

# LIBERATION CALCULATOR IMPLEMENTATION STUDY

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**ABSTRACT** This paper outlines the details of a study conducted to assess the feasibility of implementing a newly developed liberation calculator as a day to day tool for estimating the extent of liberation at identified key points within the plant. Using reconstituted plant exits PSD, weekly liberated carats (%) from January 2007 to August 2008 were calculated using the tool. Statistical analysis was performed on the results which were then compared with the plant's historical liberation performance having been estimated using granulometry. It was found out that the liberated carats results obtained using the calculator did not significantly differ from those obtained using granulometry and that any discrepancies or suspiciously outlying results are purely a result of random error and not systematic error in either of the two methods. It was therefore concluded that replacing granulometry with the calculator is clearly feasible. It was however recommended that the two be run parallel for some time before granulometry is substituted.

## 1 INTRODUCTION

Liberation is an integral part of any diamonds processing plant. Although difficult to quantify, the extent of liberation in a processing plant can be diagnosed by the level of fracture (grind) that a plant completes at any given stage of comminution. Comminution is a repetitive process. It is continued incorporating comminution equipment and recycling until all the material has been reduced to a required size. In the metallurgical industry, comminution commences as soon as excavation from the ground is done (Ashock and Denis, 2006).

The orientation and arrangement of comminution equipment which can aid quantifying liberation extent has historically had little attention. This is because the plant's total grind is the main requirement. Nevertheless, decreasing ore grades, increasing operating costs and many other factors do warrant the need to have process quality assurance measures (Metals Dog Minerals, 2008). This gives assurance that the existing design and operational procedures and standards enable revenue improvement and optimal equipment utilization at minimum possible costs. In Orapa and Letlhakane Mines (OLM), a calculator that is able to estimate liberation at key identified points within the plant was developed by the metallurgical team. This would enable analysis of

how much liberation is required. Historically, a tool referred to as granulometry had been used in the estimation of liberation extent. However, the developed calculator incorporates an estimate of the amount of grits and slimes produced, something that granulometry neglects (Chibaya, 2008). This helps in making assessments of how the plant can be altered to improve stability and obtain the right level of liberation. Statistical data analysis was therefore carried out on historical data in order to investigate the feasibility of implementing the developed calculator at Orapa number 2 plant and subsequently all other plants. This document reports on the details of findings of the analysis. Conclusions as well as suggestions of the next course of action are also covered.

## 2 METHODOLOGY

### 2.1 Liberation Calculator Concept

The curve of a Size Fraction Distribution (SFD) of diamonds (carats) within an ore-body determined geologically per pipe (facies) and is referred to as the Total Content Curve (TCC). Table 3.2 shows the cumulative SFD while figure 3.1 shows the TCC which was used in this study. TCC gives a distribution in terms of size of diamonds which would be obtained if the concentration and

recovery process was 100% efficient, i.e. if all the diamonds were recovered. The table below (1) gives an illustration of the ore-body carats SFD given that size fractions  $c_1, c_2, \dots, c_n$  have % masses  $m_1, m_2, \dots, m_n$ .

Table 1: Size Fraction Distribution illustration

Size (mm)	% Mass
$c_1$	$m_1$
$c_2$	$m_2$
.	.
.	.
$c_n$	$m_n$

$$\sum_{i=1}^n m_i = 100$$

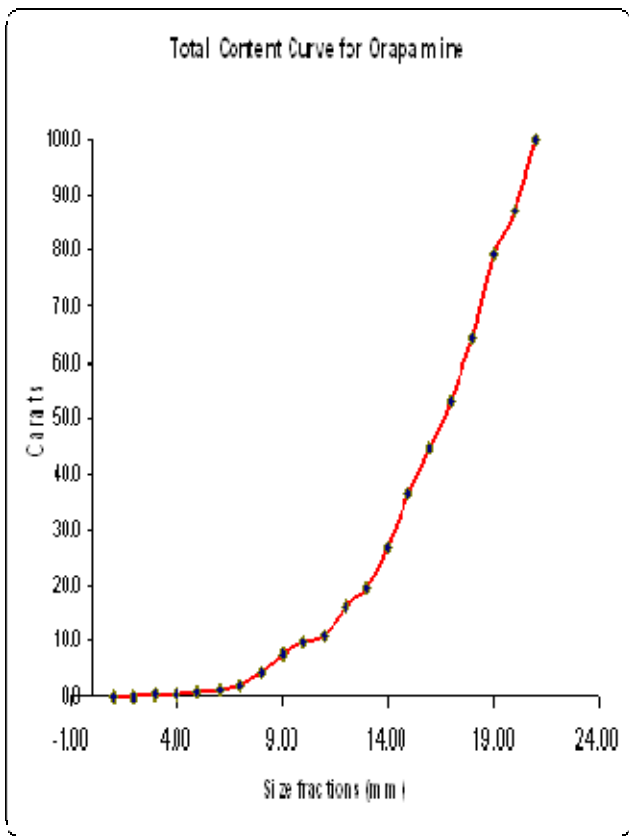


Figure 1: Cumulative Total Content Curve (TCC) for Orapa mine

Diamonds in an ore-body are locked (or contained) within the diamond ore (kimberlite). The sole aim of comminution in diamond processing is therefore to continuously reduce the kimberlite containing the diamond hence releasing the diamonds and availing them for recovery. This releasing of diamonds from the host rocks is referred to as liberation. The liberation calculator developed in Orapa number 2 plant is based on the following concepts;

Assuming that the diamonds are evenly distributed across all size fractions of the plant exit, if combined plant exit (tailings, grits & slimes and concentrate) have a PSD of  $x_1, x_2, \dots, x_n$  for size fractions  $s_1, s_2, \dots, s_n$  as illustrated in table 1 below;

Table 2: Plant exit PSD

Size (mm)	% Mass
$s_1$	$x_1$
$s_2$	$x_2$
.	.
.	.
.	.
$s_n$	$x_n$

Then the amount of diamonds of size  $c_i$  (from the TCC) in the material of size  $s_i$  is given by;

$$Amount = m_i x_i \quad [1]$$

$m_i$  = % mass of carats of size  $c_i$

$x_i$  = % mass of plant exit of size  $s_i$

such that the same % mass of carats (diamonds) of size  $c_i, m_i$  is given by;

$$m_i = \sum_{i=1}^n m_i x_i \quad [2]$$

It should be noted that the number of size fractions for carats and those for plant exits do not necessarily have to be the same. Table 3 below illustrates the concept explained above;

Table 3: Amount of diamonds per plant exit size fraction

Size	C <sub>1</sub>	C <sub>2</sub>	...	C <sub>n</sub>	
<b>%mass</b>	$m_1$	$m_2$	...	$m_n$	
<b>Size</b>	<b>%mass</b>				
$S_1$	$x_1$	$m_1 x_1$	$m_2 x_1$	...	$m_n x_1$
$S_2$	$x_2$	$m_1 x_2$	$m_2 x_2$	...	$m_n x_2$
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
$S_n$	$x_n$	$m_1 x_n$	$m_2 x_n$	...	$m_n x_n$

$$m_1 \sum x_i = m_1 \quad m_2 \sum x_i = m_2 \dots \quad m_n \sum x_i = m_n \quad \sum m_i = 100\%$$

For liberation to be deemed to have occurred, the diameter of the diamond's host rock,  $D$  multiplied by an empirical factor referred to as the preferential liberation factor (PLF) should be less than the diameter of the diamond,  $d$ . Mathematically expressed;

$$d > PLF \times D \quad [3]$$

$D$  = diameter of host rock in mm

$d$  = diameter of diamond in mm

PLF = dimensionless factor

The PLF is determined geologically based on the TCC. The standard value of PLF for diamonds in the De Beers group is 0.35 (Chibaya, 2007). Therefore, the ratio of diamond to host rock diameter should be greater than 0.35 for liberation of diamonds to occur. In simple terms, the host shock should be at most about 3 times the diamond it contains in size for liberation to occur.

It is therefore possible to find out if the diamonds of sizes,  $c_1$  to  $c_n$  assumed to have been evenly distributed in material of size fractions  $x_1$  to  $x_n$  are liberated. This is done by finding out if the product of the plant exit diameter and PLF is greater than the diamond diameter. Having determined if diamonds of size  $c_i$  in plant exit material of size fraction  $x_1$  to  $x_n$ , the amount of diamonds in size fractions in which liberation occurred is then expressed as a % of the total amount of diamonds of size  $c_i$ ,  $m_i$ . This is the percentage liberated carats for diamonds of size  $c_i$ . The overall % liberation is calculated by adding together liberated diamonds of different sizes per plant exit size fraction and then summing up everything together. For example if for diamonds of size  $c_1$ , liberation occurred in 16 out of a total of 20 plant exit fractions and for diamonds of size  $c_2$ , liberation occurred in 19 out of 20 fractions, the % liberated carats for diamonds of size  $c_1$  and  $c_2$  are 80% and 95% respectively. On the other hand, if the amount of diamonds of size  $c_1$  in material of size  $s_1$  is  $y$  (as calculated in table 3.4) and those of size  $c_2$  in the same size fraction is  $z$  with liberation having occurred in both cases, the liberation for that material size fraction is  $y+z$ . The procedure is repeated for all the material size fractions  $s_1$  to  $s_n$  and then all the liberation values are added together to find the overall % liberated carats.

## 2.2 Analysis Procedure

1. Number 2 plant's historical (from January 2007 to August 2008) liberation performance data was obtained from the laboratory database.
2. PSD's of tailings and thickening underflow (grits & slimes) for the same period were also obtained. Since the plant concentrate constitutes a maximum of 0.05 % of plant exits, its effect on the overall plant exit PSD is considered insignificant and was therefore ignored at this stage. Using a split ratio of 40: 60 for tailings to grits & slimes, a PSD of a reconstituted plant exit was calculated for the selected weeks of the period mentioned above as detailed in appendix 1.1. Figure 3.2 below shows cumulative PSD graphs for tailings, grits & slimes and the reconstituted plant exit for the week ending 5<sup>th</sup> January, 2007.

3. The liberated carats for each of the weeks were calculated using the liberation calculator first at a PLF of 0.35 and then at a PLF of 0.275.
4. Granulometry obtained and liberation calculator obtained liberated carats values were compared by plotting a graph of liberated carats for different weeks for both methods. The variability within each data set was also calculated and discrepancies were accounted for.
5. A student T-test as described in appendix 1.2 was performed to quantitatively establish the difference (or absence of) in values obtained by the calculator and those obtained by conventional granulometry.
6. This analytical work enabled the establishment of whether substituting the liberation calculator for granulometry is actually feasible.

Figure 2 shows graphs of cumulative PSD's of both tailings and grits & slimes (both of which are plant exit) and the resultant cumulative PSD after the two had been reconstituted.

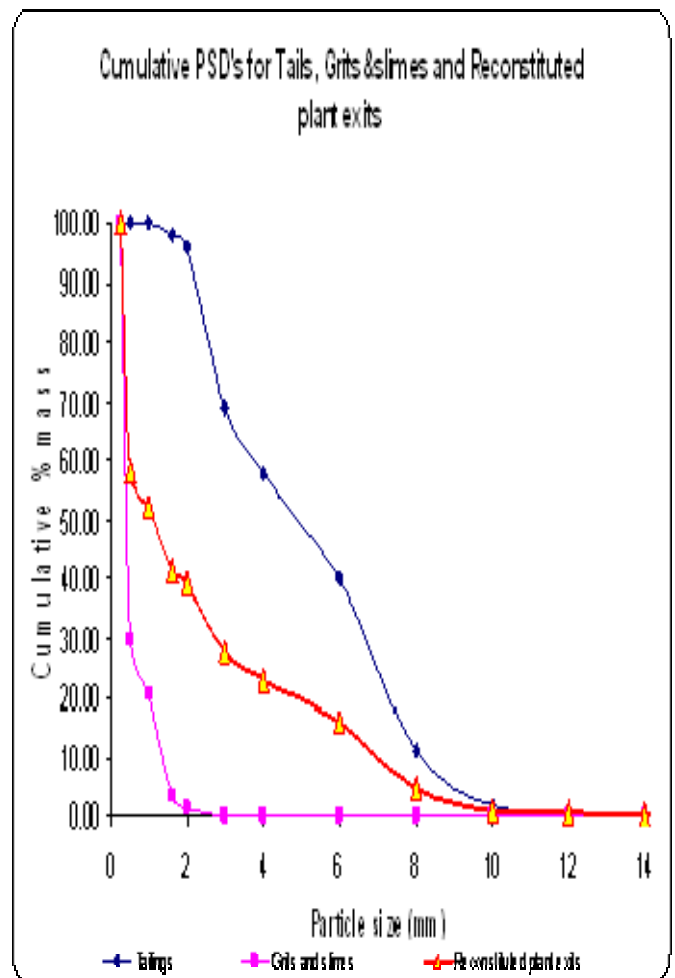


Figure 2: Cumulative PSD graph for tailings, grits & slimes and the reconstituted plant exit for week ending 5<sup>th</sup> January, 2007

### 3 RESULTS

Figure 3 above shows graphs of plots of liberated carats obtained using granulometry and those obtained using the liberated calculator for both PLF=0.35 and PLF=0.275 for different weeks starting from January 2007 to August 2008. The percentage by which values of liberated carats obtained using the calculator (for both PLF=0.35 and 0.275) deviate from the ones obtained using conventional granulometry is represented by Figure 4.2(4). Table 4.1 above shows results of a t-test performed to test if the mean values of data sets obtained using the calculator are significantly different from the mean value of the granulometry data set. In both cases, the null hypothesis,  $H_0$  was that “the arithmetic means of the 2 data sets (calculator and granulometry) are not significantly different and that any discrepancies or suspiciously outlying values are purely a result of random but not systematic errors”. The null hypothesis was accepted in both cases.

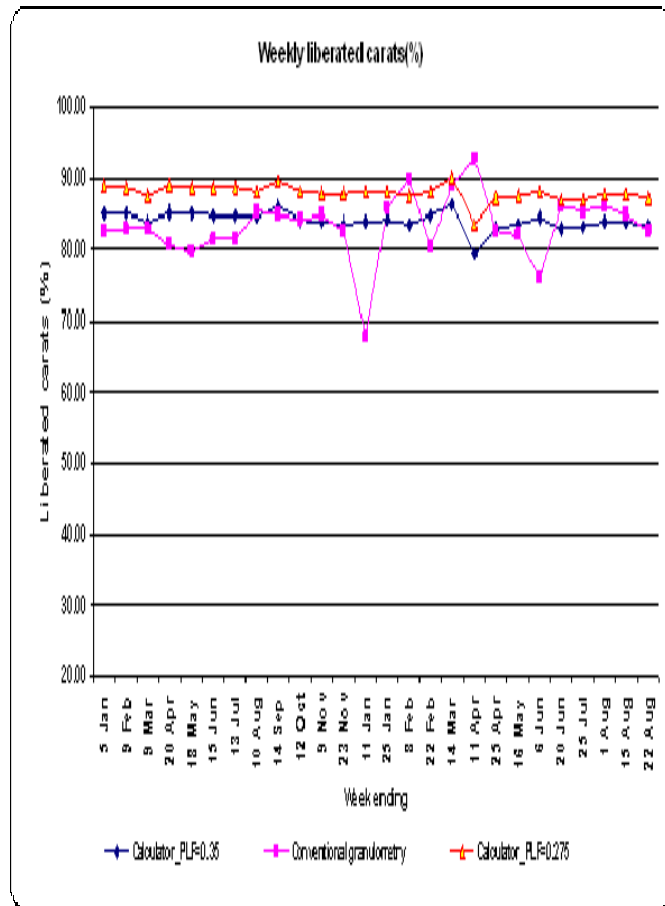


Figure 3: Weekly liberated carats obtained using both granulometry and liberation calculator

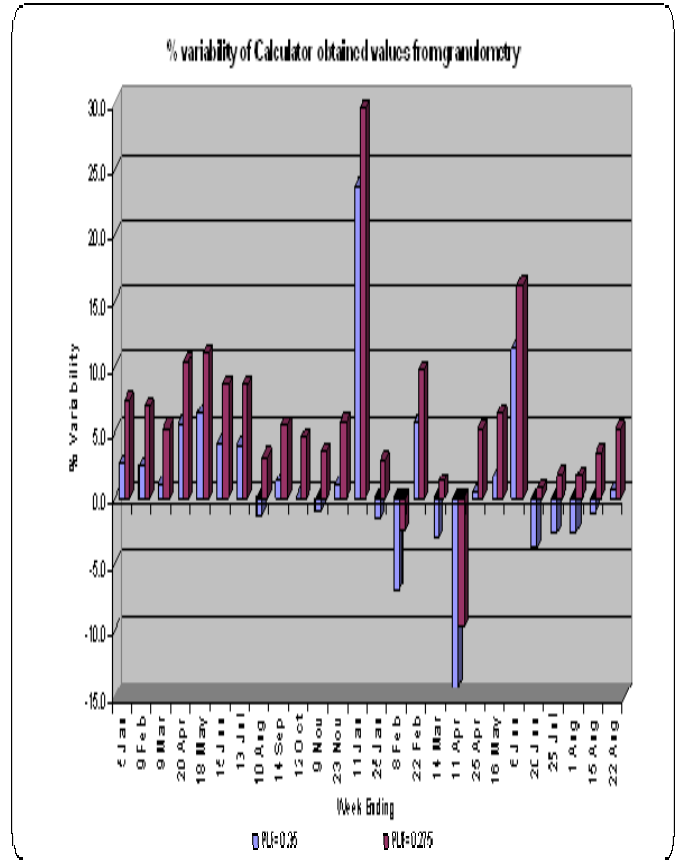


Figure 4: Percentage Variability of calculator obtained values from granulometry

Table 4.1: Statistical T test

Data set	$T_{\text{calculated}}$	$T_{\text{critical}}$	Result
PLF=0.350	0.4296	2.787	$H_0$ accepted
PLF=0.275	0.0001	2.787	$H_0$ accepted

### 4 DISCUSSION OF RESULTS

#### 4.1 Calculator vs. Granulometry obtained values

Figure 3 is a plot of liberated carats values for different weeks obtained using the conventional granulometry and the liberation calculator at PLF 0.35 and 0.275. Except for a few discrepancies in the data, a visual examination shows that the three graphs run close to each other suggesting that the data sets are not significantly different from each other. That is to say, the liberated carats values obtained using the calculator are not significantly different from those obtained using the conventional granulometry. The few discrepancies that can be observed on the graph can be ascribed to errors in sampling and granulometry procedure. This is because granulometry involves the manual

separation of waste from kimberlite, a task difficult to carry out and prone to error especially with very small particles. In other words, it is very difficult to do the kimberlite-waste separation when it comes to very small particles since they are difficult to detect what they are. A smaller preferential liberation factor of 0.275 instead of 0.35 resulted in an average increase of 4.5% in the value of the liberated carats. A theoretical explanation to this is that a decrease in PLF affords a decrease in total plant grind without necessarily leaving some diamonds locked in. Since liberation occurs if and only if the product of the PLF and the diameter of the host rock,  $D$  is less than the diamond diameter,  $d$  then a decrease in PLF affords the rise in  $D$  without the product of the two being greater than  $d$ . Practically speaking, a smaller PLF implies a decrease in the ratio of diamonds to host rock which increases the probability of diamonds being unlocked from host rock. In this case for example, the initial PLF of 0.35 meant that liberation occurs if the ratio of diamond diameter to host rock diameter is less than 0.35 and reducing PLF to 0.275 means the reduction in the ratio of diamond diameter to host rock diameter hence increases the extent of liberation.

#### **4.2 Percentage variability of the calculator from granulometry results**

Figure 4 is a bar chart showing the percentage variability of liberated carats values obtained using the calculator (for both PLF = 0.35 and 0.275) from those obtained through granulometry. Although the figure does not communicate any new information as far as the comparison between the calculator and granulometry is concerned, it gives a good pictorial representation of the insignificance of the difference between values obtained by the two methods. Apart from three discrepancies on the weeks ending 11 January, 11 March and 6 June, 2008, all the deviations are of a unit order of magnitude. The discrepancies can again be ascribed to the errors in sampling and carrying out granulometry already described.

#### **4.3 Statistical test of significance (T test)**

Although the above analytical pieces of work which are both pictorial representations strongly suggest that the liberation calculator essentially yields the same results as granulometry in estimating liberation, it suffices to have a concrete quantifiable method to support this claim. Table 4.1 therefore shows results of a T-test performed to test significance of difference between the arithmetic mean values of liberated carats values

obtained using the calculator and those obtained using conventional granulometry. Assuming that the distributions of each data set are normally distributed, the null hypothesis,  $H_0$  was such that “the arithmetic means of the 2 data sets (calculator and granulometry) are not significantly different and that any discrepancies or suspiciously outlying values are purely a result of random but not systematic errors”. In other words the two methods of finding liberation do yield the same results. As evident from table 4.1 the calculated T value is less than the critical (tabulated) T value at 95% confidence level in both cases. The null hypothesis is therefore accepted in both cases. Statistically speaking this is proof enough that the mean values of data set for the calculator and that of granulometry are not significantly different. This means that the calculator does essentially yield “the same” results as granulometry at least based on the data at hand.

### **5 CONCLUSIONS**

Based on the statistical analysis done on the historical plant liberation performance and the available input database data, it can be safely concluded that the use the liberation calculator as a day to day tool for estimating the extent of liberation is feasible due to the fact that;

1. The liberation calculator does essentially produce the same results of estimating “% liberated carats” that granulometry does.
2. The plant concentrate (which contributes only up to 0.05% of plant exits) does not significantly affect the plant exit’s PSD and the liberation calculator can therefore be used without necessarily having to get the concentrate PSD.

### **6 RECOMMENDATIONS**

Although the results so far clearly indicate that the substitution of the calculator for granulometry is feasible, caution still has to be exercised to ensure that the calculator will work every time and in all situations.

1. It is therefore suggested that before a final decision is made to actually replace granulometry with calculator, the two be run parallel this time sampling and doing PSD tests knowing that they will be used in the calculator to see if they indeed yield the same results.
2. It is also recommended that a trial run be carried out where samples will be collected and primarily dedicated to this work for a suitable period of time.

## 7 REFERENCES

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