6716 | 56.9385 | 31.8601 | 28.8000 | 28.3000 | 1.4600 | 34.0000 | 8.8200 | 27.1000 | 27.6000 | 1.6400 | 33.2000 | 10.3300 |
| | 0.0659 | 0.2461 | 0.4716 | 12.1733 | 7.7433 | 57.5132 | 31.8990 | 28.9000 | 28.4000 | 1.4200 | 34.1000 | 8.6100 | 27.1000 | 27.6000 | 1.6500 | 33.4000 | 10.1100 |
| | 0.0661 | 0.2465 | 0.4725 | 12.1895 | 7.7857 | 57.4122 | 31.9802 | 28.9000 | 28.4000 | 1.3600 | 34.1000 | 8.4000 | 27.9000 | 28.1000 | 1.4700 | 33.7000 | 9.5700 |
| | 0.0652 | 0.2507 | 0.4732 | 12.5097 | 7.8816 | 57.7480 | 31.6230 | 28.9000 | 28.4000 | 1.2900 | 34.5000 | 8.3700 | 27.7000 | 27.6000 | 1.5400 | 33.2000 | 10.1800 |
| | 0.0683 | 0.1845 | 0.4958 | 9.4084 | 6.2017 | 56.6200 | 37.6664 | 29.9000 | 28.4000 | 0.9400 | 33.5000 | 9.1100 | 27.5000 | 26.2000 | 1.1300 | 31.3000 | 13.5500 |
| | 0.0684 | 0.1871 | 0.4926 | 9.4734 | 6.2558 | 56.5707 | 37.2837 | 29.8000 | 28.4000 | 0.9300 | 33.4000 | 9.3400 | 27.8000 | 26.7000 | 1.2400 | 31.7000 | 12.5000 |
| | 0.0697 | 0.1916 | 0.4885 | 9.5275 | 6.4035 | 56.0970 | 36.8712 | 29.9000 | 28.5000 | 0.9600 | 33.4000 | 8.9900 | 27.6000 | 26.7000 | 1.1700 | 31.6000 | 12.7900 |
| | 0.0682 | 0.1906 | 0.4907 | 9.6276 | 6.3359 | 56.6554 | 36.8986 | 30.0000 | 28.7000 | 0.8700 | 33.8000 | 8.5300 | 27.1000 | 25.8000 | 1.1500 | 30.3000 | 15.1500 |
| | 0.0679 | 0.1904 | 0.4947 | 9.7115 | 6.3688 | 56.7531 | 37.1646 | 29.6000 | 28.4000 | 1.0000 | 34.0000 | 8.7600 | 28.4000 | 27.4000 | 1.2300 | 32.6000 | 11.0500 |

**Data for reagent test 2(uncalibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 2 | 0.4262 | -1.6692 | 2.4481 | 25.0847 | 19.8594 | 12.7323 | 19.2255 | 0.3050 | 0.0332 | -0.3382 | 1.3050 | 1.0332 | 0.6618 | 17.5225 | -10.7579 | 13.5743 | 53.3710 |
| | 0.3361 | -1.6329 | 2.1145 | 24.9698 | 19.7613 | 12.4692 | 19.0668 | 0.3096 | 0.0366 | -0.3462 | 1.3096 | 1.0366 | 0.6538 | 17.3610 | -10.6502 | 13.7340 | 49.0837 |
| | 0.2613 | -1.4416 | 2.4912 | 25.0065 | 19.7851 | 12.3828 | 19.0581 | 0.3121 | 0.0383 | -0.3504 | 1.3121 | 1.0383 | 0.6496 | 17.3964 | -10.6307 | 13.8772 | 48.7373 |
| | 0.0948 | -1.3103 | 2.8143 | 24.7877 | 19.5916 | 12.3733 | 18.9175 | 0.3103 | 0.0358 | -0.3462 | 1.3103 | 1.0358 | 0.6538 | 17.1136 | -10.5242 | 13.6227 | 47.1986 |
| | 0.4994 | -1.4373 | 2.3016 | 24.5263 | 19.3409 | 12.4752 | 18.7808 | 0.3067 | 0.0302 | -0.3368 | 1.3067 | 1.0302 | 0.6632 | 16.7621 | -10.3768 | 13.0349 | 57.6141 |
| | 0.1345 | -0.6745 | 2.3909 | 21.8852 | 18.5165 | 11.6344 | 17.3453 | 0.2615 | 0.0677 | -0.3292 | 1.2615 | 1.0677 | 0.6708 | 14.5270 | -12.1560 | 12.5514 | 39.2835 |
| | 0.1755 | -1.1554 | 2.4234 | 21.8861 | 18.5193 | 11.4613 | 17.2889 | 0.2656 | 0.0714 | -0.3370 | 1.2656 | 1.0714 | 0.6630 | 14.5184 | -12.1208 | 12.7398 | 41.2524 |
| | 0.1228 | -1.3491 | 2.8367 | 22.0453 | 18.6176 | 11.3826 | 17.3485 | 0.2704 | 0.0733 | -0.3437 | 1.2704 | 1.0733 | 0.6563 | 14.6846 | -12.0870 | 12.9959 | 42.8078 |
| | -0.1840 | -0.9066 | 2.1308 | 21.6448 | 18.3034 | 11.0665 | 17.0049 | 0.2727 | 0.0765 | -0.3492 | 1.2727 | 1.0765 | 0.6508 | 14.1789 | -11.9111 | 12.8842 | 41.4059 |
| | 0.4734 | -0.9744 | 2.7149 | 22.1368 | 18.7027 | 11.3274 | 17.4732 | 0.2718 | 0.0765 | -0.3483 | 1.2718 | 1.0765 | 0.6517 | 14.9460 | -12.2457 | 13.3000 | 41.4508 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Lab angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 2 | 0.0962 | 0.4928 | 0.0984 | 3.9249 | 3.8834 | 45.2814 | 2.2407 | 17.3226 | 30.4000 | 28.3000 | 1.5900 | 32.3000 | 8.8600 | 30.6000 | 28.6000 | 1.4700 | 33.8000 | 8.19 |
| | 0.0973 | 0.5007 | 0.0979 | 3.9311 | 3.9530 | 44.8222 | 2.2305 | 17.3801 | 30.6000 | 28.4000 | 1.5600 | 32.8000 | 8.3200 | 30.6000 | 28.6000 | 1.4800 | 33.5000 | 8.38 |
| | 0.0978 | 0.5049 | 0.0981 | 3.9501 | 4.0030 | 44.6040 | 2.2245 | 17.4818 | 30.6000 | 28.4000 | 1.6600 | 32.9000 | 8.5100 | 30.5000 | 28.5000 | 1.5100 | 33.5000 | 8.28 |
| | 0.0969 | 0.5009 | 0.0972 | 3.9161 | 3.9189 | 44.9726 | 2.2288 | 17.2168 | 30.5000 | 28.5000 | 1.7300 | 33.1000 | 8.3000 | 30.4000 | 28.4000 | 1.5300 | 33.0000 | 8.26 |
| | 0.0951 | 0.4923 | 0.0962 | 3.8742 | 3.7633 | 45.7727 | 2.2427 | 16.6653 | 30.8000 | 26.1000 | 1.2800 | 31.4000 | 12.7700 | 30.7000 | 28.6000 | 1.4700 | 33.5000 | 8.37 |
| | 0.1120 | 0.4682 | 0.0858 | 2.7591 | 3.5027 | 38.1863 | 2.3413 | 17.4775 | 28.1000 | 28.6000 | 1.4600 | 33.2000 | 8.4100 | 29.8000 | 27.8000 | 1.2400 | 33.4000 | 9.54 |
| | 0.1130 | 0.4761 | 0.0858 | 2.7755 | 3.5792 | 37.7359 | 2.3328 | 17.5898 | 28.7000 | 26.8000 | 1.3600 | 32.3000 | 11.1000 | 29.8000 | 27.8000 | 1.2200 | 33.6000 | 9.54 |
| | 0.1132 | 0.4834 | 0.0865 | 2.8306 | 3.6655 | 37.6451 | 2.3215 | 17.7529 | 28.9000 | 27.0000 | 1.3000 | 32.1000 | 11.2400 | 29.7000 | 27.8000 | 1.2300 | 33.6000 | 9.53 |
| | 0.1141 | 0.4886 | 0.0849 | 2.7777 | 3.6536 | 37.2082 | 2.3180 | 17.5502 | 28.3000 | 26.4000 | 1.3800 | 31.5000 | 11.9800 | 29.9000 | 28.1000 | 1.2000 | 33.5000 | 9.33 |
| | 0.1142 | 0.4875 | 0.0872 | 2.8419 | 3.7448 | 37.1720 | 2.3157 | 18.0810 | 28.9000 | 27.0000 | 1.3200 | 32.2000 | 11.0000 | 29.9000 | 28.0000 | 1.1800 | 33.6000 | 9.33 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 4 | -0.0588 | -0.5203 | 2.3768 | 31.2249 | 26.8414 | 20.4065 | 25.4787 | 0.2256 | 0.0535 | -0.1990 | 1.2256 | 1.0535 | 0.8010 | 21.6006 | -16.4270 | 11.5673 | 48.4372 |
| | -0.1063 | -0.7089 | 2.2757 | 32.0515 | 27.4817 | 20.7951 | 26.0966 | 0.2282 | 0.0531 | -0.2031 | 1.2282 | 1.0531 | 0.7969 | 22.4662 | -16.6625 | 11.9630 | 50.8586 |
| | -0.1677 | -0.5743 | 2.6125 | 31.7270 | 27.1400 | 20.5004 | 25.7762 | 0.2309 | 0.0530 | -0.2047 | 1.2309 | 1.0530 | 0.7953 | 22.0507 | -16.3664 | 11.8855 | 55.3234 |
| | 0.0411 | -0.2896 | 2.7908 | 31.1660 | 26.6804 | 20.1056 | 25.3045 | 0.2317 | 0.0544 | -0.2054 | 1.2317 | 1.0544 | 0.7946 | 21.4341 | -16.1242 | 11.7498 | 57.2499 |
| | -0.0393 | -0.7062 | 2.1518 | 30.9147 | 26.4427 | 20.0181 | 25.1126 | 0.2311 | 0.0530 | -0.2028 | 1.2311 | 1.0530 | 0.7972 | 21.1421 | -15.9819 | 11.5467 | 37.3616 |
| | -0.1688 | -0.5924 | 2.5106 | 37.1452 | 32.9253 | 25.2174 | 31.0858 | 0.1973 | 0.0588 | -0.1897 | 1.1973 | 1.0588 | 0.8103 | 28.9907 | -21.3683 | 13.5058 | 35.4481 |
| | -0.1362 | -0.4415 | 2.7710 | 39.2787 | 35.2389 | 26.9748 | 33.1558 | 0.1847 | 0.0628 | -0.1864 | 1.1847 | 1.0628 | 0.8136 | 31.7428 | -23.3759 | 14.3066 | 44.5244 |
| | 0.0005 | -0.5265 | 2.3647 | 39.5195 | 35.4397 | 27.2183 | 33.3842 | 0.1838 | 0.0615 | -0.1846 | 1.1838 | 1.0615 | 0.8154 | 32.0110 | -23.5036 | 14.2751 | 35.3426 |
| | -0.0686 | -0.7496 | 2.4890 | 40.4969 | 36.2542 | 27.9359 | 34.2191 | 0.1835 | 0.0595 | -0.1835 | 1.1835 | 1.0595 | 0.8165 | 33.0766 | -23.9464 | 14.4813 | 37.6185 |
| | 0.0082 | -0.4290 | 3.0033 | 40.6329 | 36.4476 | 28.3760 | 34.4752 | 0.1908 | 0.0614 | -0.1893 | 1.1908 | 1.0614 | 0.8107 | 33.2605 | -24.2235 | 14.1528 | 45.4932 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 4 | 0.0991 | 0.3464 | 0.1225 | 3.3382 | 3.4569 | 44.0146 | 20.0930 | 30.6000 | 28.1000 | 1.5400 | 33.5000 | 8.2300 |
| | 0.0990 | 0.3511 | 0.1257 | 3.4779 | 3.5943 | 44.0696 | 20.5137 | 30.3000 | 27.9000 | 1.6800 | 33.4000 | 8.4700 |
| | 0.0986 | 0.3539 | 0.1244 | 3.4838 | 3.5763 | 44.2457 | 20.2278 | 30.8000 | 28.2000 | 1.4600 | 33.5000 | 8.2400 |
| | 0.0991 | 0.3549 | 0.1222 | 3.4150 | 3.5331 | 44.0278 | 19.9522 | 30.6000 | 28.2000 | 1.5300 | 33.7000 | 8.1500 |
| | 0.0982 | 0.3525 | 0.1212 | 3.3916 | 3.4655 | 44.3897 | 19.7178 | 30.5000 | 28.0000 | 1.5000 | 33.8000 | 8.2500 |
| | 0.1074 | 0.3229 | 0.1457 | 3.3649 | 3.9888 | 40.2435 | 25.2949 | 27.3000 | 25.1000 | 1.2500 | 30.5000 | 14.6200 |
| | 0.1119 | 0.3132 | 0.1540 | 3.3098 | 4.2052 | 38.2135 | 27.4087 | 28.7000 | 26.6000 | 1.3800 | 32.1000 | 11.4000 |
| | 0.1113 | 0.3112 | 0.1550 | 3.3301 | 4.1925 | 38.4786 | 27.5011 | 27.2000 | 25.0000 | 1.2800 | 29.8000 | 15.2100 |
| | 0.1103 | 0.3101 | 0.1588 | 3.4400 | 4.2588 | 38.9361 | 27.9884 | 27.9000 | 25.8000 | 1.2800 | 31.0000 | 13.4100 |
| | 0.1097 | 0.3086 | 0.1593 | 3.3735 | 4.1458 | 39.1322 | 26.4598 | 29.4000 | 27.3000 | 1.2500 | 33.0000 | 10.0000 |

**Data for reagent test 3 (rejected for analysis) (uncalibrated)**

|  | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 2 | 0.2615 | -1.8320 | 2.4840 | 40.4660 | 32.7496 | 25.6239 | 32.2734 | 0.2539 | 0.0148 | -0.2061 | 1.2539 | 1.0148 | 0.7939 | 30.3598 | -17.0596 | 13.6062 |
|  | 0.2055 | -1.2638 | 2.1799 | 36.1503 | 28.9745 | 21.6271 | 28.2441 | 0.2802 | 0.0260 | -0.2345 | 1.2802 | 1.0260 | 0.7655 | 25.4399 | -14.5195 | 13.4382 |
|  | 0.1620 | -1.6065 | 2.5522 | 39.4319 | 31.5341 | 23.4784 | 30.8094 | 0.2800 | 0.0237 | -0.2380 | 1.2800 | 1.0237 | 0.7620 | 28.8834 | -15.5929 | 14.6309 |
|  | 0.2420 | -1.5917 | 2.7535 | 37.1750 | 30.1571 | 22.8826 | 29.3972 | 0.2642 | 0.0260 | -0.2212 | 1.2642 | 1.0260 | 0.7788 | 26.8253 | -15.7116 | 13.4095 |
|  | 0.4053 | -2.1573 | 2.1329 | 32.0307 | 26.3650 | 19.3748 | 25.2480 | 0.2688 | 0.0446 | -0.2329 | 1.2688 | 1.0446 | 0.7671 | 21.5050 | -14.2659 | 12.4620 |
|  | 0.3137 | -1.3455 | 2.2749 | 33.7615 | 27.9214 | 21.3057 | 26.9886 | 0.2511 | 0.0348 | -0.2108 | 1.2511 | 1.0348 | 0.7892 | 23.5516 | -15.4521 | 12.1862 |
|  | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu | Fe | MoS2 | S | Insol | % solids |  |  |  |
| reagent test 3, cell 2 | 0.0800 | 0.3668 | 0.1587 | 5.4563 | 4.2499 | 52.0795 | 21.8218 | 27.1000 | 28.3000 | 1.3500 | 34.0000 | 8.6300 | 33.0749 |  |  |  |
|  | 0.0843 | 0.4020 | 0.1418 | 5.1461 | 4.2671 | 50.3264 | 19.7874 | 28.0000 | 28.2000 | 1.4200 | 34.2000 | 8.6900 | 25.4009 |  |  |  |
|  | 0.0842 | 0.4046 | 0.1546 | 5.6608 | 4.6829 | 50.3893 | 21.3832 | 28.7000 | 28.4000 | 1.4300 | 33.9000 | 8.4600 | 25.7276 |  |  |  |
|  | 0.0849 | 0.3838 | 0.1458 | 5.0417 | 4.2120 | 50.1009 | 20.6677 | 26.4000 | 27.3000 | 1.4200 | 32.9000 | 11.8400 | 25.6747 |  |  |  |
|  | 0.0921 | 0.3954 | 0.1256 | 4.1820 | 3.8885 | 47.0443 | 18.9453 | 26.3000 | 27.1000 | 1.3400 | 32.0000 | 12.7500 | 18.4895 |  |  |  |
|  | 0.0885 | 0.3691 | 0.1324 | 4.2518 | 3.7506 | 48.5696 | 19.6830 | 25.3000 | 25.4000 | 1.3200 | 30.5000 | 15.8100 | 18.6158 |  |  |  |

|  | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 4 | -0.1119 | -0.9629 | 2.4746 | 46.6930 | 41.2384 | 31.1963 | 39.0333 | 0.1963 | 0.0565 | -0.2007 | 1.1963 | 1.0565 | 0.7993 | 22.4799 | -18.0478 | 11.8932 |
|  | 0.0069 | -0.2842 | 2.3078 | 49.3716 | 41.5954 | 29.4832 | 39.4723 | 0.2507 | 0.0538 | -0.2529 | 1.2507 | 1.0538 | 0.7471 | 23.3871 | -15.9243 | 13.9015 |
|  | -0.0891 | -0.1517 | 2.5659 | 45.4885 | 40.6136 | 32.6746 | 38.9163 | 0.1685 | 0.0436 | -0.1599 | 1.1685 | 1.0436 | 0.8401 | 21.9220 | -18.6613 | 9.9007 |
|  | 0.0144 | -0.0606 | 2.7084 | 43.1106 | 38.6363 | 31.2198 | 36.9769 | 0.1685 | 0.0456 | -0.1584 | 1.1685 | 1.0456 | 0.8416 | 20.1349 | -17.9416 | 9.3585 |
|  | -0.1225 | -0.2891 | 2.1397 | 43.2172 | 38.1235 | 28.8008 | 36.0321 | 0.1993 | 0.0580 | -0.2005 | 1.1993 | 1.0580 | 0.7995 | 19.7734 | -16.7216 | 11.0910 |
|  | -0.0073 | -0.4028 | 2.4501 | 42.8860 | 37.8541 | 29.0377 | 35.9087 | 0.1958 | 0.0554 | -0.1941 | 1.1958 | 1.0554 | 0.8059 | 19.5552 | -16.7220 | 10.6352 |
|  | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu | Fe | MoS2 | S | Insol | % solids |  |  |  |
| reagent test 3, cell 4 | 0.1079 | 0.3318 | 0.1831 | 4.3573 | 5.1904 | 40.0377 | 21.6178 | 18.1400 | 24.8400 | 1.4900 | 27.7700 | 22.4000 | 18.1400 |  |  |  |
|  | 0.1016 | 0.4025 | 0.1936 | 5.9916 | 6.4369 | 42.9095 | 21.1514 | 17.0700 | 23.3100 | 1.5100 | 25.3700 | 26.7900 | 17.0700 |  |  |  |
|  | 0.1036 | 0.2780 | 0.1784 | 3.7907 | 4.1863 | 42.0084 | 21.3203 | 17.4500 | 21.5900 | 1.4500 | 22.6400 | 29.0000 | 17.4500 |  |  |  |
|  | 0.1037 | 0.2786 | 0.1691 | 3.4921 | 3.8990 | 41.9599 | 20.3056 | 18.8200 | 23.7000 | 1.2000 | 24.4400 | 27.7600 | 18.8200 |  |  |  |
|  | 0.1077 | 0.3333 | 0.1695 | 4.0635 | 4.8230 | 40.1598 | 20.0720 | 13.0200 | 16.6300 | 1.0400 | 15.3100 | 43.2800 | 13.0200 |  |  |  |
|  | 0.1058 | 0.3225 | 0.1682 | 4.0018 | 4.6670 | 40.7441 | 19.9278 | 11.2900 | 14.5600 | 0.9910 | 13.6000 | 46.6500 | 11.2900 |  |  |  |

**Data for reagent test 4 (uncalibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green nor | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 4, cell 2 | 0.0934 | -1.3176 | 2.4992 | 46.4201 | 41.3456 | 30.4975 | 38.7463 | 0.1982 | 0.0670 | -0.2126 | 1.1982 | 1.0670 | 0.7874 | 23.1610 | -18.6412 | 12.7579 |
| | 0.1140 | -0.8522 | 2.4034 | 47.5575 | 42.2174 | 30.8092 | 39.5193 | 0.2035 | 0.0683 | -0.2204 | 1.2035 | 1.0683 | 0.7796 | 23.9654 | -18.8103 | 13.3105 |
| | 0.3458 | -0.7879 | 2.1074 | 48.4133 | 43.0001 | 31.3509 | 40.2464 | 0.2030 | 0.0684 | -0.2210 | 1.2030 | 1.0684 | 0.7790 | 24.6483 | -19.1534 | 13.5622 |
| | 0.0201 | -0.9232 | 2.6941 | 48.6129 | 43.1303 | 31.2489 | 40.3232 | 0.2056 | 0.0696 | -0.2250 | 1.2056 | 1.0696 | 0.7750 | 24.7690 | -19.1264 | 13.7711 |
| | -0.0041 | -0.5152 | 3.0059 | 48.4960 | 42.8467 | 30.9682 | 40.0943 | 0.2096 | 0.0687 | -0.2276 | 1.2096 | 1.0687 | 0.7724 | 24.5770 | -18.8191 | 13.7769 |
| | 0.4307 | -2.0478 | 2.2619 | 38.4744 | 35.1635 | 29.2567 | 33.6217 | 0.1372 | 0.0436 | -0.1193 | 1.1372 | 1.0436 | 0.8807 | 17.5776 | -17.7090 | 7.7029 |
| | 0.5371 | -2.3094 | 2.1213 | 32.2327 | 30.2640 | 27.4470 | 29.3056 | 0.1000 | 0.0327 | -0.0633 | 1.1000 | 1.0327 | 0.9367 | 13.0990 | -16.6673 | 4.4904 |
| | 0.7405 | -2.7194 | 2.3223 | 33.3603 | 31.3459 | 28.0883 | 30.2581 | 0.1026 | 0.0360 | -0.0716 | 1.1026 | 1.0360 | 0.9284 | 14.0344 | -17.1848 | 4.9659 |
| | 0.7532 | -2.5075 | 1.9596 | 33.5230 | 31.3960 | 28.2221 | 30.3724 | 0.1039 | 0.0338 | -0.0708 | 1.1039 | 1.0338 | 0.9292 | 14.1176 | -17.1401 | 4.9099 |
| | 0.6095 | -3.0173 | 1.8000 | 33.5333 | 31.3861 | 28.1566 | 30.3510 | 0.1049 | 0.0341 | -0.0722 | 1.1049 | 1.0341 | 0.9278 | 14.1112 | -17.1012 | 4.9673 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 4, cell 2 | 0.1134 | 0.3429 | 0.1820 | 4.2042 | 5.4865 | 37.5139 | 22.5895 | 27.9000 | 27.1000 | 1.3000 | 32.6000 | 11.2800 | 21.1103 |
| | 0.1135 | 0.3522 | 0.1865 | 4.4236 | 5.7703 | 37.4882 | 23.0441 | 27.3000 | 26.5000 | 1.4400 | 32.5000 | 11.4400 | 20.3375 |
| | 0.1137 | 0.3524 | 0.1899 | 4.4926 | 5.8863 | 37.3704 | 23.4691 | 27.4000 | 26.8000 | 1.3100 | 32.7000 | 11.9400 | 32.7280 |
| | 0.1140 | 0.3572 | 0.1906 | 4.5585 | 5.9980 | 37.2477 | 23.5688 | 27.1000 | 26.7000 | 1.3500 | 32.7000 | 12.5600 | 22.8510 |
| | 0.1130 | 0.3614 | 0.1902 | 4.6606 | 6.0213 | 37.7361 | 23.3234 | 27.1000 | 26.8000 | 1.2600 | 32.2000 | 11.9600 | 24.9879 |
| | 0.1024 | 0.2210 | 0.1509 | 2.6260 | 3.0681 | 42.4989 | 19.6274 | 23.1000 | 28.1000 | 1.0300 | 31.6000 | 15.4100 | 26.2063 |
| | 0.0977 | 0.1484 | 0.1264 | 1.4919 | 1.5206 | 44.5524 | 17.2647 | 23.6000 | 28.8000 | 1.0800 | 32.0000 | 14.2200 | 33.9869 |
| | 0.1029 | 0.1580 | 0.1308 | 1.5640 | 1.7198 | 42.2765 | 17.8895 | 22.8000 | 27.8000 | 1.0100 | 31.3000 | 16.2600 | 33.4669 |
| | 0.0998 | 0.1582 | 0.1315 | 1.6249 | 1.6999 | 43.6895 | 17.8305 | 23.0000 | 27.7000 | 1.0600 | 30.8000 | 17.1200 | 34.1277 |
| | 0.1000 | 0.1603 | 0.1315 | 1.6429 | 1.7271 | 43.5798 | 17.8095 | 23.2000 | 27.8000 | 1.1000 | 30.9000 | 16.5200 | 39.1608 |

**Data for reagent test 5 (uncalibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 2 | 0.2817 | -1.4596 | 1.9921 | 37.1937 | 34.5008 | 28.3284 | 32.6707 | 0.1385 | 0.0560 | -0.1329 | 1.1385 | 1.0560 | 0.8671 | 24.4477 | -21.8682 | 9.8223 | |
| | 0.4935 | -1.6583 | 1.9525 | 36.2902 | 33.5799 | 27.3344 | 31.7324 | 0.1437 | 0.0583 | -0.1385 | 1.1437 | 1.0583 | 0.8615 | 23.4501 | -21.1552 | 9.8674 | |
| | 0.0692 | -1.3837 | 2.1796 | 35.8423 | 33.1055 | 26.9750 | 31.3044 | 0.1450 | 0.0575 | -0.1382 | 1.1450 | 1.0575 | 0.8618 | 22.9549 | -20.8104 | 9.7204 | |
| | 0.3335 | -1.3180 | 1.9656 | 36.8888 | 33.9423 | 27.3035 | 32.0420 | 0.1513 | 0.0594 | -0.1479 | 1.1513 | 1.0594 | 0.8521 | 23.8958 | -21.0468 | 10.3796 | |
| | 0.2995 | -1.6210 | 2.1153 | 37.2197 | 34.2604 | 27.2977 | 32.2573 | 0.1538 | 0.0621 | -0.1536 | 1.1538 | 1.0621 | 0.8464 | 24.2184 | -21.1767 | 10.7608 | |
| | 0.4567 | -1.4660 | 1.9223 | 32.7981 | 30.3074 | 24.9887 | 28.6929 | 0.1421 | 0.0558 | -0.1266 | 1.1421 | 1.0558 | 0.8734 | 19.8797 | -19.2643 | 8.5949 | |
| | 0.3477 | -1.9859 | 2.4705 | 29.9398 | 27.7633 | 23.3196 | 26.3347 | 0.1369 | 0.0542 | -0.1143 | 1.1369 | 1.0542 | 0.8857 | 17.0717 | -17.9961 | 7.4125 | |
| | 0.5336 | -1.7628 | 2.2758 | 29.3460 | 27.1147 | 22.8481 | 25.7621 | 0.1391 | 0.0524 | -0.1128 | 1.1391 | 1.0524 | 0.8872 | 16.3943 | -17.5043 | 7.1886 | |
| | 0.3693 | -2.2462 | 2.4870 | 29.3516 | 27.0682 | 22.7694 | 25.7231 | 0.1412 | 0.0523 | -0.1147 | 1.1412 | 1.0523 | 0.8853 | 16.3590 | -17.4007 | 7.2360 | |
| | 0.5019 | -1.9425 | 2.2942 | 28.8513 | 26.5861 | 22.0044 | 25.1431 | 0.1476 | 0.0572 | -0.1245 | 1.1476 | 1.0572 | 0.8755 | 15.7980 | -16.9796 | 7.5397 | |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 2 | 0.1160 | 0.2383 | 0.1459 | 2.2727 | 3.0930 | 36.3243 | 23.9744 | 27.3000 | 27.5000 | 0.8400 | | 9.2400 | 31.0000 | 28.4000 | 1.4200 | 34.0000 | 8.07 |
| | 0.1162 | 0.2467 | 0.1423 | 2.2907 | 3.1276 | 36.2288 | 23.3444 | 26.6000 | 27.0000 | 0.8400 | | 10.4700 | 31.0000 | 28.4000 | 1.4300 | 33.9000 | 7.9 |
| | 0.1152 | 0.2473 | 0.1406 | 2.2955 | 3.0812 | 36.7080 | 22.9701 | 27.9000 | 27.9000 | 0.8400 | | 8.6100 | 30.9000 | 28.4000 | 1.4300 | 34.0000 | 7.79 |
| | 0.1154 | 0.2598 | 0.1447 | 2.4752 | 3.3341 | 36.5847 | 23.4684 | 26.6000 | 27.1000 | 0.9000 | | 9.7600 | 31.1000 | 28.6000 | 1.4000 | 34.2000 | 7.58 |
| | 0.1169 | 0.2664 | 0.1460 | 2.5154 | 3.4775 | 35.8974 | 23.7548 | 27.2000 | 27.6000 | 0.8400 | | 8.7000 | 31.1000 | 28.4000 | 1.3900 | 33.8000 | 7.9 |
| | 0.1128 | 0.2351 | 0.1286 | 2.0630 | 2.6903 | 37.7937 | 21.1157 | 26.9000 | 28.5000 | 0.6900 | | 8.6200 | 30.5000 | 28.4000 | 1.0700 | 33.9000 | 8.45 |
| | 0.1117 | 0.2209 | 0.1174 | 1.7823 | 2.2618 | 38.2794 | 19.4644 | 26.3000 | 28.5000 | 0.6500 | | 8.8500 | 30.5000 | 28.4000 | 1.0800 | 33.9000 | 8.31 |
| | 0.1092 | 0.2212 | 0.1151 | 1.7983 | 2.1925 | 39.4326 | 18.9256 | 26.3000 | 28.5000 | 0.6500 | | 9.4200 | 30.5000 | 28.4000 | 1.0700 | 34.1000 | 8.35 |
| | 0.1088 | 0.2241 | 0.1151 | 1.8336 | 2.2143 | 39.6481 | 18.8500 | 26.5000 | 28.6000 | 0.6800 | | 9.0200 | 30.5000 | 28.4000 | 1.0600 | 34.1000 | 8.34 |
| | 0.1112 | 0.2370 | 0.1131 | 1.8507 | 2.3352 | 38.5102 | 18.5813 | 25.8000 | 28.4000 | 0.7300 | | 8.9300 | 30.5000 | 28.4000 | 1.0900 | 34.2000 | 8.25 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 4 | -0.0637 | -0.5880 | 1.3761 | 19.2177 | 15.0141 | 9.8838 | 14.0260 | 0.3706 | 0.0715 | -0.2955 | 1.3706 | 1.0715 | 0.7045 | 84.7256 | -30.9824 | 39.5219 |
| | -0.1270 | -0.2812 | 1.1445 | 19.0149 | 14.8701 | 9.7327 | 13.8602 | 0.3723 | 0.0736 | -0.2980 | 1.3723 | 1.0736 | 0.7020 | 83.7702 | -30.7490 | 39.4189 |
| | 0.0662 | -0.8961 | 1.3387 | 19.3880 | 15.1389 | 9.8617 | 14.1179 | 0.3736 | 0.0730 | -0.3014 | 1.3736 | 1.0730 | 0.6986 | 85.5072 | -31.0677 | 40.3184 |
| | 0.2023 | -0.1925 | 1.0953 | 18.9313 | 14.7911 | 9.4671 | 13.7181 | 0.3805 | 0.0792 | -0.3101 | 1.3805 | 1.0792 | 0.6899 | 83.2580 | -30.3088 | 40.2202 |
| | 0.1356 | -0.8432 | 1.4717 | 19.5794 | 15.2527 | 9.7994 | 14.1981 | 0.3793 | 0.0748 | -0.3099 | 1.3793 | 1.0748 | 0.6901 | 86.2972 | -30.9158 | 41.2667 |
| | 0.0059 | -0.1305 | 1.0616 | 18.3516 | 14.3781 | 9.0695 | 13.2556 | 0.3851 | 0.0859 | -0.3159 | 1.3851 | 1.0859 | 0.6841 | 80.5070 | -29.6759 | 39.7342 |
| | 0.2473 | -0.3225 | 1.3465 | 19.5694 | 15.2837 | 9.7283 | 14.1829 | 0.3803 | 0.0784 | -0.3145 | 1.3803 | 1.0784 | 0.6855 | 86.3505 | -31.1600 | 41.7219 |
| | -0.1590 | -0.7664 | 1.1878 | 17.8323 | 15.3133 | 12.0123 | 14.3699 | 0.2414 | 0.0660 | -0.1643 | 1.2414 | 1.0660 | 0.8357 | 80.4602 | -42.2286 | 27.3491 |
| | 0.1413 | -1.2278 | 1.4999 | 18.1622 | 15.6311 | 12.3148 | 14.6866 | 0.2370 | 0.0647 | -0.1617 | 1.2370 | 1.0647 | 0.8383 | 85.1821 | -44.8589 | 28.5817 |
| | -0.1367 | -0.6237 | 1.0844 | 19.0303 | 15.9576 | 12.5024 | 15.1464 | 0.2564 | 0.0538 | -0.1744 | 1.2564 | 1.0538 | 0.8256 | 88.2048 | -42.9024 | 29.9887 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 4 | 0.0918 | 0.4859 | 0.0754 | 3.0972 | 2.8606 | 47.1907 | 50.2267 | 20.3000 | 23.6000 | 1.2100 | | 17.2900 | 20.3000 |
| | 0.0923 | 0.4884 | 0.0746 | 3.0618 | 2.8550 | 46.9528 | 49.9977 | 19.0490 | 25.8300 | 0.8060 | | 18.9400 | 19.0490 |
| | 0.0924 | 0.4914 | 0.0760 | 3.1398 | 2.9314 | 46.9189 | 50.9105 | 20.9000 | 24.2000 | 1.2000 | | 16.0200 | 20.9000 |
| | 0.0939 | 0.5002 | 0.0742 | 3.0776 | 2.9358 | 46.2776 | 50.3681 | 14.2940 | 22.2500 | 0.7600 | | 29.6500 | 14.2940 |
| | 0.0930 | 0.4996 | 0.0768 | 3.2052 | 3.0198 | 46.6674 | 51.5710 | 21.4000 | 24.8000 | 1.2700 | | 15.2600 | 21.4000 |
| | 0.0955 | 0.5060 | 0.0720 | 2.9736 | 2.9045 | 45.5886 | 49.6003 | 9.7170 | 16.8500 | 0.6190 | | 42.4700 | 9.7170 |
| | 0.0941 | 0.5029 | 0.0767 | 3.1902 | 3.0583 | 46.1790 | 52.0791 | 10.2370 | 17.5600 | 0.6460 | | 41.5900 | 10.2370 |
| | 0.0911 | 0.3146 | 0.0675 | 1.8787 | 1.8132 | 46.0797 | 52.2729 | 10.8200 | 18.1500 | 0.6260 | | 40.4200 | 10.8200 |
| | 0.0944 | 0.3221 | 0.0712 | 1.8876 | 1.8217 | 46.0584 | 53.2479 | 6.9560 | 14.2600 | 0.5410 | | 47.6900 | 6.9560 |
| | 0.0886 | 0.3410 | 0.0746 | 2.2344 | 1.9622 | 48.5434 | 52.7082 | 11.0960 | 18.1900 | 0.6080 | | 40.1700 | 11.0960 |

**Uncalibrated results for North Parkes underground sulphide ore (continued)**

| | time | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | Hue | Sat | Val | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 ml SIBX (2) | 30 | 39.8876 | 30.1914 | 21.5783 | 30.5524 | 2.3055 | 1.9882 | 1.7063 | 1.3055 | 0.9882 | 0.7063 | 54.5641 | 15.9494 | 31.4924 | 0.0784 | 0.4590 | 0.1564 | 0.4136 |
| | 60 | 44.2279 | 33.2470 | 25.7119 | 34.3956 | 2.2859 | 1.9666 | 1.7475 | 1.2859 | 0.9666 | 0.7475 | 61.5507 | 19.0143 | 29.7688 | 0.0678 | 0.4186 | 0.1734 | 0.4477 |
| | 90 | 44.2567 | 33.3346 | 26.5615 | 34.7176 | 2.2748 | 1.9602 | 1.7651 | 1.2748 | 0.9602 | 0.7651 | 61.7477 | 19.2284 | 27.7169 | 0.0638 | 0.3998 | 0.1736 | 0.4609 |
| | 120 | 44.1264 | 33.2131 | 26.3142 | 34.5512 | 2.2771 | 1.9613 | 1.7616 | 1.2771 | 0.9613 | 0.7616 | 61.4909 | 19.1620 | 28.0472 | 0.0646 | 0.4037 | 0.1730 | 0.4526 |
| | 180 | 43.7118 | 32.6310 | 25.5662 | 33.9697 | 2.2868 | 1.9606 | 1.7526 | 1.2868 | 0.9606 | 0.7526 | 60.4345 | 19.5460 | 28.6893 | 0.0649 | 0.4151 | 0.1714 | 0.4325 |
| | 240 | 44.1019 | 32.7768 | 25.6303 | 34.1696 | 2.2907 | 1.9592 | 1.7501 | 1.2907 | 0.9592 | 0.7501 | 60.8779 | 20.0569 | 29.1312 | 0.0645 | 0.4188 | 0.1729 | 0.4025 |
| | 300 | 45.1639 | 33.4849 | 25.2985 | 34.6491 | 2.3035 | 1.9664 | 1.7301 | 1.3035 | 0.9664 | 0.7301 | 62.4306 | 20.3187 | 32.1136 | 0.0687 | 0.4399 | 0.1771 | 0.3808 |
| | 360 | 46.6981 | 34.9349 | 24.6890 | 35.4406 | 2.3176 | 1.9857 | 1.6966 | 1.3176 | 0.9857 | 0.6966 | 65.1965 | 19.4463 | 37.3033 | 0.0776 | 0.4713 | 0.1831 | 0.3771 |
| 1 ml SIBX (3) | 30 | 56.2626 | 43.0043 | 32.9250 | 44.0640 | 2.2768 | 1.9760 | 1.7472 | 1.2768 | 0.9760 | 0.7472 | 81.9754 | 21.8536 | 37.8029 | 0.0720 | 0.4148 | 0.2206 | 0.4275 |
| | 60 | 54.6840 | 41.3342 | 32.1809 | 42.7330 | 2.2797 | 1.9673 | 1.7531 | 1.2797 | 0.9673 | 0.7531 | 78.8478 | 22.7038 | 35.6379 | 0.0678 | 0.4115 | 0.2144 | 0.3947 |
| | 90 | 55.8145 | 42.3258 | 32.5328 | 43.5577 | 2.2814 | 1.9717 | 1.7469 | 1.2814 | 0.9717 | 0.7469 | 80.8211 | 22.6016 | 37.3365 | 0.0701 | 0.4171 | 0.2189 | 0.3865 |
| | 120 | 53.3748 | 40.6160 | 30.7780 | 41.5896 | 2.2834 | 1.9766 | 1.7400 | 1.2834 | 0.9766 | 0.7400 | 77.0136 | 21.1210 | 36.8751 | 0.0726 | 0.4234 | 0.2093 | 0.5417 |
| | 180 | 50.1832 | 38.4847 | 29.4382 | 39.3687 | 2.2747 | 1.9775 | 1.7478 | 1.2747 | 0.9775 | 0.7478 | 72.2222 | 19.3043 | 33.9922 | 0.0727 | 0.4134 | 0.1968 | 0.3842 |
| | 240 | 46.5740 | 36.1767 | 28.1584 | 36.9697 | 2.2598 | 1.9785 | 1.7617 | 1.2598 | 0.9785 | 0.7617 | 66.9335 | 17.0588 | 30.2657 | 0.0726 | 0.3954 | 0.1826 | 0.3806 |
| | 300 | 45.6202 | 35.3441 | 27.9104 | 36.2916 | 2.2570 | 1.9739 | 1.7691 | 1.2570 | 0.9739 | 0.7691 | 65.2582 | 17.1650 | 28.6842 | 0.0700 | 0.3882 | 0.1789 | 0.3805 |
| | 360 | 48.0347 | 37.1480 | 29.6176 | 38.2667 | 2.2553 | 1.9708 | 1.7740 | 1.2553 | 0.9708 | 0.7740 | 69.2003 | 18.3221 | 29.3925 | 0.0681 | 0.3834 | 0.1884 | 0.3827 |
| 2 ml SIBX (1) | 30 | 66.8463 | 48.8280 | 32.7083 | 49.4609 | 2.3515 | 1.9872 | 1.6613 | 1.3515 | 0.9872 | 0.6613 | 95.8990 | 29.5720 | 56.7803 | 0.0787 | 0.5107 | 0.2621 | 0.1836 |
| | 60 | 67.0007 | 49.0505 | 32.9082 | 49.6532 | 2.3494 | 1.9879 | 1.6628 | 1.3494 | 0.9879 | 0.6628 | 96.2787 | 29.3678 | 56.7596 | 0.0789 | 0.5088 | 0.2627 | 0.1463 |
| | 90 | 64.8699 | 47.2146 | 32.0309 | 48.0385 | 2.3504 | 1.9828 | 1.6668 | 1.3504 | 0.9828 | 0.6668 | 92.6223 | 29.3341 | 54.2939 | 0.0771 | 0.5062 | 0.2544 | 0.1823 |
| | 120 | 64.5017 | 47.0146 | 34.1038 | 48.5400 | 2.3288 | 1.9686 | 1.7026 | 1.3288 | 0.9686 | 0.7026 | 92.2716 | 29.8076 | 48.6484 | 0.0708 | 0.4713 | 0.2529 | 0.1620 |
| | 180 | 68.2818 | 50.4850 | 36.2249 | 51.6639 | 2.3217 | 1.9772 | 1.7012 | 1.3217 | 0.9772 | 0.7012 | 99.0446 | 29.4619 | 52.0227 | 0.0741 | 0.4695 | 0.2678 | 0.1514 |
| | 240 | 69.0508 | 50.8657 | 36.2038 | 52.0401 | 2.3269 | 1.9774 | 1.6957 | 1.3269 | 0.9774 | 0.6957 | 100.0000 | 30.1386 | 53.3457 | 0.0744 | 0.4757 | 0.2708 | 0.1299 |
| | 300 | 68.0321 | 49.8146 | 35.1217 | 50.9895 | 2.3342 | 1.9770 | 1.6888 | 1.3342 | 0.9770 | 0.6888 | 98.0068 | 30.3686 | 53.5144 | 0.0744 | 0.4837 | 0.2668 | 0.1212 |
| | 360 | 67.2164 | 49.1459 | 34.8570 | 50.4064 | 2.3335 | 1.9750 | 1.6915 | 1.3335 | 0.9750 | 0.6915 | 96.6553 | 30.2883 | 52.4359 | 0.0736 | 0.4814 | 0.2636 | 0.1060 |
| 2 ml SIBX (2) | 30 | 66.9184 | 48.9318 | 32.8016 | 49.5506 | 2.3505 | 1.9875 | 1.6620 | 1.3505 | 0.9875 | 0.6620 | 96.0762 | 29.4767 | 56.7706 | 0.0788 | 0.5098 | 0.2624 | 0.1891 |
| | 60 | 64.1595 | 46.6162 | 32.5002 | 47.7586 | 2.3434 | 1.9761 | 1.6805 | 1.3434 | 0.9761 | 0.6805 | 91.4649 | 29.5522 | 51.6633 | 0.0743 | 0.4934 | 0.2516 | 0.1842 |
| | 90 | 68.5254 | 50.7450 | 36.4352 | 51.9019 | 2.3203 | 1.9777 | 1.7020 | 1.3203 | 0.9777 | 0.7020 | 99.5290 | 29.3654 | 52.1127 | 0.0743 | 0.4683 | 0.2687 | 0.1705 |
| | 120 | 68.7322 | 50.5965 | 36.1782 | 51.8356 | 2.3260 | 1.9761 | 1.6979 | 1.3260 | 0.9761 | 0.6979 | 99.4683 | 30.1600 | 52.7232 | 0.0738 | 0.4736 | 0.2695 | 0.1751 |
| | 180 | 68.0929 | 49.8861 | 35.2226 | 51.0672 | 2.3334 | 1.9769 | 1.6897 | 1.3334 | 0.9769 | 0.6897 | 98.1385 | 30.3433 | 53.4288 | 0.0744 | 0.4827 | 0.2670 | 0.1540 |
| | 240 | 64.4495 | 46.9679 | 33.7914 | 48.4030 | 2.3315 | 1.9704 | 1.6981 | 1.3315 | 0.9704 | 0.6981 | 92.1604 | 29.7008 | 49.2981 | 0.0716 | 0.4757 | 0.2527 | 0.1217 |
| | 300 | 59.8609 | 41.7744 | 28.4699 | 43.3684 | 2.3803 | 1.9632 | 1.6565 | 1.3803 | 0.9632 | 0.6565 | 82.5882 | 31.9216 | 50.5428 | 0.0706 | 0.5244 | 0.2347 | 0.1147 |
| | 360 | 60.2015 | 41.8538 | 30.2086 | 44.0880 | 2.3655 | 1.9493 | 1.6852 | 1.3655 | 0.9493 | 0.6852 | 83.0257 | 33.0686 | 46.7841 | 0.0647 | 0.4982 | 0.2361 | 0.0712 |

**Calibrated results for North Parkes underground sulphide ore**

| | time | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | Hue | Sat | Val | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 ml SIBX (1) | 30 | 42.4667 | 37.6854 | 32.6038 | 38.3394 | 0.1078 | -0.0171 | -0.1498 | 1.1078 | 0.9829 | 0.8502 | 68.3017 | 5.9313 | 17.7687 | 0.0682 | 0.3788 | 0.1881 | 0.5884 |
| | 60 | 39.0684 | 34.2899 | 29.2971 | 34.9336 | 0.1188 | -0.0184 | -0.1619 | 1.1188 | 0.9816 | 0.8381 | 61.3852 | 6.1499 | 17.6421 | 0.0682 | 0.3936 | 0.1731 | 0.4462 |
| | 90 | 40.0399 | 35.4242 | 31.5875 | 36.3710 | 0.1010 | -0.0261 | -0.1316 | 1.1010 | 0.9739 | 0.8684 | 63.7412 | 6.5664 | 14.2871 | 0.0625 | 0.3616 | 0.1774 | 0.4676 |
| | 120 | 38.3660 | 33.9999 | 30.9435 | 35.0753 | 0.0941 | -0.0306 | -0.1181 | 1.0941 | 0.9694 | 0.8819 | 60.7827 | 6.6551 | 11.9615 | 0.0589 | 0.3477 | 0.1700 | 0.4791 |
| | 180 | 37.8872 | 33.8136 | 31.1237 | 34.8885 | 0.0860 | -0.0308 | -0.1080 | 1.0860 | 0.9692 | 0.8920 | 60.2868 | 6.2957 | 10.7032 | 0.0577 | 0.3353 | 0.1678 | 0.4865 |
| | 240 | 37.3859 | 33.3227 | 30.5547 | 34.3647 | 0.0880 | -0.0303 | -0.1111 | 1.0880 | 0.9697 | 0.8889 | 59.2647 | 6.2258 | 10.9249 | 0.0583 | 0.3388 | 0.1656 | 0.4940 |
| | 300 | 37.5026 | 33.5590 | 30.9033 | 34.5927 | 0.0842 | -0.0299 | -0.1068 | 1.0842 | 0.9701 | 0.8932 | 59.6990 | 6.0409 | 10.5064 | 0.0581 | 0.3333 | 0.1661 | 0.4899 |
| | 360 | 37.5037 | 33.6276 | 30.9802 | 34.6391 | 0.0829 | -0.0292 | -0.1059 | 1.0829 | 0.9708 | 0.8941 | 59.8047 | 5.8948 | 10.4254 | 0.0583 | 0.3317 | 0.1661 | 0.4944 |
| 0.5 ml SIBX (2) | 30 | 39.5211 | 35.2764 | 30.5676 | 33.7097 | 0.1725 | 0.0464 | -0.0933 | 1.1725 | 1.0464 | 0.9067 | 63.1416 | 5.0852 | 16.3830 | 0.0667 | 0.3810 | 0.1659 | 0.3942 |
| | 60 | 37.0181 | 32.8895 | 29.1858 | 31.6859 | 0.1686 | 0.0380 | -0.0793 | 1.1686 | 1.0380 | 0.9207 | 58.3013 | 5.6639 | 13.5913 | 0.0620 | 0.3693 | 0.1554 | 0.4211 |
| | 90 | 35.6317 | 31.6443 | 28.4425 | 30.5950 | 0.1649 | 0.0344 | -0.0707 | 1.1649 | 1.0344 | 0.9293 | 55.7224 | 5.7739 | 12.1174 | 0.0595 | 0.3614 | 0.1496 | 0.4428 |
| | 120 | 36.6606 | 32.7877 | 29.0471 | 31.4873 | 0.1643 | 0.0413 | -0.0776 | 1.1643 | 1.0413 | 0.9224 | 57.9498 | 5.0596 | 13.4831 | 0.0634 | 0.3659 | 0.1539 | 0.4518 |
| | 180 | 35.6746 | 31.8677 | 27.8989 | 30.5240 | 0.1687 | 0.0440 | -0.0859 | 1.1687 | 1.0440 | 0.9141 | 55.9968 | 4.7728 | 14.0889 | 0.0652 | 0.3740 | 0.1497 | 0.4465 |
| | 240 | 36.4017 | 32.5631 | 28.2815 | 31.1071 | 0.1703 | 0.0469 | -0.0911 | 1.1703 | 1.0469 | 0.9089 | 57.4093 | 4.5850 | 14.9581 | 0.0668 | 0.3784 | 0.1528 | 0.4558 |
| | 300 | 36.4927 | 32.6742 | 28.4480 | 31.2214 | 0.1691 | 0.0466 | -0.0892 | 1.1691 | 1.0466 | 0.9108 | 57.6328 | 4.5757 | 14.7847 | 0.0666 | 0.3764 | 0.1532 | 0.4401 |
| | 360 | 37.2498 | 33.3886 | 29.2558 | 31.9425 | 0.1666 | 0.0454 | -0.0848 | 1.1666 | 1.0454 | 0.9152 | 59.1331 | 4.7143 | 14.5399 | 0.0657 | 0.3720 | 0.1563 | 0.4756 |
| 0.5 ml SIBX (3) | 30 | 35.9364 | 31.9286 | 28.5133 | 33.3388 | 0.0781 | -0.0424 | -0.1449 | 1.0781 | 0.9576 | 0.8551 | 56.2939 | 5.6457 | 12.7197 | 0.0621 | 0.3537 | 0.1618 | 0.4768 |
| | 60 | 35.4861 | 31.6472 | 28.4192 | 33.0429 | 0.0740 | -0.0422 | -0.1400 | 1.0740 | 0.9578 | 0.8600 | 55.6447 | 5.4173 | 12.0655 | 0.0618 | 0.3475 | 0.1597 | 0.4673 |
| | 90 | 35.9252 | 32.2056 | 29.1269 | 33.6186 | 0.0688 | -0.0420 | -0.1339 | 1.0688 | 0.9580 | 0.8661 | 56.7474 | 5.2451 | 11.5343 | 0.0613 | 0.3396 | 0.1617 | 0.4767 |
| | 120 | 36.9295 | 33.2895 | 30.4445 | 34.7769 | 0.0620 | -0.0428 | -0.1247 | 1.0620 | 0.9572 | 0.8753 | 58.9610 | 5.2187 | 10.7887 | 0.0599 | 0.3284 | 0.1662 | 0.4663 |
| | 180 | 36.4220 | 32.9222 | 30.0939 | 34.3504 | 0.0604 | -0.0416 | -0.1240 | 1.0604 | 0.9584 | 0.8760 | 58.1339 | 4.9296 | 10.6360 | 0.0605 | 0.3269 | 0.1639 | 0.4751 |
| | 240 | 35.8079 | 32.5784 | 29.4722 | 33.8063 | 0.0594 | -0.0364 | -0.1284 | 1.0594 | 0.9636 | 0.8716 | 57.2507 | 4.1107 | 11.1971 | 0.0639 | 0.3296 | 0.1612 | 0.4590 |
| | 300 | 35.6873 | 32.4000 | 29.3477 | 33.6616 | 0.0603 | -0.0374 | -0.1283 | 1.0603 | 0.9626 | 0.8717 | 56.9205 | 4.2884 | 11.0989 | 0.0633 | 0.3301 | 0.1606 | 0.4447 |
| | 360 | 37.6761 | 34.4173 | 30.5685 | 35.4792 | 0.0620 | -0.0298 | -0.1386 | 1.0620 | 0.9702 | 0.8614 | 60.9563 | 3.5356 | 13.2326 | 0.0685 | 0.3391 | 0.1696 | 0.4418 |
| 1 ml SIBX (1) | 30 | 41.3143 | 36.1095 | 29.5687 | 36.0873 | 0.1449 | 0.0006 | -0.1806 | 1.1449 | 1.0006 | 0.8194 | 65.1766 | 5.9895 | 22.1451 | 0.0730 | 0.4219 | 0.1814 | 0.4015 |
| | 60 | 41.1392 | 36.0253 | 30.0513 | 36.1400 | 0.1384 | -0.0032 | -0.1685 | 1.1384 | 0.9968 | 0.8315 | 65.0110 | 6.1575 | 20.5369 | 0.0708 | 0.4099 | 0.1806 | 0.4482 |
| | 90 | 40.0110 | 34.8498 | 29.3837 | 35.1350 | 0.1389 | -0.0081 | -0.1639 | 1.1389 | 0.9919 | 0.8361 | 62.6919 | 6.6756 | 19.2397 | 0.0684 | 0.4068 | 0.1756 | 0.4583 |
| | 120 | 39.8387 | 34.7981 | 29.6096 | 35.1220 | 0.1342 | -0.0092 | -0.1569 | 1.1342 | 0.9908 | 0.8431 | 62.5481 | 6.5900 | 18.3812 | 0.0676 | 0.3995 | 0.1749 | 0.4653 |
| | 180 | 36.7463 | 32.0129 | 27.7133 | 32.4895 | 0.1311 | -0.0147 | -0.1471 | 1.1311 | 0.9853 | 0.8529 | 56.7683 | 6.6506 | 15.7819 | 0.0643 | 0.3908 | 0.1613 | 0.4654 |
| | 240 | 37.1181 | 32.9258 | 28.4816 | 33.1571 | 0.1196 | -0.0073 | -0.1408 | 1.1196 | 0.9927 | 0.8592 | 58.3282 | 5.2600 | 15.6894 | 0.0671 | 0.3800 | 0.1629 | 0.4701 |
| | 300 | 37.7144 | 33.7587 | 29.3762 | 33.9205 | 0.1121 | -0.0047 | -0.1343 | 1.1121 | 0.9953 | 0.8657 | 59.9152 | 4.7292 | 15.2951 | 0.0683 | 0.3711 | 0.1656 | 0.4617 |
| | 360 | 37.0015 | 32.8929 | 26.0158 | 32.3597 | 0.1437 | 0.0165 | -0.1965 | 1.1437 | 1.0165 | 0.8035 | 57.9694 | 3.4157 | 22.2544 | 0.0803 | 0.4325 | 0.1624 | 0.4647 |

Calibrated results for North Parkes underground sulphide ore (continued)

| | time | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | Hue | Sat | Val | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 ml SIBX (2) | 30 | 34.3771 | 30.4099 | 24.3614 | 30.5524 | 0.1251 | -0.0047 | -0.2026 | 1.1251 | 0.9953 | 0.7974 | 52.8668 | 3.7715 | 19.9841 | 0.0784 | 0.4590 | 0.1564 | 0.4136 |
| | 60 | 38.1178 | 33.4877 | 29.0282 | 34.3956 | 0.1086 | -0.0261 | -0.1568 | 1.1086 | 0.9739 | 0.8432 | 59.7185 | 6.2261 | 16.0810 | 0.0677 | 0.4192 | 0.1734 | 0.4477 |
| | 90 | 38.1426 | 33.5759 | 29.9873 | 34.7176 | 0.0987 | -0.0328 | -0.1363 | 1.0987 | 0.9672 | 0.8637 | 59.9614 | 6.7168 | 13.6195 | 0.0638 | 0.3999 | 0.1736 | 0.4609 |
| | 120 | 38.0303 | 33.4535 | 29.7081 | 34.5512 | 0.1007 | -0.0318 | -0.1402 | 1.1007 | 0.9682 | 0.8598 | 59.6982 | 6.6276 | 14.0660 | 0.0646 | 0.4037 | 0.1730 | 0.4526 |
| | 180 | 37.6730 | 32.8672 | 28.8636 | 33.9697 | 0.1089 | -0.0324 | -0.1502 | 1.1089 | 0.9676 | 0.8498 | 58.5939 | 6.9865 | 14.9951 | 0.0649 | 0.4150 | 0.1714 | 0.4325 |
| | 240 | 38.0091 | 33.0140 | 28.9360 | 34.1696 | 0.1124 | -0.0338 | -0.1532 | 1.1124 | 0.9662 | 0.8468 | 58.9923 | 7.3589 | 15.3580 | 0.0645 | 0.4189 | 0.1729 | 0.4025 |
| | 300 | 38.9244 | 33.7272 | 28.5614 | 34.6491 | 0.1238 | -0.0262 | -0.1766 | 1.1238 | 0.9738 | 0.8234 | 60.4495 | 7.0270 | 18.4942 | 0.0684 | 0.4403 | 0.1771 | 0.3808 |
| | 360 | 40.2467 | 35.1877 | 27.8733 | 35.4406 | 0.1370 | -0.0067 | -0.2159 | 1.1370 | 0.9933 | 0.7841 | 63.1443 | 5.2210 | 24.1388 | 0.0772 | 0.4728 | 0.1831 | 0.3771 |
| 1 ml SIBX (3) | 30 | 49.0164 | 42.6606 | 35.7081 | 44.0640 | 0.1124 | -0.0318 | -0.1897 | 1.1124 | 0.9682 | 0.8103 | 79.0335 | 7.9754 | 23.9709 | 0.0720 | 0.4149 | 0.2206 | 0.4275 |
| | 60 | 47.6412 | 41.0039 | 34.9010 | 42.7330 | 0.1149 | -0.0405 | -0.1832 | 1.1149 | 0.9595 | 0.8168 | 75.9362 | 9.2790 | 21.9849 | 0.0677 | 0.4114 | 0.2144 | 0.3947 |
| | 90 | 48.6261 | 41.9876 | 35.2827 | 43.5577 | 0.1163 | -0.0361 | -0.1898 | 1.1163 | 0.9639 | 0.8102 | 77.8591 | 8.8243 | 23.5700 | 0.0700 | 0.4169 | 0.2189 | 0.3865 |
| | 120 | 46.5006 | 40.2914 | 33.3796 | 41.5896 | 0.1185 | -0.0310 | -0.1982 | 1.1185 | 0.9690 | 0.8018 | 74.1783 | 7.8091 | 23.8303 | 0.0724 | 0.4239 | 0.2093 | 0.5417 |
| | 180 | 43.7201 | 38.1771 | 31.9265 | 39.3687 | 0.1106 | -0.0303 | -0.1891 | 1.1106 | 0.9697 | 0.8109 | 69.5947 | 6.8379 | 21.5664 | 0.0727 | 0.4134 | 0.1968 | 0.3842 |
| | 240 | 40.5756 | 35.8876 | 30.5386 | 36.9697 | 0.0977 | -0.0293 | -0.1742 | 1.0977 | 0.9707 | 0.8258 | 64.5610 | 5.6127 | 18.4831 | 0.0726 | 0.3956 | 0.1826 | 0.3806 |
| | 300 | 39.7447 | 35.0617 | 30.2696 | 36.2916 | 0.0952 | -0.0339 | -0.1660 | 1.0952 | 0.9661 | 0.8340 | 62.9316 | 6.0347 | 16.9840 | 0.0700 | 0.3883 | 0.1789 | 0.3805 |
| | 360 | 41.8482 | 36.8512 | 32.1211 | 38.2667 | 0.0937 | -0.0370 | -0.1608 | 1.0937 | 0.9630 | 0.8392 | 66.7593 | 6.7117 | 17.0158 | 0.0682 | 0.3836 | 0.1884 | 0.3827 |
| 2 ml SIBX (1) | 30 | 54.4572 | 45.5675 | 33.0006 | 49.4609 | 0.1011 | -0.0787 | -0.3329 | 1.1011 | 0.9213 | 0.6671 | 85.7994 | 10.4171 | 40.7103 | 0.0787 | 0.5108 | 0.2621 | 0.1836 |
| | 60 | 54.5830 | 45.7752 | 33.2023 | 49.6531 | 0.0994 | -0.0781 | -0.3314 | 1.0994 | 0.9219 | 0.6686 | 86.1655 | 10.1974 | 40.6481 | 0.0789 | 0.5090 | 0.2627 | 0.1463 |
| | 90 | 52.8471 | 44.0619 | 32.3172 | 48.0385 | 0.1005 | -0.0828 | -0.3277 | 1.1005 | 0.9172 | 0.6723 | 82.7977 | 10.7456 | 38.5778 | 0.0770 | 0.5066 | 0.2544 | 0.1823 |
| | 120 | 52.5471 | 43.8753 | 34.4086 | 48.5400 | 0.0835 | -0.0963 | -0.2921 | 1.0835 | 0.9037 | 0.7079 | 82.5458 | 11.7042 | 32.5811 | 0.0708 | 0.4723 | 0.2529 | 0.1620 |
| | 180 | 55.6266 | 47.1139 | 36.5487 | 51.6639 | 0.0768 | -0.0881 | -0.2927 | 1.0768 | 0.9119 | 0.7073 | 88.8268 | 10.4303 | 35.1754 | 0.0741 | 0.4695 | 0.2678 | 0.1514 |
| | 240 | 56.2531 | 47.4692 | 36.5273 | 52.0401 | 0.0810 | -0.0879 | -0.2980 | 1.0810 | 0.9121 | 0.7020 | 89.6569 | 10.8207 | 36.3716 | 0.0743 | 0.4756 | 0.2708 | 0.1299 |
| | 300 | 55.4232 | 46.4882 | 35.4356 | 50.9895 | 0.0872 | -0.0884 | -0.3052 | 1.0872 | 0.9116 | 0.6948 | 87.7802 | 11.2054 | 36.8291 | 0.0744 | 0.4839 | 0.2668 | 0.1212 |
| | 360 | 54.7587 | 45.8642 | 35.1685 | 50.4064 | 0.0864 | -0.0902 | -0.3023 | 1.0864 | 0.9098 | 0.6977 | 86.5424 | 11.3629 | 35.8948 | 0.0736 | 0.4815 | 0.2636 | 0.1060 |
| 2 ml SIBX (2) | 30 | 59.9313 | 50.8697 | 37.0083 | 49.5506 | 0.2096 | 0.0266 | -0.2532 | 1.2096 | 1.0266 | 0.7468 | 96.3347 | 9.6043 | 43.9626 | 0.0788 | 0.5099 | 0.2624 | 0.1891 |
| | 60 | 57.4605 | 48.4624 | 36.6682 | 47.7586 | 0.2037 | 0.0146 | -0.2328 | 1.2037 | 1.0146 | 0.7672 | 91.6844 | 10.7664 | 38.7180 | 0.0741 | 0.4938 | 0.2516 | 0.1842 |
| | 90 | 61.3706 | 52.7547 | 41.1078 | 51.9019 | 0.1826 | 0.0164 | -0.2081 | 1.1826 | 1.0164 | 0.7919 | 100.0000 | 9.5850 | 37.8474 | 0.0742 | 0.4684 | 0.2687 | 0.1705 |
| | 120 | 61.5557 | 52.6003 | 40.8179 | 51.8356 | 0.1875 | 0.0146 | -0.2124 | 1.1875 | 1.0146 | 0.7876 | 99.8711 | 10.3026 | 38.4881 | 0.0737 | 0.4735 | 0.2695 | 0.1751 |
| | 180 | 60.9832 | 51.8617 | 39.7397 | 51.0672 | 0.1943 | 0.0155 | -0.2219 | 1.1943 | 1.0155 | 0.7781 | 98.4726 | 10.5614 | 39.5337 | 0.0743 | 0.4828 | 0.2670 | 0.1540 |
| | 240 | 57.7203 | 48.8280 | 38.1251 | 48.4030 | 0.1926 | 0.0087 | -0.2123 | 1.1926 | 1.0087 | 0.7877 | 92.4428 | 11.0840 | 35.7862 | 0.0716 | 0.4757 | 0.2527 | 0.1217 |
| | 300 | 53.6107 | 43.4288 | 32.1211 | 43.3684 | 0.2403 | 0.0012 | -0.2643 | 1.2403 | 1.0012 | 0.7357 | 82.3962 | 14.3356 | 38.7126 | 0.0706 | 0.5284 | 0.2347 | 0.1147 |
| | 360 | 53.9157 | 43.5113 | 34.0828 | 44.0880 | 0.2238 | -0.0128 | -0.2283 | 1.2238 | 0.9872 | 0.7717 | 82.8472 | 15.8018 | 34.0383 | 0.0646 | 0.4991 | 0.2361 | 0.0712 |

# Appendix C Kennecott Copper Concentrator Plant data

Data for reagent test 1 (calibrated)

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 1, cell 2 | -1.3250 | -1.4958 | 2.3537 | 65.6991 | 56.6729 | 50.1159 | 57.4960 | 0.1427 | -0.0143 | -0.1284 | 1.1427 | 0.9857 | 0.8716 | 90.4299 | 11.5342 | 21.0561 | 45.4875 |
| | -1.1608 | -1.6948 | 2.4294 | 66.8135 | 57.5484 | 50.6894 | 58.3504 | 0.1450 | -0.0137 | -0.1313 | 1.1450 | 0.9863 | 0.8687 | 91.9915 | 11.7694 | 21.8877 | 47.6469 |
| | -1.4381 | -1.9600 | 2.6398 | 67.7094 | 58.0872 | 51.2558 | 59.0175 | 0.1473 | -0.0158 | -0.1315 | 1.1473 | 0.9842 | 0.8685 | 93.0692 | 12.4358 | 22.0640 | 47.8350 |
| | -0.8224 | -1.3596 | 2.2454 | 67.8391 | 58.2115 | 51.3270 | 59.1259 | 0.1474 | -0.0155 | -0.1319 | 1.1474 | 0.9845 | 0.8681 | 93.2765 | 12.4093 | 22.1848 | 48.6525 |
| | -1.1491 | -2.2050 | 2.7491 | 67.9366 | 58.0185 | 51.1085 | 59.0212 | 0.1511 | -0.0170 | -0.1341 | 1.1511 | 0.9830 | 0.8659 | 93.0849 | 12.9512 | 22.4583 | 47.5190 |
| | -1.0474 | -1.8739 | 2.4249 | 70.3114 | 62.6622 | 57.1156 | 63.3631 | 0.1097 | -0.0111 | -0.0986 | 1.1097 | 0.9889 | 0.9014 | 100.0000 | 9.3920 | 17.6269 | 31.3674 |
| | -1.0175 | -1.5127 | 2.1985 | 69.8616 | 62.1620 | 56.5656 | 62.8631 | 0.1113 | -0.0112 | -0.1002 | 1.1113 | 0.9888 | 0.8998 | 99.1756 | 9.4666 | 17.7865 | 40.2683 |
| | -0.5499 | -0.6968 | 1.2616 | 69.2850 | 61.5660 | 55.7914 | 62.2141 | 0.1137 | -0.0104 | -0.1032 | 1.1137 | 0.9896 | 0.8968 | 98.1636 | 9.4052 | 18.2205 | 36.6314 |
| | -0.3865 | -0.3512 | 1.0234 | 69.5962 | 61.7665 | 56.1140 | 62.4922 | 0.1137 | -0.0116 | -0.1021 | 1.1137 | 0.9884 | 0.8979 | 98.5622 | 9.6816 | 18.0135 | 34.4828 |
| | -0.1797 | -0.1176 | 1.4118 | 70.1635 | 62.2608 | 56.5891 | 63.0045 | 0.1136 | -0.0118 | -0.1018 | 1.1136 | 0.9882 | 0.8982 | 99.4248 | 9.7898 | 18.0957 | 41.7925 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 1, cell 2 | 0.0701 | 0.2372 | 0.2576 | 6.2047 | 4.1946 | 55.9398 | 24.0083 | 29.0000 | 28.4000 | 1.4100 | 34.2000 | 8.5900 | 26.5000 | 27.6000 | 1.7200 | 33.7000 | 10.0400 |
| | 0.0709 | 0.2413 | 0.2620 | 6.3817 | 4.3617 | 55.6486 | 24.8513 | 28.8000 | 28.3000 | 1.4600 | 34.0000 | 8.8200 | 27.1000 | 27.6000 | 1.6400 | 33.2000 | 10.3300 |
| | 0.0692 | 0.2430 | 0.2655 | 6.5985 | 4.4023 | 56.2901 | 25.3272 | 28.9000 | 28.4000 | 1.4200 | 34.1000 | 8.6100 | 27.1000 | 27.6000 | 1.6500 | 33.4000 | 10.1100 |
| | 0.0695 | 0.2434 | 0.2660 | 6.6071 | 4.4263 | 56.1806 | 25.4196 | 28.9000 | 28.4000 | 1.3600 | 34.1000 | 8.4000 | 27.9000 | 28.1000 | 1.4700 | 33.7000 | 9.5700 |
| | 0.0684 | 0.2477 | 0.2664 | 6.7883 | 4.4803 | 56.5752 | 25.9250 | 28.9000 | 28.4000 | 1.2900 | 34.5000 | 8.3700 | 27.7000 | 27.6000 | 1.5400 | 33.2000 | 10.1800 |
| | 0.0701 | 0.1877 | 0.2757 | 5.2571 | 3.5503 | 55.9676 | 19.9729 | 29.9000 | 28.4000 | 0.9400 | 33.5000 | 9.1100 | 27.5000 | 26.2000 | 1.1300 | 31.3000 | 13.5500 |
| | 0.0702 | 0.1903 | 0.2740 | 5.2930 | 3.5794 | 55.9313 | 20.1488 | 29.8000 | 28.4000 | 0.9300 | 33.4000 | 9.3400 | 27.8000 | 26.7000 | 1.2400 | 31.7000 | 12.5000 |
| | 0.0713 | 0.1948 | 0.2717 | 5.3228 | 3.6602 | 55.4858 | 20.5048 | 29.9000 | 28.5000 | 0.9600 | 33.4000 | 8.9900 | 27.6000 | 26.7000 | 1.1700 | 31.6000 | 12.7900 |
| | 0.0699 | 0.1937 | 0.2729 | 5.3786 | 3.6232 | 56.0347 | 20.4504 | 30.0000 | 28.7000 | 0.8700 | 33.8000 | 8.5300 | 27.1000 | 25.8000 | 1.1500 | 30.3000 | 15.1500 |
| | 0.0696 | 0.1935 | 0.2752 | 5.4254 | 3.6423 | 56.1250 | 20.5741 | 29.6000 | 28.4000 | 1.0000 | 34.0000 | 8.7600 | 28.4000 | 27.4000 | 1.2300 | 32.6000 | 11.0500 |

**Data for reagent test 2 (calibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 2 | 0.43 | -1.67 | 2.45 | 37.21 | 33.10 | 21.72 | 30.67 | 0.21 | 0.08 | -0.29 | 1.21 | 1.08 | 0.71 | 47.30 | 0.79 | 29.03 | 53.37 |
| | 0.34 | -1.63 | 2.11 | 37.03 | 32.93 | 21.27 | 30.41 | 0.22 | 0.08 | -0.30 | 1.22 | 1.08 | 0.70 | 46.99 | 0.68 | 29.63 | 49.08 |
| | 0.26 | -1.44 | 2.49 | 37.09 | 32.97 | 21.12 | 30.40 | 0.22 | 0.08 | -0.31 | 1.22 | 1.08 | 0.69 | 47.06 | 0.63 | 30.04 | 48.74 |
| | 0.09 | -1.31 | 2.81 | 36.76 | 32.65 | 21.11 | 30.17 | 0.22 | 0.08 | -0.30 | 1.22 | 1.08 | 0.70 | 46.51 | 0.78 | 29.39 | 47.20 |
| | 0.50 | -1.44 | 2.30 | 36.38 | 32.23 | 21.28 | 29.96 | 0.21 | 0.08 | -0.29 | 1.21 | 1.08 | 0.71 | 45.83 | 1.12 | 28.15 | 57.61 |
| | 0.13 | -0.67 | 2.39 | 37.18 | 37.93 | 24.97 | 33.36 | 0.11 | 0.14 | -0.25 | 1.11 | 1.14 | 0.75 | 53.54 | -10.23 | 29.38 | 39.28 |
| | 0.18 | -1.16 | 2.42 | 37.18 | 37.94 | 24.60 | 33.24 | 0.12 | 0.14 | -0.26 | 1.12 | 1.14 | 0.74 | 53.53 | -10.41 | 30.18 | 41.25 |
| | 0.12 | -1.35 | 2.84 | 37.45 | 38.14 | 24.43 | 33.34 | 0.12 | 0.14 | -0.27 | 1.12 | 1.14 | 0.73 | 53.88 | -10.46 | 31.00 | 42.81 |
| | -0.18 | -0.91 | 2.13 | 36.77 | 37.49 | 23.75 | 32.67 | 0.13 | 0.15 | -0.27 | 1.13 | 1.15 | 0.73 | 52.75 | -10.51 | 31.04 | 41.41 |
| | 0.47 | -0.97 | 2.71 | 37.61 | 38.31 | 24.31 | 33.41 | 0.13 | 0.15 | -0.27 | 1.13 | 1.15 | 0.73 | 54.16 | -10.64 | 31.61 | 41.45 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 2 | 0.12 | 0.42 | 0.15 | 3.66 | 5.58 | 33.31 | 29.04 | 30.40 | 28.30 | 1.59 | 32.30 | 8.86 | 30.60 | 28.60 | 1.47 | 33.80 | 8.19 |
| | 0.12 | 0.43 | 0.15 | 3.69 | 5.70 | 32.90 | 29.64 | 30.60 | 28.40 | 1.56 | 32.80 | 8.32 | 30.60 | 28.60 | 1.48 | 33.50 | 8.38 |
| | 0.12 | 0.43 | 0.15 | 3.71 | 5.78 | 32.72 | 30.04 | 30.60 | 28.40 | 1.66 | 32.90 | 8.51 | 30.50 | 28.50 | 1.51 | 33.50 | 8.28 |
| | 0.12 | 0.43 | 0.14 | 3.68 | 5.65 | 33.11 | 29.40 | 30.50 | 28.50 | 1.73 | 33.10 | 8.30 | 30.40 | 28.40 | 1.53 | 33.00 | 8.26 |
| | 0.12 | 0.41 | 0.14 | 3.64 | 5.39 | 34.03 | 28.17 | 30.80 | 26.10 | 1.28 | 31.40 | 12.77 | 30.70 | 28.60 | 1.47 | 33.50 | 8.37 |
| | 0.18 | 0.34 | 0.15 | 0.83 | 5.55 | 8.54 | 31.11 | 28.10 | 28.60 | 1.46 | 33.20 | 8.41 | 29.80 | 27.80 | 1.24 | 33.40 | 9.54 |
| | 0.18 | 0.35 | 0.15 | 0.87 | 5.72 | 8.64 | 31.92 | 28.70 | 26.80 | 1.36 | 32.30 | 11.10 | 29.80 | 27.80 | 1.22 | 33.60 | 9.54 |
| | 0.18 | 0.36 | 0.15 | 0.95 | 5.89 | 9.15 | 32.72 | 28.90 | 27.00 | 1.30 | 32.10 | 11.24 | 29.70 | 27.80 | 1.23 | 33.60 | 9.53 |
| | 0.18 | 0.37 | 0.15 | 0.93 | 5.90 | 8.95 | 32.77 | 28.30 | 26.40 | 1.38 | 31.50 | 11.98 | 29.90 | 28.10 | 1.20 | 33.50 | 9.33 |
| | 0.18 | 0.37 | 0.15 | 0.97 | 6.01 | 9.13 | 33.35 | 28.90 | 27.00 | 1.32 | 32.20 | 11.00 | 29.90 | 28.00 | 1.18 | 33.60 | 9.33 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 4 | -0.0588 | -0.5203 | 2.3768 | 29.8926 | 27.0392 | 21.5540 | 26.1619 | 0.1426 | 0.0335 | -0.1761 | 1.1426 | 1.0335 | 0.8239 | 36.4442 | 1.4611 | 15.0832 | 0.1096 |
| | -0.1063 | -0.7089 | 2.2757 | 30.6840 | 27.6842 | 21.9645 | 26.7776 | 0.1459 | 0.0339 | -0.1797 | 1.1459 | 1.0339 | 0.8203 | 37.6387 | 1.5937 | 15.7158 | 0.1093 |
| | -0.1677 | -0.5743 | 2.6125 | 30.3733 | 27.3400 | 21.6532 | 26.4555 | 0.1481 | 0.0334 | -0.1815 | 1.1481 | 1.0334 | 0.8185 | 37.0459 | 1.6975 | 15.6726 | 0.1087 |
| | 0.0411 | -0.2896 | 2.7908 | 29.8363 | 26.8770 | 21.2363 | 25.9832 | 0.1483 | 0.0344 | -0.1827 | 1.1483 | 1.0344 | 0.8173 | 36.1923 | 1.5965 | 15.5260 | 0.1093 |
| | -0.0393 | -0.7062 | 2.1518 | 29.5957 | 26.6375 | 21.1438 | 25.7923 | 0.1475 | 0.0328 | -0.1802 | 1.1475 | 1.0328 | 0.8198 | 35.7778 | 1.6888 | 15.1886 | 0.1083 |
| | -0.1688 | -0.5924 | 2.5106 | 32.3975 | 29.3806 | 23.8109 | 28.5297 | 0.1356 | 0.0298 | -0.1654 | 1.1356 | 1.0298 | 0.8346 | 40.6650 | 1.6351 | 15.3293 | 0.1081 |
| | -0.1362 | -0.4415 | 2.7710 | 34.2583 | 31.4452 | 25.4703 | 30.3913 | 0.1272 | 0.0347 | -0.1619 | 1.1272 | 1.0347 | 0.8381 | 44.1832 | 0.9053 | 16.0777 | 0.1133 |
| | 0.0005 | -0.5265 | 2.3647 | 34.4683 | 31.6243 | 25.7001 | 30.5976 | 0.1265 | 0.0336 | -0.1601 | 1.1265 | 1.0336 | 0.8399 | 44.5171 | 0.9895 | 15.9760 | 0.1126 |
| | -0.0686 | -0.7496 | 2.4890 | 35.3208 | 32.3511 | 26.3777 | 31.3499 | 0.1267 | 0.0319 | -0.1586 | 1.1267 | 1.0319 | 0.8414 | 45.8487 | 1.1820 | 16.1573 | 0.1113 |
| | 0.0082 | -0.4290 | 3.0033 | 35.4394 | 32.5237 | 26.7933 | 31.5854 | 0.1220 | 0.0297 | -0.1517 | 1.1220 | 1.0297 | 0.8483 | 46.1489 | 1.2137 | 15.5493 | 0.1105 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 4 | 0.1096 | 0.2790 | 0.1172 | 2.3026 | 2.8165 | 39.2672 | 15.1538 | 30.6000 | 28.1000 | 1.5400 | 33.5000 | 8.2300 |
| | 0.1093 | 0.2842 | 0.1203 | 2.4160 | 2.9405 | 39.4077 | 15.7964 | 30.3000 | 27.9000 | 1.6800 | 33.4000 | 8.4700 |
| | 0.1087 | 0.2871 | 0.1191 | 2.4333 | 2.9311 | 39.6986 | 15.7642 | 30.8000 | 28.2000 | 1.4600 | 33.5000 | 8.2400 |
| | 0.1093 | 0.2882 | 0.1170 | 2.3832 | 2.9001 | 39.4129 | 15.6079 | 30.6000 | 28.2000 | 1.5300 | 33.7000 | 8.1500 |
| | 0.1083 | 0.2856 | 0.1161 | 2.3678 | 2.8357 | 39.8623 | 15.2822 | 30.5000 | 28.0000 | 1.5000 | 33.8000 | 8.2500 |
| | 0.1081 | 0.2650 | 0.1270 | 2.4116 | 2.8775 | 39.9653 | 15.4163 | 27.3000 | 25.1000 | 1.2500 | 30.5000 | 14.6200 |
| | 0.1133 | 0.2565 | 0.1343 | 2.3268 | 3.0245 | 37.5720 | 16.1032 | 28.7000 | 26.6000 | 1.3800 | 32.1000 | 11.4000 |
| | 0.1126 | 0.2544 | 0.1352 | 2.3407 | 3.0069 | 37.8987 | 16.0066 | 27.2000 | 25.0000 | 1.2800 | 29.8000 | 15.2100 |
| | 0.1113 | 0.2532 | 0.1385 | 2.4229 | 3.0469 | 38.4919 | 16.2005 | 27.9000 | 25.8000 | 1.2800 | 31.0000 | 13.4100 |
| | 0.1105 | 0.2440 | 0.1390 | 2.3654 | 2.9328 | 38.8870 | 15.5966 | 29.4000 | 27.3000 | 1.2500 | 33.0000 | 10.0000 |

**Data for reagent test 3 (rejected for analysis) (calibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 2 | 0.2615 | -1.8320 | 2.4840 | 45.4530 | 41.3867 | 32.1734 | 39.6710 | 0.1457 | 0.0432 | -0.1890 | 1.1457 | 1.0432 | 0.8110 | 61.8264 | 1.1335 | 24.0888 |
| | 0.2055 | -1.2638 | 2.1799 | 40.6055 | 36.6160 | 27.1551 | 34.7922 | 0.1671 | 0.0524 | -0.2195 | 1.1671 | 1.0524 | 0.7805 | 53.5004 | 1.1204 | 24.7116 |
| | 0.1620 | -1.6065 | 2.5522 | 44.2915 | 39.8507 | 29.4796 | 37.8739 | 0.1694 | 0.0522 | -0.2216 | 1.1694 | 1.0522 | 0.7784 | 59.2542 | 1.3756 | 26.9760 |
| | 0.2420 | -1.5917 | 2.7535 | 40.4450 | 36.6746 | 27.8685 | 34.9960 | 0.1557 | 0.0480 | -0.2037 | 1.1557 | 1.0480 | 0.7963 | 53.5503 | 1.0070 | 23.0883 |
| | 0.4053 | -2.1573 | 2.1329 | 34.8482 | 32.0630 | 23.5963 | 30.1692 | 0.1551 | 0.0628 | -0.2179 | 1.1551 | 1.0628 | 0.7821 | 45.0631 | -0.5469 | 21.7587 |
| | 0.3137 | -1.3455 | 2.2749 | 36.7313 | 33.9558 | 25.9480 | 32.2117 | 0.1403 | 0.0541 | -0.1945 | 1.1403 | 1.0541 | 0.8055 | 48.4141 | -0.4271 | 20.6703 |
| | **Hue** | **Sat** | **Val** | **Cr** | **Cb** | **RGB angle** | **Length** | **Cu** | **Fe** | **MoS2** | **S** | **Insol** | **% solids** | | | |
| reagent test 3, cell 2 | 0.1156 | 0.2922 | 0.1782 | 3.4210 | 4.6237 | 36.4972 | 24.1155 | 27.1000 | 28.3000 | 1.3500 | 34.0000 | 8.6300 | 33.0749 | | | |
| | 0.1172 | 0.3312 | 0.1592 | 3.3985 | 4.7206 | 35.7511 | 24.7370 | 28.0000 | 28.2000 | 1.4200 | 34.2000 | 8.6900 | 25.4009 | | | |
| | 0.1167 | 0.3344 | 0.1737 | 3.7670 | 5.1847 | 36.0011 | 27.0111 | 28.7000 | 28.4000 | 1.4300 | 33.9000 | 8.4600 | 25.7276 | | | |
| | 0.1167 | 0.3110 | 0.1586 | 3.1984 | 4.4023 | 35.9991 | 23.1103 | 26.4000 | 27.3000 | 1.4200 | 32.9000 | 11.8400 | 25.6747 | | | |
| | 0.1254 | 0.3229 | 0.1367 | 2.5588 | 4.1088 | 31.9126 | 21.7656 | 26.3000 | 27.1000 | 1.3400 | 32.0000 | 12.7500 | 18.4895 | | | |
| | 0.1238 | 0.2936 | 0.1440 | 2.5069 | 3.9069 | 32.6869 | 20.6748 | 25.3000 | 25.4000 | 1.3200 | 30.5000 | 15.8100 | 18.6158 | | | |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 4 | -0.1119 | -0.9629 | 0.3307 | 39.2470 | 36.1778 | 28.3719 | 34.5989 | 0.1343 | 0.0456 | -0.1800 | 1.1343 | 1.0456 | 0.8200 | 52.4463 | 0.1683 | 20.3525 |
| | 0.0069 | -0.2842 | 0.2540 | 41.4985 | 36.4910 | 26.8139 | 34.9345 | 0.1879 | 0.0446 | -0.2325 | 1.1879 | 1.0446 | 0.7675 | 53.7419 | 3.0929 | 25.9049 |
| | -0.0891 | -0.1517 | 0.2573 | 38.2346 | 35.6298 | 29.7163 | 34.5269 | 0.1074 | 0.0319 | -0.1393 | 1.1074 | 1.0319 | 0.8607 | 51.4435 | 0.3918 | 15.6866 |
| | 0.0144 | -0.0606 | 0.2567 | 38.8096 | 36.3766 | 30.8144 | 35.3335 | 0.0984 | 0.0295 | -0.1279 | 1.0984 | 1.0295 | 0.8721 | 52.7066 | 0.2611 | 14.7353 |
| | -0.1225 | -0.2891 | 0.1849 | 38.9056 | 35.8937 | 28.4268 | 34.4087 | 0.1307 | 0.0432 | -0.1738 | 1.1307 | 1.0432 | 0.8262 | 51.9520 | 0.2575 | 19.5450 |
| | -0.0073 | -0.4028 | 0.1862 | 38.6074 | 35.6401 | 28.6606 | 34.3027 | 0.1255 | 0.0390 | -0.1645 | 1.1255 | 1.0390 | 0.8355 | 51.5292 | 0.4598 | 18.4004 |
| | **Hue** | **Sat** | **Val** | **Cr** | **Cb** | **RGB angle** | **Length** | **Cu** | **Fe** | **MoS2** | **S** | **Insol** | **% solids** | | | |
| reagent test 3, cell 4 | 0.1196 | 0.2771 | 0.1539 | 2.6673 | 3.8620 | 34.6305 | 20.3532 | 18.1400 | 24.8400 | 1.4900 | 27.7700 | 22.4000 | 18.1400 | | | |
| | 0.1098 | 0.3539 | 0.1627 | 4.0460 | 4.9651 | 39.1759 | 26.0889 | 17.0700 | 23.3100 | 1.5100 | 25.3700 | 26.7900 | 17.0700 | | | |
| | 0.1157 | 0.2228 | 0.1499 | 2.1926 | 2.9669 | 36.4651 | 15.6915 | 17.4500 | 21.5900 | 1.4500 | 22.6400 | 29.0000 | 17.4500 | | | |
| | 0.1159 | 0.2060 | 0.1522 | 2.0519 | 2.7882 | 36.3499 | 14.7376 | 18.8200 | 23.7000 | 1.2000 | 24.4400 | 27.7600 | 18.8200 | | | |
| | 0.1188 | 0.2693 | 0.1526 | 2.5982 | 3.7055 | 35.0366 | 19.5466 | 13.0200 | 16.6300 | 1.0400 | 15.3100 | 43.2800 | 13.0200 | | | |
| | 0.1169 | 0.2576 | 0.1514 | 2.5220 | 3.4860 | 35.8844 | 18.4061 | 11.2900 | 14.5600 | 0.9910 | 13.6000 | 46.6500 | 11.2900 | | | |

**Data for reagent test 4 (calibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 4, cell 2 | 0.0934 | -1.3176 | 2.4992 | 45.4603 | 42.6734 | 32.7107 | 40.2815 | 0.1286 | 0.0594 | -0.1879 | 1.1286 | 1.0594 | 0.8121 | 63.43 | -1.86 | 24.90 |
| | 0.1140 | -0.8522 | 2.4034 | 46.5743 | 43.5731 | 33.0450 | 41.0641 | 0.1342 | 0.0611 | -0.1953 | 1.1342 | 1.0611 | 0.8047 | 65.03 | -1.78 | 26.28 |
| | 0.3458 | -0.7879 | 2.1074 | 47.4124 | 44.3809 | 33.6260 | 41.8065 | 0.1341 | 0.0616 | -0.1957 | 1.1341 | 1.0616 | 0.8043 | 66.42 | -1.88 | 26.79 |
| | 0.0201 | -0.9232 | 2.6941 | 47.6079 | 44.5154 | 33.5167 | 41.8800 | 0.1368 | 0.0629 | -0.1997 | 1.1368 | 1.0629 | 0.8003 | 66.66 | -1.89 | 27.37 |
| | -0.0041 | -0.5152 | 3.0059 | 47.4934 | 44.2227 | 33.2156 | 41.6439 | 0.1405 | 0.0619 | -0.2024 | 1.1405 | 1.0619 | 0.7976 | 66.23 | -1.53 | 27.51 |
| | 0.4307 | -2.0478 | 2.2619 | 34.3311 | 32.1719 | 26.6327 | 31.0452 | 0.1058 | 0.0363 | -0.1421 | 1.1058 | 1.0363 | 0.8579 | 45.21 | -0.15 | 14.60 |
| | 0.5371 | -2.3094 | 2.1213 | 28.7616 | 27.6893 | 24.9853 | 27.1454 | 0.0595 | 0.0200 | -0.0796 | 1.0595 | 1.0200 | 0.9204 | 37.07 | -0.24 | 7.24 |
| | 0.7405 | -2.7194 | 2.3223 | 29.7677 | 28.6791 | 25.5691 | 28.0053 | 0.0629 | 0.0241 | -0.0870 | 1.0629 | 1.0241 | 0.9130 | 38.80 | -0.52 | 8.21 |
| | 0.7532 | -2.5075 | 1.9596 | 29.9129 | 28.7249 | 25.6908 | 28.1096 | 0.0642 | 0.0219 | -0.0860 | 1.0642 | 1.0219 | 0.9140 | 38.93 | -0.27 | 8.09 |
| | 0.6095 | -3.0173 | 1.8000 | 29.9221 | 28.7158 | 25.6313 | 28.0897 | 0.0652 | 0.0223 | -0.0875 | 1.0652 | 1.0223 | 0.9125 | 38.92 | -0.27 | 8.23 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 4, cell 2 | 0.1302 | 0.2805 | 0.1783 | 2.7094 | 4.7625 | 29.6358 | 24.9679 | 27.9000 | 27.1000 | 1.3000 | 32.6000 | 11.2800 | 21.1103 |
| | 0.1297 | 0.2905 | 0.1826 | 2.8976 | 5.0410 | 29.8907 | 26.3450 | 27.3000 | 26.5000 | 1.4400 | 32.5000 | 11.4400 | 20.3375 |
| | 0.1300 | 0.2908 | 0.1859 | 2.9389 | 5.1446 | 29.7378 | 26.8592 | 27.4000 | 26.8000 | 1.3100 | 32.7000 | 11.9400 | 32.7280 |
| | 0.1301 | 0.2960 | 0.1867 | 3.0008 | 5.2601 | 29.7044 | 27.4389 | 27.1000 | 26.7000 | 1.3500 | 32.7000 | 12.5600 | 22.8510 |
| | 0.1285 | 0.3006 | 0.1862 | 3.1112 | 5.2900 | 30.4612 | 27.5568 | 27.1000 | 26.8000 | 1.2600 | 32.2000 | 11.9600 | 24.9879 |
| | 0.1199 | 0.2242 | 0.1346 | 1.8812 | 2.7378 | 34.4943 | 14.6001 | 23.1000 | 28.1000 | 1.0300 | 31.6000 | 15.4100 | 26.2063 |
| | 0.1193 | 0.1313 | 0.1128 | 0.9296 | 1.3391 | 34.7665 | 7.2448 | 23.6000 | 28.8000 | 1.0800 | 32.0000 | 14.2200 | 33.9869 |
| | 0.1235 | 0.1410 | 0.1167 | 0.9802 | 1.5189 | 32.8347 | 8.2265 | 22.8000 | 27.8000 | 1.0100 | 31.3000 | 16.2600 | 33.4669 |
| | 0.1198 | 0.1411 | 0.1173 | 1.0337 | 1.5004 | 34.5647 | 8.0971 | 23.0000 | 27.7000 | 1.0600 | 30.8000 | 17.1200 | 34.1277 |
| | 0.1198 | 0.1434 | 0.1173 | 1.0500 | 1.5251 | 34.5452 | 8.2302 | 23.2000 | 27.8000 | 1.1000 | 30.9000 | 16.5200 | 39.1608 |

**Data for reagent test 5 (calibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 2 | 0.2817 | -1.4596 | 1.9921 | 51.5803 | 54.9038 | 47.1725 | 51.2189 | 0.0071 | 0.0719 | -0.0790 | 1.0071 | 1.0719 | 0.9210 | 82.2490 | -11.9486 | 15.9524 | |
| | 0.4935 | -1.6583 | 1.9525 | 50.3274 | 53.4384 | 45.5173 | 49.7610 | 0.0114 | 0.0739 | -0.0853 | 1.0114 | 1.0739 | 0.9147 | 79.8051 | -11.7238 | 16.5285 | |
| | 0.0692 | -1.3837 | 2.1796 | 49.7062 | 52.6834 | 44.9188 | 49.1028 | 0.0123 | 0.0729 | -0.0852 | 1.0123 | 1.0729 | 0.9148 | 78.5774 | -11.3766 | 16.2577 | |
| | 0.3335 | -1.3180 | 1.9656 | 51.1575 | 54.0152 | 45.4659 | 50.2129 | 0.0188 | 0.0757 | -0.0945 | 1.0188 | 1.0757 | 0.9055 | 80.8210 | -11.7231 | 18.0902 | |
| | 0.2995 | -1.6210 | 2.1153 | 51.6163 | 54.5213 | 45.4562 | 50.5313 | 0.0215 | 0.0790 | -0.1004 | 1.0215 | 1.0790 | 0.8996 | 81.6200 | -12.1717 | 19.2279 | |
| | 0.4567 | -1.4660 | 1.9223 | 40.1604 | 42.2503 | 34.5981 | 39.0030 | 0.0297 | 0.0833 | -0.1129 | 1.0297 | 1.0833 | 0.8871 | 60.9473 | -9.7414 | 16.6927 | |
| | 0.3477 | -1.9859 | 2.4705 | 36.6604 | 38.7037 | 32.2872 | 35.8838 | 0.0216 | 0.0786 | -0.1002 | 1.0216 | 1.0786 | 0.8998 | 54.9086 | -8.7920 | 13.9323 | |
| | 0.5336 | -1.7628 | 2.2758 | 35.9333 | 37.7996 | 31.6344 | 35.1224 | 0.0231 | 0.0762 | -0.0993 | 1.0231 | 1.0762 | 0.9007 | 53.4185 | -8.2889 | 13.4653 | |
| | 0.3693 | -2.2462 | 2.4870 | 35.9402 | 37.7347 | 31.5253 | 35.0667 | 0.0249 | 0.0761 | -0.1010 | 1.0249 | 1.0761 | 0.8990 | 53.3274 | -8.1888 | 13.6102 | |
| | 0.5019 | -1.9425 | 2.2942 | 35.3276 | 37.0627 | 30.4661 | 34.2855 | 0.0304 | 0.0810 | -0.1114 | 1.0304 | 1.0810 | 0.8886 | 52.1384 | -8.3561 | 14.5578 | |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 2 | 0.2383 | 0.1408 | 0.2153 | -1.2702 | 2.8871 | 23.7479 | 2.2137 | 27.3000 | 27.5000 | 0.8400 | | 9.2400 | 31.0000 | 28.4000 | 1.4200 | 34.0000 | 8.07 |
| | 0.2321 | 0.1482 | 0.2096 | -1.1207 | 3.0014 | 20.4748 | 2.1877 | 26.6000 | 27.0000 | 0.8400 | | 10.4700 | 31.0000 | 28.4000 | 1.4300 | 33.9000 | 7.9 |
| | 0.2306 | 0.1474 | 0.2066 | -1.0540 | 2.9527 | 19.6454 | 2.1814 | 27.9000 | 27.9000 | 0.8400 | | 8.6100 | 30.9000 | 28.4000 | 1.4300 | 34.0000 | 7.79 |
| | 0.2224 | 0.1583 | 0.2118 | -0.9021 | 3.3130 | 15.2317 | 2.1458 | 26.6000 | 27.1000 | 0.9000 | | 9.7600 | 31.1000 | 28.6000 | 1.4000 | 34.2000 | 7.58 |
| | 0.2201 | 0.1663 | 0.2138 | -0.8796 | 3.5314 | 13.9866 | 2.1351 | 27.2000 | 27.6000 | 0.8400 | | 8.7000 | 31.1000 | 28.4000 | 1.3900 | 33.8000 | 7.9 |
| | 0.2122 | 0.1811 | 0.1657 | -0.5198 | 3.0344 | 9.7206 | 2.0991 | 26.9000 | 28.5000 | 0.6900 | | 8.6200 | 30.5000 | 28.4000 | 1.0700 | 33.9000 | 8.45 |
| | 0.2197 | 0.1658 | 0.1518 | -0.6147 | 2.5015 | 13.8049 | 2.1337 | 26.3000 | 28.5000 | 0.6500 | | 8.8500 | 30.5000 | 28.4000 | 1.0800 | 33.9000 | 8.31 |
| | 0.2171 | 0.1631 | 0.1482 | -0.5309 | 2.4178 | 12.3848 | 2.1226 | 26.3000 | 28.5000 | 0.6500 | | 9.4200 | 30.5000 | 28.4000 | 1.0700 | 34.1000 | 8.35 |
| | 0.2148 | 0.1646 | 0.1480 | -0.4824 | 2.4477 | 11.1491 | 2.1124 | 26.5000 | 28.6000 | 0.6800 | | 9.0200 | 30.5000 | 28.4000 | 1.0600 | 34.1000 | 8.34 |
| | 0.2105 | 0.1780 | 0.1453 | -0.4072 | 2.6256 | 8.8147 | 2.0919 | 25.8000 | 28.4000 | 0.7300 | | 8.9300 | 30.5000 | 28.4000 | 1.0900 | 34.2000 | 8.25 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 4 | -0.0637 | -0.5880 | 1.3761 | 20.9512 | 16.9919 | 11.3095 | 16.4176 | 0.2761 | 0.0350 | -0.3111 | 1.2761 | 1.0350 | 0.6889 | 18.9495 | 4.5411 | 16.6354 |
| | -0.1270 | -0.2812 | 1.1445 | 20.7302 | 16.8289 | 11.1367 | 16.2319 | 0.2771 | 0.0368 | -0.3139 | 1.2771 | 1.0368 | 0.6861 | 18.6217 | 4.4326 | 16.6132 |
| | 0.0662 | -0.8961 | 1.3387 | 21.1369 | 17.1332 | 11.2843 | 16.5181 | 0.2796 | 0.0372 | -0.3169 | 1.2796 | 1.0372 | 0.6831 | 19.2200 | 4.5577 | 17.0372 |
| | 0.2023 | -0.1925 | 1.0953 | 20.6391 | 16.7395 | 10.8327 | 16.0704 | 0.2843 | 0.0416 | -0.3259 | 1.2843 | 1.0416 | 0.6741 | 18.4466 | 4.3639 | 17.0845 |
| | 0.1356 | -0.8432 | 1.4717 | 21.3456 | 17.2620 | 11.2130 | 16.6069 | 0.2853 | 0.0395 | -0.3248 | 1.2853 | 1.0395 | 0.6752 | 19.4858 | 4.6427 | 17.5393 |
| | 0.0059 | -0.1305 | 1.0616 | 19.7648 | 15.9130 | 10.0359 | 15.2379 | 0.2971 | 0.0443 | -0.3414 | 1.2971 | 1.0443 | 0.6586 | 16.9228 | 4.3918 | 16.9207 |
| | 0.2473 | -0.3225 | 1.3465 | 21.0763 | 16.9153 | 10.7648 | 16.2521 | 0.2968 | 0.0408 | -0.3376 | 1.2968 | 1.0408 | 0.6624 | 18.8964 | 4.8290 | 17.8223 |
| | -0.1590 | -0.7664 | 1.1878 | 19.2055 | 16.9480 | 13.2923 | 16.4819 | 0.1652 | 0.0283 | -0.1935 | 1.1652 | 1.0283 | 0.8065 | 18.1214 | 1.8060 | 10.6220 |
| | 0.1413 | -1.2278 | 1.4999 | 19.5608 | 17.2998 | 13.6270 | 16.8292 | 0.1623 | 0.0280 | -0.1903 | 1.1623 | 1.0280 | 0.8097 | 18.7654 | 1.7824 | 10.6544 |
| | -0.1367 | -0.6237 | 1.0844 | 20.4957 | 17.6612 | 13.8345 | 17.3304 | 0.1826 | 0.0191 | -0.2017 | 1.1826 | 1.0191 | 0.7983 | 19.6991 | 2.8842 | 11.4428 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 4 | 0.0982 | 0.4602 | 0.0822 | 3.0022 | 3.0657 | 44.4005 | 17.2441 | 20.3000 | 23.6000 | 1.2100 | | 17.2900 | 20.3000 |
| | 0.0989 | 0.4628 | 0.0813 | 2.9675 | 3.0614 | 44.1073 | 17.1943 | 19.0490 | 25.8300 | 0.8060 | | 18.9400 | 19.0490 |
| | 0.0989 | 0.4661 | 0.0829 | 3.0462 | 3.1449 | 44.0860 | 17.6363 | 20.9000 | 24.2000 | 1.2000 | | 16.0200 | 20.9000 |
| | 0.1004 | 0.4751 | 0.0809 | 2.9879 | 3.1549 | 43.4428 | 17.6330 | 14.2940 | 22.2500 | 0.7600 | | 29.6500 | 14.2940 |
| | 0.0995 | 0.4747 | 0.0837 | 3.1153 | 3.2442 | 43.8389 | 18.1434 | 21.4000 | 24.8000 | 1.2700 | | 15.2600 | 21.4000 |
| | 0.1007 | 0.4922 | 0.0775 | 2.9556 | 3.1349 | 43.3133 | 17.4814 | 9.7170 | 16.8500 | 0.6190 | | 42.4700 | 9.7170 |
| | 0.0994 | 0.4892 | 0.0827 | 3.1730 | 3.2999 | 43.8771 | 18.4649 | 10.2370 | 17.5600 | 0.6460 | | 41.5900 | 10.2370 |
| | 0.1030 | 0.3079 | 0.0753 | 1.7533 | 1.9296 | 42.2597 | 10.7744 | 10.8200 | 18.1500 | 0.6260 | | 40.4200 | 10.8200 |
| | 0.1032 | 0.3034 | 0.0767 | 1.7572 | 1.9376 | 42.2053 | 10.8025 | 6.9560 | 14.2600 | 0.5410 | | 47.6900 | 6.9560 |
| | 0.0957 | 0.3250 | 0.0804 | 2.1252 | 2.0893 | 45.4877 | 11.8007 | 11.0960 | 18.1900 | 0.6080 | | 40.1700 | 11.0960 |

**Data for reagent test 1(uncalibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 1, cell 2 | -1.3250 | -1.4958 | 2.3537 | 116.6859 | 99.8635 | 88.6527 | 101.0666 | 0.1546 | -0.0119 | -0.1229 | 1.1546 | 0.9881 | 0.8771 | 47.6087 | -29.0380 | 12.1015 | 45.4875 |
| | -1.1608 | -1.6948 | 2.4294 | 118.6651 | 101.4062 | 89.6672 | 102.5789 | 0.1569 | -0.0114 | -0.1259 | 1.1569 | 0.9886 | 0.8741 | 48.5438 | -29.2979 | 12.5114 | 47.6469 |
| | -1.4381 | -1.9600 | 2.6398 | 120.2563 | 102.3557 | 90.6691 | 103.7588 | 0.1591 | -0.0135 | -0.1262 | 1.1591 | 0.9865 | 0.8738 | 49.2136 | -29.3058 | 12.5913 | 47.8350 |
| | -0.8224 | -1.3596 | 2.2454 | 120.4867 | 102.5748 | 90.7950 | 103.9506 | 0.1591 | -0.0132 | -0.1266 | 1.1591 | 0.9868 | 0.8734 | 49.3348 | -29.3686 | 12.6531 | 48.6525 |
| | -1.1491 | -2.2050 | 2.7491 | 120.6598 | 102.2346 | 90.4086 | 103.7654 | 0.1628 | -0.0147 | -0.1287 | 1.1628 | 0.9853 | 0.8713 | 49.2468 | -28.9382 | 12.7442 | 47.5190 |
| | -1.0474 | -1.8739 | 2.4249 | 126.4252 | 112.6758 | 103.1178 | 113.4098 | 0.1149 | -0.0065 | -0.0908 | 1.1149 | 0.9935 | 0.9092 | 54.3169 | -36.0328 | 10.9617 | 31.3674 |
| | -1.0175 | -1.5127 | 2.1985 | 125.6163 | 111.7764 | 102.1249 | 112.5090 | 0.1166 | -0.0065 | -0.0924 | 1.1166 | 0.9935 | 0.9076 | 53.8225 | -35.6180 | 11.0115 | 40.2683 |
| | -0.5499 | -0.6968 | 1.2616 | 124.5797 | 110.7048 | 100.7270 | 111.3403 | 0.1190 | -0.0057 | -0.0954 | 1.1190 | 0.9943 | 0.9046 | 53.2091 | -35.1297 | 11.1916 | 36.6314 |
| | -0.3865 | -0.3512 | 1.0234 | 125.1391 | 111.0653 | 101.3095 | 111.8408 | 0.1190 | -0.0069 | -0.0943 | 1.1190 | 0.9931 | 0.9057 | 53.4608 | -35.1898 | 11.0920 | 34.4828 |
| | -0.1797 | -0.1176 | 1.4118 | 126.1592 | 111.9541 | 102.1673 | 112.7623 | 0.1189 | -0.0072 | -0.0941 | 1.1189 | 0.9928 | 0.9059 | 53.9854 | -35.4497 | 11.1487 | 41.7925 |
| | **Hue** | **Sat** | **Val** | **Cr** | **Cb** | **RGB angle** | **Length** | **Cu (con)** | **Fe** | **MoS2** | **S** | **Insol** | **Cu (top)** | **Fe** | **MoS2** | **S** | **Insol** |
| reagent test 1, cell 2 | 0.0667 | 0.2403 | 0.4576 | 11.4628 | 7.3766 | 57.2356 | 31.4607 | 29.0000 | 28.4000 | 1.4100 | 34.2000 | 8.5900 | 26.5000 | 27.6000 | 1.7200 | 33.7000 | 10.0400 |
| | 0.0675 | 0.2444 | 0.4654 | 11.7840 | 7.6716 | 56.9385 | 31.8601 | 28.8000 | 28.3000 | 1.4600 | 34.0000 | 8.8200 | 27.1000 | 27.6000 | 1.6400 | 33.2000 | 10.3300 |
| | 0.0659 | 0.2461 | 0.4716 | 12.1733 | 7.7433 | 57.5132 | 31.8990 | 28.9000 | 28.4000 | 1.4200 | 34.1000 | 8.6100 | 27.1000 | 27.6000 | 1.6500 | 33.4000 | 10.1100 |
| | 0.0661 | 0.2465 | 0.4725 | 12.1895 | 7.7857 | 57.4122 | 31.9802 | 28.9000 | 28.4000 | 1.3600 | 34.1000 | 8.4000 | 27.9000 | 28.1000 | 1.4700 | 33.7000 | 9.5700 |
| | 0.0652 | 0.2507 | 0.4732 | 12.5097 | 7.8816 | 57.7480 | 31.6230 | 28.9000 | 28.4000 | 1.2900 | 34.5000 | 8.3700 | 27.7000 | 27.6000 | 1.5400 | 33.2000 | 10.1800 |
| | 0.0683 | 0.1845 | 0.4958 | 9.4084 | 6.2017 | 56.6200 | 37.6664 | 29.9000 | 28.4000 | 0.9400 | 33.5000 | 9.1100 | 27.5000 | 26.2000 | 1.1300 | 31.3000 | 13.5500 |
| | 0.0684 | 0.1871 | 0.4926 | 9.4734 | 6.2558 | 56.5707 | 37.2837 | 29.8000 | 28.4000 | 0.9300 | 33.4000 | 9.3400 | 27.8000 | 26.7000 | 1.2400 | 31.7000 | 12.5000 |
| | 0.0697 | 0.1916 | 0.4885 | 9.5275 | 6.4035 | 56.0970 | 36.8712 | 29.9000 | 28.5000 | 0.9600 | 33.4000 | 8.9900 | 27.6000 | 26.7000 | 1.1700 | 31.6000 | 12.7900 |
| | 0.0682 | 0.1906 | 0.4907 | 9.6276 | 6.3359 | 56.6554 | 36.8986 | 30.0000 | 28.7000 | 0.8700 | 33.8000 | 8.5300 | 27.1000 | 25.8000 | 1.1500 | 30.3000 | 15.1500 |
| | 0.0679 | 0.1904 | 0.4947 | 9.7115 | 6.3688 | 56.7531 | 37.1646 | 29.6000 | 28.4000 | 1.0000 | 34.0000 | 8.7600 | 28.4000 | 27.4000 | 1.2300 | 32.6000 | 11.0500 |

**Data for reagent test 2(uncalibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 2 | 0.4262 | -1.6692 | 2.4481 | 25.0847 | 19.8594 | 12.7323 | 19.2255 | 0.3050 | 0.0332 | -0.3382 | 1.3050 | 1.0332 | 0.6618 | 17.5225 | -10.7579 | 13.5743 | 53.3710 |
| | 0.3361 | -1.6329 | 2.1145 | 24.9698 | 19.7613 | 12.4692 | 19.0668 | 0.3096 | 0.0366 | -0.3462 | 1.3096 | 1.0366 | 0.6538 | 17.3610 | -10.6502 | 13.7340 | 49.0837 |
| | 0.2613 | -1.4416 | 2.4912 | 25.0065 | 19.7851 | 12.3828 | 19.0581 | 0.3121 | 0.0383 | -0.3504 | 1.3121 | 1.0383 | 0.6496 | 17.3964 | -10.6307 | 13.8772 | 48.7373 |
| | 0.0948 | -1.3103 | 2.8143 | 24.7877 | 19.5916 | 12.3733 | 18.9175 | 0.3103 | 0.0358 | -0.3462 | 1.3103 | 1.0358 | 0.6538 | 17.1136 | -10.5242 | 13.6227 | 47.1986 |
| | 0.4994 | -1.4373 | 2.3016 | 24.5263 | 19.3409 | 12.4752 | 18.7808 | 0.3067 | 0.0302 | -0.3368 | 1.3067 | 1.0302 | 0.6632 | 16.7621 | -10.3768 | 13.0349 | 57.6141 |
| | 0.1345 | -0.6745 | 2.3909 | 21.8852 | 18.5165 | 11.6344 | 17.3453 | 0.2615 | 0.0677 | -0.3292 | 1.2615 | 1.0677 | 0.6708 | 14.5270 | -12.1560 | 12.5514 | 39.2835 |
| | 0.1755 | -1.1554 | 2.4234 | 21.8861 | 18.5193 | 11.4613 | 17.2889 | 0.2656 | 0.0714 | -0.3370 | 1.2656 | 1.0714 | 0.6630 | 14.5184 | -12.1208 | 12.7398 | 41.2524 |
| | 0.1228 | -1.3491 | 2.8367 | 22.0453 | 18.6176 | 11.3826 | 17.3485 | 0.2704 | 0.0733 | -0.3437 | 1.2704 | 1.0733 | 0.6563 | 14.6846 | -12.0870 | 12.9959 | 42.8078 |
| | -0.1840 | -0.9066 | 2.1308 | 21.6448 | 18.3034 | 11.0665 | 17.0049 | 0.2727 | 0.0765 | -0.3492 | 1.2727 | 1.0765 | 0.6508 | 14.1789 | -11.9111 | 12.8842 | 41.4059 |
| | 0.4734 | -0.9744 | 2.7149 | 22.1368 | 18.7027 | 11.3274 | 17.4732 | 0.2718 | 0.0765 | -0.3483 | 1.2718 | 1.0765 | 0.6517 | 14.9460 | -12.2457 | 13.3000 | 41.4508 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Lab angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 2 | 0.0962 | 0.4928 | 0.0984 | 3.9249 | 3.8834 | 45.2814 | 2.2407 | 17.3226 | 30.4000 | 28.3000 | 1.5900 | 32.3000 | 8.8600 | 30.6000 | 28.6000 | 1.4700 | 33.8000 | 8.19 |
| | 0.0973 | 0.5007 | 0.0979 | 3.9311 | 3.9530 | 44.8222 | 2.2305 | 17.3801 | 30.6000 | 28.4000 | 1.5600 | 32.8000 | 8.3200 | 30.6000 | 28.6000 | 1.4800 | 33.5000 | 8.38 |
| | 0.0978 | 0.5049 | 0.0981 | 3.9501 | 4.0030 | 44.6040 | 2.2245 | 17.4818 | 30.6000 | 28.4000 | 1.6600 | 32.9000 | 8.5100 | 30.5000 | 28.5000 | 1.5100 | 33.5000 | 8.28 |
| | 0.0969 | 0.5009 | 0.0972 | 3.9161 | 3.9189 | 44.9726 | 2.2288 | 17.2168 | 30.5000 | 28.5000 | 1.7300 | 33.1000 | 8.3000 | 30.4000 | 28.4000 | 1.5300 | 33.0000 | 8.26 |
| | 0.0951 | 0.4923 | 0.0962 | 3.8742 | 3.7633 | 45.7727 | 2.2427 | 16.6653 | 30.8000 | 26.1000 | 1.2800 | 31.4000 | 12.7700 | 30.7000 | 28.6000 | 1.4700 | 33.5000 | 8.37 |
| | 0.1120 | 0.4682 | 0.0858 | 2.7591 | 3.5027 | 38.1863 | 2.3413 | 17.4775 | 28.1000 | 28.6000 | 1.4600 | 33.2000 | 8.4100 | 29.8000 | 27.8000 | 1.2400 | 33.4000 | 9.54 |
| | 0.1130 | 0.4761 | 0.0858 | 2.7755 | 3.5792 | 37.7359 | 2.3328 | 17.5898 | 28.7000 | 26.8000 | 1.3600 | 32.3000 | 11.1000 | 29.8000 | 27.8000 | 1.2200 | 33.6000 | 9.54 |
| | 0.1132 | 0.4834 | 0.0865 | 2.8306 | 3.6655 | 37.6451 | 2.3215 | 17.7529 | 28.9000 | 27.0000 | 1.3000 | 32.1000 | 11.2400 | 29.7000 | 27.8000 | 1.2300 | 33.6000 | 9.53 |
| | 0.1141 | 0.4886 | 0.0849 | 2.7777 | 3.6536 | 37.2082 | 2.3180 | 17.5502 | 28.3000 | 26.4000 | 1.3800 | 31.5000 | 11.9800 | 29.9000 | 28.1000 | 1.2000 | 33.5000 | 9.33 |
| | 0.1142 | 0.4875 | 0.0872 | 2.8419 | 3.7448 | 37.1720 | 2.3157 | 18.0810 | 28.9000 | 27.0000 | 1.3200 | 32.2000 | 11.0000 | 29.9000 | 28.0000 | 1.1800 | 33.6000 | 9.33 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green norm | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 4 | -0.0588 | -0.5203 | 2.3768 | 31.2249 | 26.8414 | 20.4065 | 25.4787 | 0.2256 | 0.0535 | -0.1990 | 1.2256 | 1.0535 | 0.8010 | 21.6006 | -16.4270 | 11.5673 | 48.4372 |
| | -0.1063 | -0.7089 | 2.2757 | 32.0515 | 27.4817 | 20.7951 | 26.0966 | 0.2282 | 0.0531 | -0.2031 | 1.2282 | 1.0531 | 0.7969 | 22.4662 | -16.6625 | 11.9630 | 50.8586 |
| | -0.1677 | -0.5743 | 2.6125 | 31.7270 | 27.1400 | 20.5004 | 25.7762 | 0.2309 | 0.0530 | -0.2047 | 1.2309 | 1.0530 | 0.7953 | 22.0507 | -16.3664 | 11.8855 | 55.3234 |
| | 0.0411 | -0.2896 | 2.7908 | 31.1660 | 26.6804 | 20.1056 | 25.3045 | 0.2317 | 0.0544 | -0.2054 | 1.2317 | 1.0544 | 0.7946 | 21.4341 | -16.1242 | 11.7498 | 57.2499 |
| | -0.0393 | -0.7062 | 2.1518 | 30.9147 | 26.4427 | 20.0181 | 25.1126 | 0.2311 | 0.0530 | -0.2028 | 1.2311 | 1.0530 | 0.7972 | 21.1421 | -15.9819 | 11.5467 | 37.3616 |
| | -0.1688 | -0.5924 | 2.5106 | 37.1452 | 32.9253 | 25.2174 | 31.0858 | 0.1973 | 0.0588 | -0.1897 | 1.1973 | 1.0588 | 0.8103 | 28.9907 | -21.3683 | 13.5058 | 35.4481 |
| | -0.1362 | -0.4415 | 2.7710 | 39.2787 | 35.2389 | 26.9748 | 33.1558 | 0.1847 | 0.0628 | -0.1864 | 1.1847 | 1.0628 | 0.8136 | 31.7428 | -23.3759 | 14.3066 | 44.5244 |
| | 0.0005 | -0.5265 | 2.3647 | 39.5195 | 35.4397 | 27.2183 | 33.3842 | 0.1838 | 0.0615 | -0.1846 | 1.1838 | 1.0615 | 0.8154 | 32.0110 | -23.5036 | 14.2751 | 35.3426 |
| | -0.0686 | -0.7496 | 2.4890 | 40.4969 | 36.2542 | 27.9359 | 34.2191 | 0.1835 | 0.0595 | -0.1835 | 1.1835 | 1.0595 | 0.8165 | 33.0766 | -23.9464 | 14.4813 | 37.6185 |
| | 0.0082 | -0.4290 | 3.0033 | 40.6329 | 36.4476 | 28.3760 | 34.4752 | 0.1908 | 0.0614 | -0.1893 | 1.1908 | 1.0614 | 0.8107 | 33.2605 | -24.2235 | 14.1528 | 45.4932 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 2, cell 4 | 0.0991 | 0.3464 | 0.1225 | 3.3382 | 3.4569 | 44.0146 | 20.0930 | 30.6000 | 28.1000 | 1.5400 | 33.5000 | 8.2300 |
| | 0.0990 | 0.3511 | 0.1257 | 3.4779 | 3.5943 | 44.0696 | 20.5137 | 30.3000 | 27.9000 | 1.6800 | 33.4000 | 8.4700 |
| | 0.0986 | 0.3539 | 0.1244 | 3.4838 | 3.5763 | 44.2457 | 20.2278 | 30.8000 | 28.2000 | 1.4600 | 33.5000 | 8.2400 |
| | 0.0991 | 0.3549 | 0.1222 | 3.4150 | 3.5331 | 44.0278 | 19.9522 | 30.6000 | 28.2000 | 1.5300 | 33.7000 | 8.1500 |
| | 0.0982 | 0.3525 | 0.1212 | 3.3916 | 3.4655 | 44.3897 | 19.7178 | 30.5000 | 28.0000 | 1.5000 | 33.8000 | 8.2500 |
| | 0.1074 | 0.3229 | 0.1457 | 3.3649 | 3.9888 | 40.2435 | 25.2949 | 27.3000 | 25.1000 | 1.2500 | 30.5000 | 14.6200 |
| | 0.1119 | 0.3132 | 0.1540 | 3.3098 | 4.2052 | 38.2135 | 27.4087 | 28.7000 | 26.6000 | 1.3800 | 32.1000 | 11.4000 |
| | 0.1113 | 0.3112 | 0.1550 | 3.3301 | 4.1925 | 38.4786 | 27.5011 | 27.2000 | 25.0000 | 1.2800 | 29.8000 | 15.2100 |
| | 0.1103 | 0.3101 | 0.1588 | 3.4400 | 4.2588 | 38.9361 | 27.9884 | 27.9000 | 25.8000 | 1.2800 | 31.0000 | 13.4100 |
| | 0.1097 | 0.3086 | 0.1593 | 3.3735 | 4.1458 | 39.1322 | 26.4598 | 29.4000 | 27.3000 | 1.2500 | 33.0000 | 10.0000 |

**Data for reagent test 3 (rejected for analysis) (uncalibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 2 | 0.2615 | -1.8320 | 2.4840 | 40.4660 | 32.7496 | 25.6239 | 32.2734 | 0.2539 | 0.0148 | -0.2061 | 1.2539 | 1.0148 | 0.7939 | 30.3598 | -17.0596 | 13.6062 |
| | 0.2055 | -1.2638 | 2.1799 | 36.1503 | 28.9745 | 21.6271 | 28.2441 | 0.2802 | 0.0260 | -0.2345 | 1.2802 | 1.0260 | 0.7655 | 25.4399 | -14.5195 | 13.4382 |
| | 0.1620 | -1.6065 | 2.5522 | 39.4319 | 31.5341 | 23.4784 | 30.8094 | 0.2800 | 0.0237 | -0.2380 | 1.2800 | 1.0237 | 0.7620 | 28.8834 | -15.5929 | 14.6309 |
| | 0.2420 | -1.5917 | 2.7535 | 37.1750 | 30.1571 | 22.8826 | 29.3972 | 0.2642 | 0.0260 | -0.2212 | 1.2642 | 1.0260 | 0.7788 | 26.8253 | -15.7116 | 13.4095 |
| | 0.4053 | -2.1573 | 2.1329 | 32.0307 | 26.3650 | 19.3748 | 25.2480 | 0.2688 | 0.0446 | -0.2329 | 1.2688 | 1.0446 | 0.7671 | 21.5050 | -14.2659 | 12.4620 |
| | 0.3137 | -1.3455 | 2.2749 | 33.7615 | 27.9214 | 21.3057 | 26.9886 | 0.2511 | 0.0348 | -0.2108 | 1.2511 | 1.0348 | 0.7892 | 23.5516 | -15.4521 | 12.1862 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 2 | 0.0800 | 0.3668 | 0.1587 | 5.4563 | 4.2499 | 52.0795 | 21.8218 | 27.1000 | 28.3000 | 1.3500 | 34.0000 | 8.6300 | 33.0749 |
| | 0.0843 | 0.4020 | 0.1418 | 5.1461 | 4.2671 | 50.3264 | 19.7874 | 28.0000 | 28.2000 | 1.4200 | 34.2000 | 8.6900 | 25.4009 |
| | 0.0842 | 0.4046 | 0.1546 | 5.6608 | 4.6829 | 50.3893 | 21.3832 | 28.7000 | 28.4000 | 1.4300 | 33.9000 | 8.4600 | 25.7276 |
| | 0.0849 | 0.3838 | 0.1458 | 5.0417 | 4.2120 | 50.1009 | 20.6677 | 26.4000 | 27.3000 | 1.4200 | 32.9000 | 11.8400 | 25.6747 |
| | 0.0921 | 0.3954 | 0.1256 | 4.1820 | 3.8885 | 47.0443 | 18.9453 | 26.3000 | 27.1000 | 1.3400 | 32.0000 | 12.7500 | 18.4895 |
| | 0.0885 | 0.3691 | 0.1324 | 4.2518 | 3.7506 | 48.5696 | 19.6830 | 25.3000 | 25.4000 | 1.3200 | 30.5000 | 15.8100 | 18.6158 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 4 | -0.1119 | -0.9629 | 2.4746 | 46.6930 | 41.2384 | 31.1963 | 39.0333 | 0.1963 | 0.0565 | -0.2007 | 1.1963 | 1.0565 | 0.7993 | 22.4799 | -18.0478 | 11.8932 |
| | 0.0069 | -0.2842 | 2.3078 | 49.3716 | 41.5954 | 29.4832 | 39.4723 | 0.2507 | 0.0538 | -0.2529 | 1.2507 | 1.0538 | 0.7471 | 23.3871 | -15.9243 | 13.9015 |
| | -0.0891 | -0.1517 | 2.5659 | 45.4885 | 40.6136 | 32.6746 | 38.9163 | 0.1685 | 0.0436 | -0.1599 | 1.1685 | 1.0436 | 0.8401 | 21.9220 | -18.6613 | 9.9007 |
| | 0.0144 | -0.0606 | 2.7084 | 43.1106 | 38.6363 | 31.2198 | 36.9769 | 0.1685 | 0.0456 | -0.1584 | 1.1685 | 1.0456 | 0.8416 | 20.1349 | -17.9416 | 9.3585 |
| | -0.1225 | -0.2891 | 2.1397 | 43.2172 | 38.1235 | 28.8008 | 36.0321 | 0.1993 | 0.0580 | -0.2005 | 1.1993 | 1.0580 | 0.7995 | 19.7734 | -16.7216 | 11.0910 |
| | -0.0073 | -0.4028 | 2.4501 | 42.8860 | 37.8541 | 29.0377 | 35.9087 | 0.1958 | 0.0554 | -0.1941 | 1.1958 | 1.0554 | 0.8059 | 19.5552 | -16.7220 | 10.6352 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 3, cell 4 | 0.1079 | 0.3318 | 0.1831 | 4.3573 | 5.1904 | 40.0377 | 21.6178 | 18.1400 | 24.8400 | 1.4900 | 27.7700 | 22.4000 | 18.1400 |
| | 0.1016 | 0.4025 | 0.1936 | 5.9916 | 6.4369 | 42.9095 | 21.1514 | 17.0700 | 23.3100 | 1.5100 | 25.3700 | 26.7900 | 17.0700 |
| | 0.1036 | 0.2780 | 0.1784 | 3.7907 | 4.1863 | 42.0084 | 21.3203 | 17.4500 | 21.5900 | 1.4500 | 22.6400 | 29.0000 | 17.4500 |
| | 0.1037 | 0.2786 | 0.1691 | 3.4921 | 3.8990 | 41.9599 | 20.3056 | 18.8200 | 23.7000 | 1.2000 | 24.4400 | 27.7600 | 18.8200 |
| | 0.1077 | 0.3333 | 0.1695 | 4.0635 | 4.8230 | 40.1598 | 20.0720 | 13.0200 | 16.6300 | 1.0400 | 15.3100 | 43.2800 | 13.0200 |
| | 0.1058 | 0.3225 | 0.1682 | 4.0018 | 4.6670 | 40.7441 | 19.9278 | 11.2900 | 14.5600 | 0.9910 | 13.6000 | 46.6500 | 11.2900 |

**Data for reagent test 4 (uncalibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green nor | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 4, cell 2 | 0.0934 | -1.3176 | 2.4992 | 46.4201 | 41.3456 | 30.4975 | 38.7463 | 0.1982 | 0.0670 | -0.2126 | 1.1982 | 1.0670 | 0.7874 | 23.1610 | -18.6412 | 12.7579 |
| | 0.1140 | -0.8522 | 2.4034 | 47.5575 | 42.2174 | 30.8092 | 39.5193 | 0.2035 | 0.0683 | -0.2204 | 1.2035 | 1.0683 | 0.7796 | 23.9654 | -18.8103 | 13.3105 |
| | 0.3458 | -0.7879 | 2.1074 | 48.4133 | 43.0001 | 31.3509 | 40.2464 | 0.2030 | 0.0684 | -0.2210 | 1.2030 | 1.0684 | 0.7790 | 24.6483 | -19.1534 | 13.5622 |
| | 0.0201 | -0.9232 | 2.6941 | 48.6129 | 43.1303 | 31.2489 | 40.3232 | 0.2056 | 0.0696 | -0.2250 | 1.2056 | 1.0696 | 0.7750 | 24.7690 | -19.1264 | 13.7711 |
| | -0.0041 | -0.5152 | 3.0059 | 48.4960 | 42.8467 | 30.9682 | 40.0943 | 0.2096 | 0.0687 | -0.2276 | 1.2096 | 1.0687 | 0.7724 | 24.5770 | -18.8191 | 13.7769 |
| | 0.4307 | -2.0478 | 2.2619 | 38.4744 | 35.1635 | 29.2567 | 33.6217 | 0.1372 | 0.0436 | -0.1193 | 1.1372 | 1.0436 | 0.8807 | 17.5776 | -17.7090 | 7.7029 |
| | 0.5371 | -2.3094 | 2.1213 | 32.2327 | 30.2640 | 27.4470 | 29.3056 | 0.1000 | 0.0327 | -0.0633 | 1.1000 | 1.0327 | 0.9367 | 13.0990 | -16.6673 | 4.4904 |
| | 0.7405 | -2.7194 | 2.3223 | 33.3603 | 31.3459 | 28.0883 | 30.2581 | 0.1026 | 0.0360 | -0.0716 | 1.1026 | 1.0360 | 0.9284 | 14.0344 | -17.1848 | 4.9659 |
| | 0.7532 | -2.5075 | 1.9596 | 33.5230 | 31.3960 | 28.2221 | 30.3724 | 0.1039 | 0.0338 | -0.0708 | 1.1039 | 1.0338 | 0.9292 | 14.1176 | -17.1401 | 4.9099 |
| | 0.6095 | -3.0173 | 1.8000 | 33.5333 | 31.3861 | 28.1566 | 30.3510 | 0.1049 | 0.0341 | -0.0722 | 1.1049 | 1.0341 | 0.9278 | 14.1112 | -17.1012 | 4.9673 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 4, cell 2 | 0.1134 | 0.3429 | 0.1820 | 4.2042 | 5.4865 | 37.5139 | 22.5895 | 27.9000 | 27.1000 | 1.3000 | 32.6000 | 11.2800 | 21.1103 |
| | 0.1135 | 0.3522 | 0.1865 | 4.4236 | 5.7703 | 37.4882 | 23.0441 | 27.3000 | 26.5000 | 1.4400 | 32.5000 | 11.4400 | 20.3375 |
| | 0.1137 | 0.3524 | 0.1899 | 4.4926 | 5.8863 | 37.3704 | 23.4691 | 27.4000 | 26.8000 | 1.3100 | 32.7000 | 11.9400 | 32.7280 |
| | 0.1140 | 0.3572 | 0.1906 | 4.5585 | 5.9980 | 37.2477 | 23.5688 | 27.1000 | 26.7000 | 1.3500 | 32.7000 | 12.5600 | 22.8510 |
| | 0.1130 | 0.3614 | 0.1902 | 4.6606 | 6.0213 | 37.7361 | 23.3234 | 27.1000 | 26.8000 | 1.2600 | 32.2000 | 11.9600 | 24.9879 |
| | 0.1024 | 0.2210 | 0.1509 | 2.6260 | 3.0681 | 42.4989 | 19.6274 | 23.1000 | 28.1000 | 1.0300 | 31.6000 | 15.4100 | 26.2063 |
| | 0.0977 | 0.1484 | 0.1264 | 1.4919 | 1.5206 | 44.5524 | 17.2647 | 23.6000 | 28.8000 | 1.0800 | 32.0000 | 14.2200 | 33.9869 |
| | 0.1029 | 0.1580 | 0.1308 | 1.5640 | 1.7198 | 42.2765 | 17.8895 | 22.8000 | 27.8000 | 1.0100 | 31.3000 | 16.2600 | 33.4669 |
| | 0.0998 | 0.1582 | 0.1315 | 1.6249 | 1.6999 | 43.6895 | 17.8305 | 23.0000 | 27.7000 | 1.0600 | 30.8000 | 17.1200 | 34.1277 |
| | 0.1000 | 0.1603 | 0.1315 | 1.6429 | 1.7271 | 43.5798 | 17.8095 | 23.2000 | 27.8000 | 1.1000 | 30.9000 | 16.5200 | 39.1608 |

**Data for reagent test 5 (uncalibrated)**

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 2 | 0.2817 | -1.4596 | 1.9921 | 37.1937 | 34.5008 | 28.3284 | 32.6707 | 0.1385 | 0.0560 | -0.1329 | 1.1385 | 1.0560 | 0.8671 | 24.4477 | -21.8682 | 9.8223 | |
| | 0.4935 | -1.6583 | 1.9525 | 36.2902 | 33.5799 | 27.3344 | 31.7324 | 0.1437 | 0.0583 | -0.1385 | 1.1437 | 1.0583 | 0.8615 | 23.4501 | -21.1552 | 9.8674 | |
| | 0.0692 | -1.3837 | 2.1796 | 35.8423 | 33.1055 | 26.9750 | 31.3044 | 0.1450 | 0.0575 | -0.1382 | 1.1450 | 1.0575 | 0.8618 | 22.9549 | -20.8104 | 9.7204 | |
| | 0.3335 | -1.3180 | 1.9656 | 36.8888 | 33.9423 | 27.3035 | 32.0420 | 0.1513 | 0.0594 | -0.1479 | 1.1513 | 1.0594 | 0.8521 | 23.8958 | -21.0468 | 10.3796 | |
| | 0.2995 | -1.6210 | 2.1153 | 37.2197 | 34.2604 | 27.2977 | 32.2573 | 0.1538 | 0.0621 | -0.1536 | 1.1538 | 1.0621 | 0.8464 | 24.2184 | -21.1767 | 10.7608 | |
| | 0.4567 | -1.4660 | 1.9223 | 32.7981 | 30.3074 | 24.9887 | 28.6929 | 0.1421 | 0.0558 | -0.1266 | 1.1421 | 1.0558 | 0.8734 | 19.8797 | -19.2643 | 8.5949 | |
| | 0.3477 | -1.9859 | 2.4705 | 29.9398 | 27.7633 | 23.3196 | 26.3347 | 0.1369 | 0.0542 | -0.1143 | 1.1369 | 1.0542 | 0.8857 | 17.0717 | -17.9961 | 7.4125 | |
| | 0.5336 | -1.7628 | 2.2758 | 29.3460 | 27.1147 | 22.8481 | 25.7621 | 0.1391 | 0.0524 | -0.1128 | 1.1391 | 1.0524 | 0.8872 | 16.3943 | -17.5043 | 7.1886 | |
| | 0.3693 | -2.2462 | 2.4870 | 29.3516 | 27.0682 | 22.7694 | 25.7231 | 0.1412 | 0.0523 | -0.1147 | 1.1412 | 1.0523 | 0.8853 | 16.3590 | -17.4007 | 7.2360 | |
| | 0.5019 | -1.9425 | 2.2942 | 28.8513 | 26.5861 | 22.0044 | 25.1431 | 0.1476 | 0.0572 | -0.1245 | 1.1476 | 1.0572 | 0.8755 | 15.7980 | -16.9796 | 7.5397 | |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | Cu (top) | Fe | MoS2 | S | Insol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 2 | 0.1160 | 0.2383 | 0.1459 | 2.2727 | 3.0930 | 36.3243 | 23.9744 | 27.3000 | 27.5000 | 0.8400 | | 9.2400 | 31.0000 | 28.4000 | 1.4200 | 34.0000 | 8.07 |
| | 0.1162 | 0.2467 | 0.1423 | 2.2907 | 3.1276 | 36.2288 | 23.3444 | 26.6000 | 27.0000 | 0.8400 | | 10.4700 | 31.0000 | 28.4000 | 1.4300 | 33.9000 | 7.9 |
| | 0.1152 | 0.2473 | 0.1406 | 2.2955 | 3.0812 | 36.7080 | 22.9701 | 27.9000 | 27.9000 | 0.8400 | | 8.6100 | 30.9000 | 28.4000 | 1.4300 | 34.0000 | 7.79 |
| | 0.1154 | 0.2598 | 0.1447 | 2.4752 | 3.3341 | 36.5847 | 23.4684 | 26.6000 | 27.1000 | 0.9000 | | 9.7600 | 31.1000 | 28.6000 | 1.4000 | 34.2000 | 7.58 |
| | 0.1169 | 0.2664 | 0.1460 | 2.5154 | 3.4775 | 35.8974 | 23.7548 | 27.2000 | 27.6000 | 0.8400 | | 8.7000 | 31.1000 | 28.4000 | 1.3900 | 33.8000 | 7.9 |
| | 0.1128 | 0.2351 | 0.1286 | 2.0630 | 2.6903 | 37.7937 | 21.1157 | 26.9000 | 28.5000 | 0.6900 | | 8.6200 | 30.5000 | 28.4000 | 1.0700 | 33.9000 | 8.45 |
| | 0.1117 | 0.2209 | 0.1174 | 1.7823 | 2.2618 | 38.2794 | 19.4644 | 26.3000 | 28.5000 | 0.6500 | | 8.8500 | 30.5000 | 28.4000 | 1.0800 | 33.9000 | 8.31 |
| | 0.1092 | 0.2212 | 0.1151 | 1.7983 | 2.1925 | 39.4326 | 18.9256 | 26.3000 | 28.5000 | 0.6500 | | 9.4200 | 30.5000 | 28.4000 | 1.0700 | 34.1000 | 8.35 |
| | 0.1088 | 0.2241 | 0.1151 | 1.8336 | 2.2143 | 39.6481 | 18.8500 | 26.5000 | 28.6000 | 0.6800 | | 9.0200 | 30.5000 | 28.4000 | 1.0600 | 34.1000 | 8.34 |
| | 0.1112 | 0.2370 | 0.1131 | 1.8507 | 2.3352 | 38.5102 | 18.5813 | 25.8000 | 28.4000 | 0.7300 | | 8.9300 | 30.5000 | 28.4000 | 1.0900 | 34.2000 | 8.25 |

| | vel x | vel y | vel rel | r | g | b | av | rel red | rel green | rel blue | red norm | green non | blue norm | L | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 4 | -0.0637 | -0.5880 | 1.3761 | 19.2177 | 15.0141 | 9.8838 | 14.0260 | 0.3706 | 0.0715 | -0.2955 | 1.3706 | 1.0715 | 0.7045 | 84.7256 | -30.9824 | 39.5219 |
| | -0.1270 | -0.2812 | 1.1445 | 19.0149 | 14.8701 | 9.7327 | 13.8602 | 0.3723 | 0.0736 | -0.2980 | 1.3723 | 1.0736 | 0.7020 | 83.7702 | -30.7490 | 39.4189 |
| | 0.0662 | -0.8961 | 1.3387 | 19.3880 | 15.1389 | 9.8617 | 14.1179 | 0.3736 | 0.0730 | -0.3014 | 1.3736 | 1.0730 | 0.6986 | 85.5072 | -31.0677 | 40.3184 |
| | 0.2023 | -0.1925 | 1.0953 | 18.9313 | 14.7911 | 9.4671 | 13.7181 | 0.3805 | 0.0792 | -0.3101 | 1.3805 | 1.0792 | 0.6899 | 83.2580 | -30.3088 | 40.2202 |
| | 0.1356 | -0.8432 | 1.4717 | 19.5794 | 15.2527 | 9.7994 | 14.1981 | 0.3793 | 0.0748 | -0.3099 | 1.3793 | 1.0748 | 0.6901 | 86.2972 | -30.9158 | 41.2667 |
| | 0.0059 | -0.1305 | 1.0616 | 18.3516 | 14.3781 | 9.0695 | 13.2556 | 0.3851 | 0.0859 | -0.3159 | 1.3851 | 1.0859 | 0.6841 | 80.5070 | -29.6759 | 39.7342 |
| | 0.2473 | -0.3225 | 1.3465 | 19.5694 | 15.2837 | 9.7283 | 14.1829 | 0.3803 | 0.0784 | -0.3145 | 1.3803 | 1.0784 | 0.6855 | 86.3505 | -31.1600 | 41.7219 |
| | -0.1590 | -0.7664 | 1.1878 | 17.8323 | 15.3133 | 12.0123 | 14.3699 | 0.2414 | 0.0660 | -0.1643 | 1.2414 | 1.0660 | 0.8357 | 80.4602 | -42.2286 | 27.3491 |
| | 0.1413 | -1.2278 | 1.4999 | 18.1622 | 15.6311 | 12.3148 | 14.6866 | 0.2370 | 0.0647 | -0.1617 | 1.2370 | 1.0647 | 0.8383 | 85.1821 | -44.8589 | 28.5817 |
| | -0.1367 | -0.6237 | 1.0844 | 19.0303 | 15.9576 | 12.5024 | 15.1464 | 0.2564 | 0.0538 | -0.1744 | 1.2564 | 1.0538 | 0.8256 | 88.2048 | -42.9024 | 29.9887 |

| | Hue | Sat | Val | Cr | Cb | RGB angle | Length | Cu (con) | Fe | MoS2 | S | Insol | % solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reagent test 5, cell 4 | 0.0918 | 0.4859 | 0.0754 | 3.0972 | 2.8606 | 47.1907 | 50.2267 | 20.3000 | 23.6000 | 1.2100 | | 17.2900 | 20.3000 |
| | 0.0923 | 0.4884 | 0.0746 | 3.0618 | 2.8550 | 46.9528 | 49.9977 | 19.0490 | 25.8300 | 0.8060 | | 18.9400 | 19.0490 |
| | 0.0924 | 0.4914 | 0.0760 | 3.1398 | 2.9314 | 46.9189 | 50.9105 | 20.9000 | 24.2000 | 1.2000 | | 16.0200 | 20.9000 |
| | 0.0939 | 0.5002 | 0.0742 | 3.0776 | 2.9358 | 46.2776 | 50.3681 | 14.2940 | 22.2500 | 0.7600 | | 29.6500 | 14.2940 |
| | 0.0930 | 0.4996 | 0.0768 | 3.2052 | 3.0198 | 46.6674 | 51.5710 | 21.4000 | 24.8000 | 1.2700 | | 15.2600 | 21.4000 |
| | 0.0955 | 0.5060 | 0.0720 | 2.9736 | 2.9045 | 45.5886 | 49.6003 | 9.7170 | 16.8500 | 0.6190 | | 42.4700 | 9.7170 |
| | 0.0941 | 0.5029 | 0.0767 | 3.1902 | 3.0583 | 46.1790 | 52.0791 | 10.2370 | 17.5600 | 0.6460 | | 41.5900 | 10.2370 |
| | 0.0911 | 0.3146 | 0.0675 | 1.8787 | 1.8132 | 46.0797 | 52.2729 | 10.8200 | 18.1500 | 0.6260 | | 40.4200 | 10.8200 |
| | 0.0944 | 0.3221 | 0.0712 | 1.8876 | 1.8217 | 46.0584 | 53.2479 | 6.9560 | 14.2600 | 0.5410 | | 47.6900 | 6.9560 |
| | 0.0886 | 0.3410 | 0.0746 | 2.2344 | 1.9622 | 48.5434 | 52.7082 | 11.0960 | 18.1900 | 0.6080 | | 40.1700 | 11.0960 |

Appendix D:

# Critical Values of the Pearson Product-Moment Correlation Coefficient

| df = *n* -2 | | | | |
|---|---|---|---|---|
| **Level of Significance (p) for Two-Tailed Test** | **.10** | **.05** | **.02** | **.01** |
| df | | | | |
| 1 | .988 | .997 | .9995 | .9999 |
| 2 | .900 | .950 | .980 | .990 |
| 3 | .805 | .878 | .934 | .959 |
| 4 | .729 | .811 | .882 | .917 |
| 5 | .669 | .754 | .833 | .874 |
| 6 | .622 | .707 | .789 | .834 |
| 7 | .582 | .666 | .750 | .798 |
| 8 | .549 | .632 | .716 | .765 |
| 9 | .521 | .602 | .685 | .735 |
| 10 | .497 | .576 | .658 | .708 |
| 11 | .476 | .553 | .634 | .684 |
| 12 | .458 | .532 | .612 | .661 |
| 13 | .441 | .514 | .592 | .641 |
| 14 | .426 | .497 | .574 | .623 |
| 15 | .412 | .482 | .558 | .606 |
| 16 | .400 | .468 | .542 | .590 |

| | | | | |
|---|---|---|---|---|
| 17 | .389 | .456 | .528 | .575 |
| 18 | .378 | .444 | .516 | .561 |
| 19 | .369 | .433 | .503 | .549 |
| 20 | .360 | .423 | .492 | .537 |
| 21 | .352 | .413 | .482 | .526 |
| 22 | .344 | .404 | .472 | .515 |
| 23 | .337 | .396 | .462 | .505 |
| 24 | .330 | .388 | .453 | .496 |
| 25 | .323 | .381 | .445 | .487 |
| 26 | .317 | .374 | .437 | .479 |
| 27 | .311 | .367 | .430 | .471 |
| 28 | .306 | .361 | .423 | .463 |
| 29 | .301 | .355 | .416 | .456 |
| 30 | .296 | .349 | .409 | .449 |
| 35 | .275 | .325 | .381 | .418 |
| 40 | .257 | .304 | .358 | .393 |
| 45 | .243 | .288 | .338 | .372 |
| 50 | .231 | .273 | .322 | .354 |
| 60 | .211 | .250 | .295 | .325 |
| 70 | .195 | .232 | .274 | .303 |
| 80 | .183 | .217 | .256 | .283 |
| 90 | .173 | .205 | .242 | .267 |
| 100 | .164 | .195 | .230 | .254 |

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**Appendix E:**

```
%Takes a signal, converts to Lab\
%BE WARNED The Lab conversion is relative to the brightest Y.
%TO ENSURE that the Lab values are comparable, add artificial
%dataof the brightest white possible
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%
%Read in the Data

Red   = SomeRGB(:,1);
Green = SomeRGB(:,2);
Blue  = SomeRGB(:,3);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%
%Discard funny data

%ttl  = max(size(Red));
%half = round(ttl/2);

%NI = [half:ttl];
%NI = [1:ttl];

dr = Red;%(  NI);
dg = Green;%(NI);
db = Blue;%( NI);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%
%Invert the Gamma correection
Gamma = 2.8;

GCR = power( dr, Gamma);
GCG = power( dg, Gamma);
GCB = power( db, Gamma);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%
%To XYZ

%CM = [ [0.431 0.342 0.178];
%       [0.222 0.707 0.071];
%       [0.020 0.130 0.939]; ];

%CM = [ [0.4306 0.3416 0.1783];
%       [0.2220 0.7067 0.0713];
%       [0.0202 0.1296 0.9392]; ];

CM = [ [0.430574  0.341550  0.178325];
```

```
    [0.222015  0.706655  0.071330];
    [0.020183  0.129553  0.939180]; ];

RGB = [GCR, GCG, GCB];

%XYZ =
RGB*CM;%%%%%%%%%%%%%WRONG!%%%%%%%%%%%%%%%%
XYZ = RGB*(CM');

X = XYZ(:,1);
Y = XYZ(:,2);
Z = XYZ(:,3);

%Xn = X;%./XYZn;
%Yn = Y;%./XYZn;
%Zn = Z;%./XYZn;

%NormedX = X./Y;
%NormedY = Y./Y;
%NormedZ = Z./Y;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%
%Transform of [255 255 255] in RGB co-ordinates

%XYZrgbMax = [255^Gamma 255^Gamma 255^Gamma]*(CM');

%Ymaximum = XYZrgbMax(3);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%
%WhitePoint

WPx = 0.312713;
WPy = 0.329016;
WPz = 1 - WPx - WPy;

WP = [WPx WPy WPz];% in xyz co-ordinates

%Find the white point in XYZ
XYZn = max( Y );

%Use Ymaximum instead -- deprecated
%XYZn = Ymaximum;

Xwp = XYZn*WPx/WPy;
Ywp = XYZn;
Zwp = XYZn*WPz/WPy;

XXX = X./Xwp;
```

```
YYY = Y./Ywp;
ZZZ = Z./Zwp;

max(XXX)
max(YYY)
max(ZZZ)

%The lab conversion itself
L = zeros( size(Y) );
a = zeros( size(Y) );
b = zeros( size(Y) );

for k = [1:max(size(Y))],

 %L
 if YYY(k) > 0.008856452,
  L(k) = 116*power( YYY(k), 1/3) - 16;
 else
  L(k) = 903.2962963*YYY(k);
 end

 %a
 a(k) = 500*( f( XXX(k) ) - f( YYY(k) ) );

 %b
 b(k) = 200*( f( YYY(k) ) - f( ZZZ(k) ) );

end

Lab = [L,a, b];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%
```