TECHNIQUE FOR ESTIMATION OF DIAMOND LOCKUP IN A DIAMOND PROCESSING PLANT

R. Machowski

BATEMAN DIAMONDS

TECHNIQUE FOR ESTIMATION OF DIAMOND LOCKUP IN A DIAMOND PROCESSING PLANT

R Machowski PrEng

Bateman Diamonds (Pty) Ltd

Abstract

In the diamond processing industry, there exists a great need to open up the debate on "diamond liberation" (or its converse: "diamond lockup") and its practical quantification. The quantification of "diamond liberation" in the context of economic consideration of diamond processes is the difference between sub-economic and profitable operations.

Traditionally, the diamond processing industry, understood "diamond liberation" more as a qualitative concept rather then a quantitative measure. It has mistakenly equalled "diamond liberation" to the level of ore fragmentation in a process circuit, whether diamonds were actually liberated or not.

In this paper, barriers to the adoption by the industry, of quantitative model for estimation of "diamond lockup" (or it converse 'diamond liberation") are listed. Furthermore, based on work done to date by some industry players, a standard user-friendly Diamond Liberation Estimation Model (DLEM) is presented, which is applicable to, (1) adoption in the existing process plants as well as, (2) the future process plant designs by design engineers.

TABLE OF CONTENTS

ACRONYMS

ACRONYM	TERM
cpht	carats per hundred tonnes
DSFD	Diamond Size Frequency Distribution
ct or cts	carat or carats
DMS	Dense Medium Separation
DLEM	Diamond Liberation Estimation Model

DEFINITIONS

TERM	DEFINITION
Tonne	Metric tonne = 1000kg
Carat	0.2g
Feed	Incoming stream to the given process.
Ep Value	Ecart Probable. Indication of the sharpness of the partition curve which are generally used to quantify the separation efficiency of a dense medium process. Ep = (d75 - d25) ÷ 2
Overall Process Recovery Efficiency	A ratio of the material of interest (eg diamonds), in the product or concentrate stream as a fraction of the incoming material of interest (eg. Diamonds) in the Feed stream to a given process. Conventionally expressed as a percentage. PE = mass of material of interest in product stream / (mass of material of interest in the feed) *100%
Tailings	Outgoing stream from the given process, that conventionally contains a lesser proportion of material of interest (eg. Diamond) then the concentrate stream.
Tracer	Suitable material used as a substitute for diamonds in order to measure unit process performance.

1. INTRODUCTION

1.1. Context

The diamond mining and diamond processing industry has long occupied itself with the issues of free-diamond recovery efficiency and diamond liberation. These are the two main pillars of successful design and operation of every diamond processing flowsheet. This is true whether with or without consciously quantifying free-diamond recovery and diamond liberation.

Traditionally, *diamond liberation* has been mistakenly equated with comminution and/or fragmentation processes. This is fundamentally incorrect as liberation implies separation of valuable mineral (diamond) from its host gangue mineral. Comminution or fragmentation simply focuses on material breakage, independent of whether it is of sufficient level to liberate diamonds or excessive to waste energy or even to destroy the diamonds.

In the typical western-style diamond flowsheet design and operation practice, diamond liberation has been conceptually verbalised but inadequately described to become a mainstream topic that would lead to development and adoption of diamond liberation measures. It has therefore never reached a stage of specification, quality measure and a significant variable of business improvement. The industry has simply selected and applied the equipment, which it believed to be the best in the faith that it will deliver or exceed expectations of high diamond liberation, which it could not actually quantify at first. It was indeed a practice of faith and extraordinary mastery by a variety of equipment manufacturers to be able to sell capital intensive equipment on all the factors and benefits but actual diamond liberation.

Some limited models and practices for estimates of diamond liberation existed since the late 1980'ies however, these were utilised for isolated cases, or used by "closed groupings" and did not have the specific objective of developing an industry audience for the topics related to diamond liberation. It was finally with the advent of concerted efforts of Diamond Value Management presented to the industry in 2004 by Roodt and Rider (2003) that Diamond Liberation became a defined topic of that could be quantitatively presented. It too however was kept in a relative concealment from the rest of the industry.

It is in the context of mineral liberation, and specifically "diamond liberation" that this paper is presented, in an attempt to open and stimulate discussion regarding this topic.

1.2. Problem Statement

The notion of *diamond liberation* from its host rock in diamond processing is understood and much talked about at a conceptual level, by the diamond processing engineers and industry players. The problem statement put for debate here is that **the practical estimation of diamond liberation is not commonly established or even understood, and often confused with mere size reduction.**

Furthermore, traditionally established models for mineral liberation, conceptually, could be used in diamond processing applications. It is the complexity of sampling and assaying of the analytes that makes the practical aspects of populating the inputs into the mineral liberation models currently impractical.

1.3. Objectives

The paper has the following objectives:

1. To open and initiate the topic of *diamond liberation* on an industry wide scale;
2. To present diamond liberation as one of the main "pillars" of a diamond processing flowsheet and its design.
3. To reflect on the true diamond liberation aspects, which are common to any mineral liberation;
4. To propose an extension and simplification of an empirical model in a step-wise fashion for diamond liberation that can be used by diamond process engineers.

2. THE FUNDAMENTALS and MINI LITERATURE REVIEW

2.1. Elements of Profitability of a Diamond Processing Systems

At the most fundamental level, the profit (normal profit and economic profit) of a diamond mining operation, or in fact, any enterprise depends on the balance of the revenue generation of the enterprise and its resulting costs (Albrecht, William 1983). For the purposes of simplicity, this has been described by Equation 1:

$$P = R - C \qquad \textbf{Eqn: 1}$$

Where:

P = Profits

R= Revenues

C = Costs

In addition, at the most fundamental level, the aspects of technical performance were grouped and published in previous work by Machowski (2005) as "Components of Diamond Recovery". For the purposes of reflection, these are listed:

1. Free-Diamond Recovery;
2. Diamond Liberation;
3. Other (eg Pilferage, Refractory diamonds, etc).

The diamond processing operation's revenues are directly proportional to:

1. the Volume and Density Treated;
2. Grade;
3. Diamond Recovery (including free-diamond recovery and liberation and Other);
4. Diamond Price;
5. Others.

It is imperative to note that the main "pillar" of the revenue stream that can actively be managed by the operators or flowsheet designers is Diamond Recovery (including free-diamond recovery and liberation and Other. A second aspect that can be managed by the operator or designer within a certain respect is the Volume or throughput of ore that is treated by the plant. The other aspects listed (grade, price, density, etc) are not in direct control of the operator or designer.

The costs of a diamond processing operation are directly proportional to:

1. The equipment costs (which in turn is a multifaceted function of its specification and partly throughput and Diamond Recovery Dependent);
2. Operating costs (fixed and variable);

3. Fiscal regime, which include taxation and average cost of capital and others.

It is evident that in both cases diamond recovery and throughput are key drivers of the profitability of a given operation. Diamond liberation, along with the free-diamond efficiency are crucial aspects that impact on profitability of a diamond processing operation and design.

2.2. Free Diamond Recovery

The "Free-Diamond Recovery" is relatively straight forward to conceptualise at a unit or the system of units level, as it is dependent on separation of liberated or "free" diamonds from the feed stream. The resulting estimate is usually reported as a ratio of recovered diamonds in the products stream versus the diamonds in the feed stream, which may be estimated through reconstitution of the diamonds in the tails stream. Some methods have been developed to establish the performance of separation equipment, either through specification, benchmarking through proxy material such as tracers or even sampling for actual diamond content in various streams.

2.3. Diamond Liberation

2.3.1. Barriers to Diamond Liberation Quantification

Conceptually, "Diamond Liberation", is more intricate to describe then the "Free-Diamond Recovery" and even more complex to estimate quantitatively. The main reasons for this are:

1. Lack of a widely accepted, diamond-specific liberation model;
2. The relative low concentrations of diamonds within the ore matrix;
3. Problems associated with sampling of particulate matter, which in diamond processing is complicated by levels of very low diamond concentration, their distributional heterogeneity and high probabilities of nugget effect, when diamond sampling is actually carried out in the +1mm size range.
4. Lack of documented and industry-agreed upon standards or proxies between abundant, diamond-like minerals and diamonds within the arena of liberation.
5. Some other contributing aspects are: the financial benefits of measuring diamond liberation; confusion between comminution mechanisms and liberation mechanisms; diamond breakage resulting from processing.

2.3.2. Diamond Liberation Concepts

At a fundamental level, the work and descriptions of mineral liberation by King (2000), is applicable to all minerals and by default has to hold true for diamond liberation. The work of King is specifically applicable in cases where there are two species under consideration: the valuable mineral and the gangue material, and the valuable mineral is emplaced within a host rock matrix, but both exhibit some differences with respect to their physical characteristics, which ultimately in the process plant can become liberated from each other, through a variety of methods. King's approach to describing mineral liberation model in general is through application of Beta Distributions, borrowed from mathematical statistics. King goes to define at least four necessary parameters that will be used in quantifying mineral liberation.

These are:

1. average grade of the valuable mineral;
2. dispersion of particle grades about the average value;
3. fraction of particles that contain only valuable mineral;
4. fraction of particles that contain only gangue mineral.

King successfully derives the relationship between liberated and un-liberated material as shown in equation 2, and uses the already mathematically derived relationships of the Beta Distribution to apply it to mineral liberation.

$$p(g) = (1 - L_o - L_1)\frac{g^{\alpha-1}(1-g)^{\beta-1}}{B(\alpha,\beta)} \text{......} for 0 < g < 1$$

WITH

$$B(\alpha,\beta) = \int_0^1 g^{\alpha-1}(1-g)^{\beta-1}dg \qquad \textbf{Eqn: 2}$$

Where:

$\mathbf{L_o}$= mass fraction of the population that consists of liberated only gangue particles.

$\mathbf{L_1}$ =mass fraction of the population that consists of liberated only valuable minerals.

g = average grade of valuable mineral in the population expressed as mass fraction.

$\boldsymbol{\sigma_g}$ = standard deviation about the mean in the population which is inserted into the function $B(\alpha,\beta)$.

From the review of the work presented by King, it is evident that conceptually, the distributional prediction of mineral liberation, and therefore its estimates, are straightforward only if the analytical techniques exist to provide sufficient input into the formulas established. Practical considerations are given to microscopic image analysis through numerous material samples on "homogenously" distributed minerals such as coal or pyritic quartz. This is where, at present, quantification of diamond liberation cannot be carried out satisfactorily due to points listed in section 2.3.1. It is however necessary that the development of techniques like image analysis and others, be done by industry and academics to be able to establish realistic and operation specific inputs into the Beta Distribution mineral liberation as described by King.

2.3.3. Granulometry Model and Other Hybrids

Diamond specific liberation modelling was proposed and outlined by Kleingeld in the late 1980'ies and later by expanded on, by Ferreira (1993), Coward and Langenhoven through the correction for total grind by reconciliation of the tailings particle size distribution and the slimes generated and Machowski with correction for process efficiency in the Recovery (2003). The essence of this ingenious, empirical model is the estimation of the potential for diamond lockup (the converse of diamond liberation) in the tailings material from a plant that has a Dense Medium Separation (DMS) stage. It is based on the probability of a spheropidally shaped kimberlite or gangue particle of a given size that could potentially contain a diamond or a population of diamonds of a certain size that would still maintain a combined density less then that of the DMS effective cutpoint, and therefore be forced to the tailings stream.

The maximum size of a diamond (Vp) that can be locked in a given size range (expressed volumetrically) is summarised by Ferreira (2003) in Equation 3.

$$Vd \leq Vp \times \frac{Ddms - Dk}{Dd - Dk}$$

Where:
Vd = Volume of diamond
Vp = Volume of particle
Dd = Density of diamond,
Ddms = Cut point density of the DMS medium
Dk = Density of Kimberlite gangue rock

Eqn: 3

Expressing this relationship as a probability distribution for each size range of sampled DMS tailings the above Equation 3 leads to Equation 4:

Probability of Carats Locked $= \sum_{i=1}^{p} Ci \times \left[Tp \Big/ \sum_{i=1}^{n} Ti \right]$

Eqn: 4

Where:
n = number of size classes
Ci = carats in size class i
Ti = Tonnes in size Class i

The model as expressed in Equation 4 is commonly referred to as a "Granulometry Model". This term is rather unfortunate as in many cases it gets confused with the simple practice of granulometry (ie size distribution determination, through sieving). The model and its practice is far more then just size distribution determination through sieving.

From the counter-positive side, the model has a variety of shortcomings, one of which is that it is incompatible with any diamond processing flowsheet where DMS stage does not feature. It is also completely "blind" to the inefficiencies of the Recovery processes.

Some further practical approximations of the inputs into the model are required, which will not be discussed at this stage, however its numerical output, offers diamond process engineers and flowsheet designers an upper limit for estimation of diamond liberation in a systematic and quantitative manner.

It must be borne in mind that the numerical output on its own is of little value unless it is compared to some baseline or is part of a regular trend that can be tracked, as the true lockup or liberation.

Further developments and realisations that diamonds, just like any other mineral more competent and harder than the matrix of its host rock, has a natural tendency to channel the applied energy through comminution processes preferentially along micro-cracks, that are a result of boundaries between harder mineral islets and the softer host rock matter. The implication from this realisation is that the lockup model as presented in Equation 4 overestimates the lockup and in reality the diamond lockup is far less than that predicted by Equation 4. This preferential fracture of the host material along micro-cracks within the host matrix has been captured in a modification to Equation 4 in a *Preferential Liberation Factor*, which very simply put, is a ratio of maximum diamond locked in a given size range to size of host rock. The estimation of this factor occurs through testwork, which unfortunately is not immune to the sampling and efficiency issues described in the earlier parts of this section.

3. DIAMOND LIBERATION ESTIMATION MODEL (DLEM)

3.1. Particle and Diamond Shape

Taking the concepts of maximum volume estimation at various DMS cutpoint densities and Kimberlite Densities, the approach is to modify the Kleingeld/Ferreira model to a specific geometry of the Kimberlite and the emplaced diamonds by considering spherical, tetrahedral and cubical volumes of particles, as shown in Figure 1.

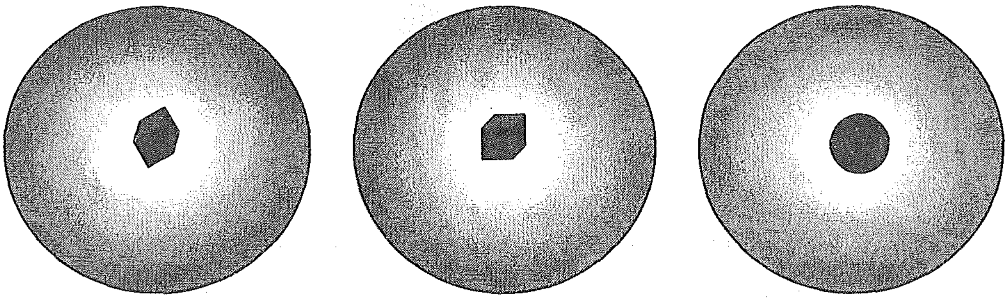

Figure 1. Various considerations of locked diamond geometry.

As Equation 3 is applicable, the specific maximum volume of diamonds locked volume considerations become dependent on actual diamond geometry. In the absence of specific diamond shape at a particular operation, the analysis should default to tetrahedral type.

Similarly to the Kleingeld/Ferreira Model (2003), the following Volumetric considerations are utilised:

$$\rho_{particle} = \frac{m_{kim} + m_{dia}}{V_{kim} + V_{dia}}$$

Which ultimately gives rise to:

$$V_{dia} \leq \frac{m_{kim} - V_{kim} * \rho_{DMScut}}{\rho_{DMScut} - \rho_{dia}}$$

Where:

$\rho_{particle}$= density of a combined particle that floats in a to tailings ie is lower or equal to the effective DMS cut-point density. **Eqn: 5**

ρ_{DMScut} = effective DMS cutpoint density.

ρ_{dia} = 3.5kg/l.

m_{kim} = mass of kimberlite.

m_{dia} = maximum mass of diamond or population of diamonds that may be locked in the kimberlite and still allow it to float.

V_{dia}= maximum volume of the locked diamonds

V_{kim}= volume the kimberlite without the locked diamonds

3.2. Diamond Separation Process

Figure 2 shows the overall simplistic balance of incoming and the product species in a diamond processing flowsheet, indicating the free species (diamond and ganugue), labelled as "Diamond" and "Ore", as well as the locked diamond in gangue ("Ore+Diamond").

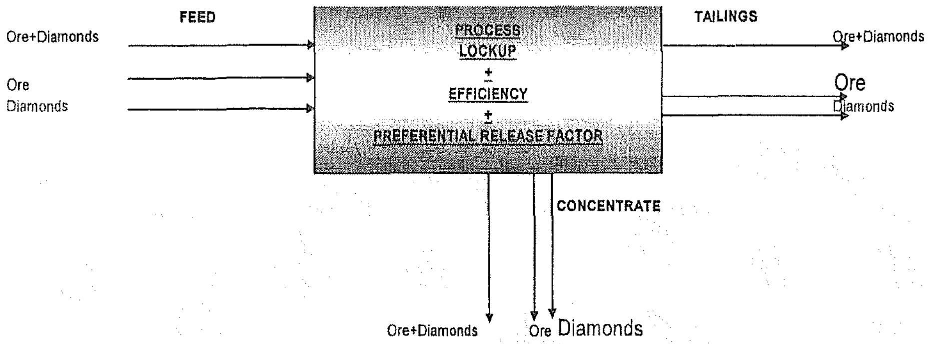

Figure 2. Diamond Separation Process indicating feed and product streams.

The relative amounts of diamonds in the tailings streams (labelled in Figure 1 as free-"Diamonds" and "Ore+Diamonds") is far less than that of "Ore". Nevertheless the lockup of diamonds depends on the relationship given in Equation 3 and the definition of process efficiency per size class, which is not discussed here. Similarly the relative amounts of gangue in the product stream (labelled in Figure 1 as "Ore" and "Ore+Diamonds") is far less than that of "Diamonds". Its relationship is mainly dependent on the definition of the process efficiency equation, which is not discussed here. Preferential Liberation Factor if know can be substituted into the preferential release term, if it is known if this has not been determined for baseline estimate a factor of 1 and 0.35 should be used.

3.3. Model Inputs

The following table indicates various model inputs. The numerical values have been chosen for illustrative purposes only.

Table 1. Various Inputs into the model.

INPUT	VALUE	UNIT
Density of kimberlite	2.5	kg/l
Density of diamond	3.5	kg/l
Diamond Geometry	Tetrahedral	Volume Calculation
Effective DMS Cutpoint Density	3.1	kg/l
Preferential Release Factor	1	
Kimberlite Shape Sphericity Factor	0.5	0..1
Potential Non-kimberlite Content (Waste)	10	5
Process Efficiency per Size Range	90	%
Bottom Cut-Point	1	mm

Top Cut-Point	25	mm
In-situ Diamond Distribution	sieving	mm or DS
Feed Tonnes		Tonnes
Tailings Tonnes		Tonnes
Recovery Tailings process Tonnes		Tonnes
Size Distribution of Tailings	sieving	mm
Percentage of Slimes Generated by the process		%
Percentage of estimated Diamond Pilferage or Breakage		%
Revenue Distribution per carat per sieve class for recovered stones		\$/ct/sieve

The implication is that all of the above inputs need to be following table indicates various model inputs. The numerical values have been chosen for illustrative purposes only.

3.4. Model Workings

The model, which has been coded into a MS-Excel spread-sheet is described below in a stepwise fashion.

1. Number of size-classes to be analysed should be decided upon (*i*) and entered into the spreadsheet.
2. Possible combinations of diamond size (using the correct volumetric type model) and kimberlite sizes from the bottom cut-point to the top cut-point should be calculated in a matrix in a resolution that corresponds to the selected size fractions in 1.
3. For reach diamond size range and kimberlite size range matrix, the potential combinations should be filtered (isolated using Excel's functions or "if" statements) based on the effective cut-point density of the DMS.
4. Total maximum diamond size should be listed per size kimberlite fraction in a column.
5. The column mentioned above should be converted from millimetres size to diamond mass in carats using a size to mass conversion table or utilising the average volume and diamond density of 3.53.
6. In the following column, the Preferential Release Factor Should be applied to each size fraction.
7. Average kimberlite particle mass for each size class should be calculated using the average kimberlite density; spherical volumetric equation; and sphericity factor.
8. Utilising the mass balance information (slimes, and tons to DMS tails) a corrected PSD should be entered per kimberlite size fraction.
9. In the following column % waste per size fraction should be applied.

10. In the following column "pure" kimberlite per size fraction should be calculated.
11. Weighted maximum diamond Carats per kimberlite size-fraction should ten be calculated.
12. The estimated in-situ diamond distribution (or in the absence of it a efficiency corrected Recovered DSFD may be used) should be entered. This diamond distribution will be used to model the individual diamond distributions per size class.
13. The next steps require that the individual maximum locked diamond be decoupled by transposing them and applying the distribution from 12 (above) and then summing all of them per kimberlite size class. As an example, the maximum diamond size in kimberlite size class of 16mm is approximately 20cts, in kimberlite size class 10mm it is approximately 5cts, but the kimberlite 16mm size class should contains some of the diamonds from the 10mm size class. These therefore have to be decoupled, appropriate distributions applied and resumed up again to establish a good estimate per kimberlite size-fraction.
14. Individual diamond size fractions can then be multiplied by the revenue price information.
15. The final step is to present the calculated lockup per size fraction in a neat and simple manner per kimberlite size-fraction, as carats per size class, percentage per size class and revenue per size class. This information may be shown in a table format or graphically as in Figure 3.

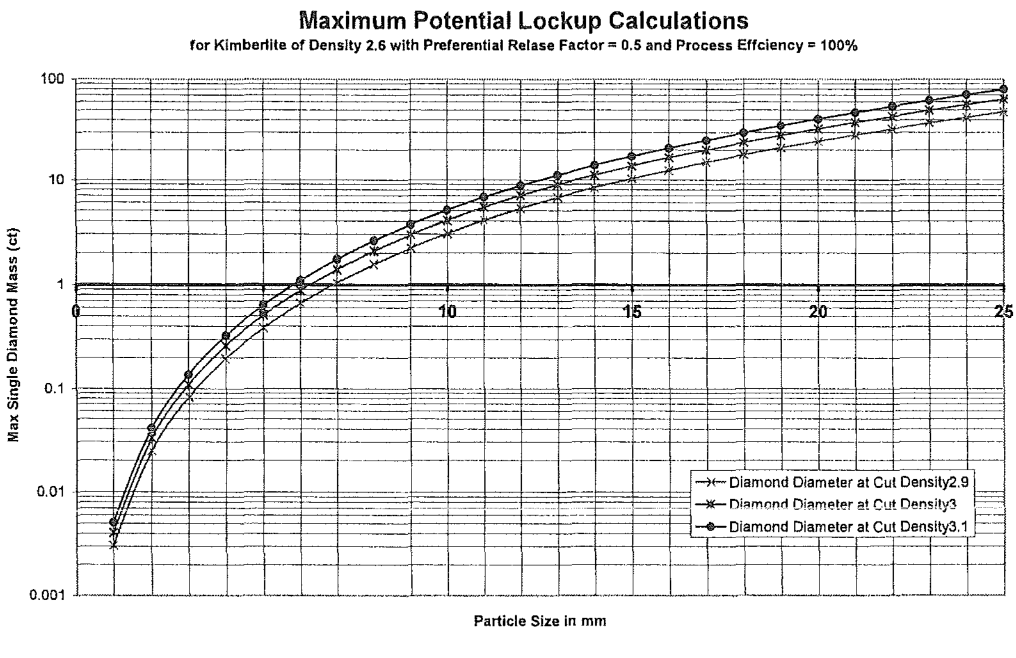

Figure 3. Example of the Diamond Lockup Output.

4. DATA CAPTURE and ANALYSIS METHODOLOGY

The application of the above described model is both for existing diamond processing operations as well as for design estimation purposes. The approach differs for design and existing diamond processing operations as not all the information is available at the time of flowsheet design.

Below, is a suggested stepwise methodology for an existing operation that consists of Comminution, DMS and Recovery stages. In the case of design related calculations the following section 4.1 should be substituted with "most likely" values or information available from the Basis of Design or any equipment performance specifications that are known from suppliers.

The following sequence should be followed to ensure correct generation of data:

4.1. Activities During Normal Plant Processing

During the Sampling of DMS Tails:

1. Sampling to happen systematically and rigorously.
2. DMS tails need to be sampled (ideally using sample cutter - the sample may then be reduced in size through a representative method eg. rotary splitter).
3. Representative tailings samples from the DMS float screens (for the individual streams) need to be taken.
4. Sample size may be reduced using representative methods (eg. rotary sample splitter) down to approximately 5kg. This however is dependent on the intrinsic heterogeneity of the material and therefore may be adapted. Initially repeat samples need to be generated to establish inter sub sample variability.
5. The size distribution of this sample is the critical ingredient of the process and this should be obtained as accurately as possible.
6. The sample may be wet screened and the various size fractions dried separately. Alternatively the sample needs to be dried and screened.
7. Ideally a "root 2" sieve series should be used. If this is not available, then at least the various size fractions from various streams should be used.

The following Information must be recorded:

1. Mass Balance for the plant at the time of DMS tailings sampling.
2. Specifically ensuring that slimes/fines is part of the mass balance.
3. DMS Concentrate Split vs Floats needs to be recorded.
4. The amount of feed to the DMS (as a percentage of head feed.
5. DMS Cut point.
6. DMS Concentrate mass.

7. Diamond SFD of the recovered diamond distribution for the sampling period.
8. X-ray and/or any other Recovery equipment performance test or audit data to populate the recovery efficiency factors.

4.2. Activities Post Completion of Sample Treatment

During the Analysis of DMS Tails Sub-samples the following must be captured:

1. In each size fraction the percentage kimberlite and gangue material must be determined. This may be done on sub samples of material.
2. Waste/Kimberlite Split - At least three sub samples from each size class should be obtained and the number of waste and kimberlite particles should be counted.
3. Average particle size and weight - The number of particles in the selected size fractions should be determined (counted) and the sub sample weight noted, so that average particle weight can be calculated.
4. Shape Sphericity Factor (ratio of actual particle volume compared with a perfect sphere of the given size) - Selected sub sampled particles should be selected and their widest and narrowest dimensions should be measured to come up with the shape sphericity factor.
5. Density of the kimberlite in the given size fraction - The method used for this is to use a water displacement method, where a known mass of material is placed in a measuring cylinder and filled with a known volume of water. Care should be taken to ensure bubbles are not trapped in or on the particles. Obtain the specific gravity of solids in each class. The specific gravity is determined by comparing the mass of solids and the volume of water displaced by the solids.
6. Density of the waste in the five size fraction - Water displacement method may be used.
7. All the obtained input information should be entered into the prepared model spreadsheet (as discussed in previous section).
8. Liberation is calculated (revenue or carats) can be looked up in the spreadsheet.

5. DISCUSSION of the DLEM

The presentation of the Diamond Liberation Estimation Model (DLEM) has as the objective to stimulate debate surrounding one of the most important pillars of diamond recovery – Diamond liberation within a processing flowsheet. It does not in any way claims to take away the credit of the various model pioneers. The DLEM model, which is based on the Kleingeld/Ferreira (1986 and 2003) Granulometry model, conceptually suffers from some of the shortcomings of the Granulometry model in that it is incompatible with diamond process flowsheets that do not possess DMS unit process. Furthermore it considers its host-rock particle and diamond geometries (volume estimates), which today remain untested.

As a tool for existing operators and diamond process engineers the DLEM model may be adequate for establish a baseline and tracking of such a baseline throughout any of the process changes or ore blending extremes. For absolute determination of diamond liberation and therefore the verification of the DLEM model a concerted effort on the part of industry would be required to achieve sufficient sample sizes for its evaluation, analytical means for processing of sub-sampled material, reduction in particulate matter sampling error (E_0) and access to equipment of sufficiently high and stable process efficiency so as not to obscure the results obtained.

As a tool for a diamond process design engineer, DLEM model offers a benchmark that can be used to predict or specify the particle size distribution of the DMS tailings so as to ensure a client required level of liberation.

6. CONCLUSIONS

The paper presented can be summed up through the following conclusions:

1. From the economic perspective of a diamond processing plant, diamond recovery (inclusive of free-diamond recovery and diamond liberation) and throughput contribute significantly to the process plant's profitability.
2. Free diamond recovery was not covered extensively by this paper. It is however understood by plant operators and designers alike and to a greater or lesser extent quantitatively measured through quality tests and specifications.
3. Diamond liberation is conceptually understood by the diamond process operators and designers at a conceptual level, but is inadequately developed or understood for quantitative management.
4. On a conceptual level diamond liberation model must be consistent with the already available mineral liberation models. The practical aspects of the particulate nature of diamonds and their low concentrations lead to inadequate establishment of verifiable liberation models.
5. Models (termed "granulometry") have been developed, which are based on the estimation of potential diamond content in DMS tailings in kimberlite particles of a given size that would result in the combined density of the particle being less than that of the effective DMS cut-point, allow for an entry-level quantitative measurement of diamond liberation, provided an agreed baseline is established.
6. Incorporation of the aspects such a Recovery plant efficiency, total effective grind, preferential release factor and volumetric enhancements regarding diamond shape allow for establishment of improved models to estimate diamond liberation.
7. A stepwise approach was taken to list the functionality of the Diamond Liberation Estimation Model (DLEM).
8. A procedure was proposed that would allow for a standardised sampling and model input generation and the resulting analysis of diamond liberation.

7. ACKNOWLEDGEMENTS

The author wishes to acknowledge S Coward from De Beers for some guiding and inspiring comments on the topic of Diamond Liberation.

8. REFERENCES

Albrecht, William P. (1983). *Economics*. Engelwood Cliffs, New Jersey: Prentice-Hall. ISBN: 01322443458.

Coward S, Langenhoven JJ. (2003). Granulomerty Spreadsheet. Document unavailable to general public. MRM. De Beers.

Ferreira JJ (2003). Granulometry and Diamond Liberation. Document unavailable to general public. MRM. De Beers.

King RP, Modelling & Simulation of Mineral Processing Systems, Butterworth Heinemann, Salt Lake City. ISBN:0750646898.

Kleingeld W (1986). Granulomtric consideration of Kleinzee Gravels. Document unavailable to general public after 2006. OED. De Beers.

Machowski R (2004). Granulometry Procedure. Document unavailable to general public. MRM. De Beers.

Machowski R (2005). Waste estimation through proxies. 2005 EMMES Conference Paper; SAIMM.

Machowski R. (2005). Sampling Considerations for Determination of Process Efficiency within a Diamond Processing Flowsheet. 2005 EMMES Conference Paper; SAIMM.

Roodt A., Rider P. (2003). Diamond Value Management; Diamond Source to Use. SAIMM.