STATE OF THE ART RECOVERY PLANT DESIGN

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Abstract

The introduction of new diamond sorting technologies as well as additional manufacturers / vendors, has increased the equipment selection and combinations available for recovery flowsheet design. This paper describes the methodology used and the benefits realized in the design of recovery plants by ensuring a fundamental understanding of the advantages and limitations of the technology embodied in the equipment, a comprehensive knowledge of the ore body characteristics, and the effective matching of this information in combination with operational commercial requirements.

1. Introduction

Technology used in diamond recovery varies considerably and is driven in most cases by the economics of the ore body. Significant improvements in a number of key technologies such as magnetics, modular grease belts and X-rays have been supplemented by new technologies developed as the core technological landscape changes. These include new laser and modified X-ray based technologies. Simultaneously, products used in other sorting applications e.g. industrial waste or fruit sorting find their way into diamond sorting most notably optical or colour sorting.

Most technologies offer some sort of benefit to the particular application, but in many cases a true understanding of the production implications of the use of a particular technology are not fully understood. This results because the diamond or gangue response to these different technologies is not uniform, and in some cases varies to the extent of making the technology unusable.

As with many other technologies a complementary support infrastructure is required to ensure that the sorting units operate at their optimum performance levels. To ensure that the primary sorting technologies perform to the desired functions, the corresponding supporting technology results must be translatable, in defining optimal primary sorting settings.

In designing a complete recovery plant, consideration must be given to the performance of the various technologies working in combination, and ensuring that overall recovery performance is not compromised by optimising an individual module's performance.

2. Current and Emerging Technologies.

Traditionally, recovery or sorting plants have employed the key technologies of magnetic separation as a form of bulk reduction, followed by X-Ray luminescence and or grease based sorting. In most operations final sorting or de-falsifying is done by hand. Therefore, it is not surprising that a major development drive has been to improve the capability, design and implementation of these technologies in order to improve the performance of these unit processes, making the overall plant more cost effective.

This has been achieved by incrementally improving the core performance of the technology or by reducing the equipment capital costs. This is demonstrated in the current designs of magnetics, X-Ray and grease based products. In some cases both capital cost and performance have improved. The introduction of these upgraded products in the mining operations has been through new projects or plant upgrades. Their introduction and operation is made significantly easier as the infrastructure and support is compatible with the installed products. It is also important that users are familiar with their operation and performance.

There has been a proliferation of lower cost technologies. Many of these are derived from colour sorting, or some variation thereof, most commonly know as optical sorting. These have been introduced in some form of scavenging application or dump re-treatment where capital costs in the design of the plants play a significant role. Typically the following developments have taken place:

- X-Ray sorting
  The developments in X-ray luminescence sorting have focused on increasing equipment throughput, being able to treat wet and dry material and making the product in general more robust. Some developments have also occurred in improving the discrimination capability of the luminescence detection system.

- Magnetic Sorting
  Magnetic sorting has seen improvements in the design of the magnet to ensure a more uniform performance across a larger material size range, as well as increasing treatment rate. Security issues around typical designs have also been addressed.

- Grease Sorting
  Grease belts have been developed to improve the performance and control of the separation process. This has focused primarily on the reliability of the product and repeatability of results. The emergence of modular grease plants is noted.

There has also been a very significant drive towards developing technology that is more diamond specific and hence more discriminatory between diamond and gangue. This has been achieved through significant investment in R&D. The key to the success of these technologies is that they must ensure that the final product, in addition to the improved discrimination benefits, is more robust and cost effective when compared with established technologies.

Some examples of these new technologies that have the potential to supersede current techniques are:

- Raman sorting
  Highly selective sorting technique which has the potential identify a diamond as the Raman peak is absolutely diamond specific. Good laser technology is becoming lower cost and more powerful, however there are still significant engineering challenges. Current applications focused more on its use as a single particle sorter.

- UV sorting
  UV sorting has similar challenges to that of X-Rays in terms of the luminescence it induces from other minerals, as well as the varied signal levels obtained from diamonds. However, it is a low cost technique which has the ability to compete with other optical sorting technologies in the market.

- X-Ray Transmission
  This technique is at its infancy of usage in the diamond industry, and it still has some performance constraints. It has the potential to be highly discriminatory, if some of the current technological challenges can be overcome.

Although the development of these sorting technologies continues, it is important to understand that a sorting machine has other critical components apart from the detection system. These are the materials handling, feed presentation and separation sub-systems. These have seen very little design change over the years with the exception being improvements in the ability to handle both dry and wet feed. It is important that these critical sub-systems work together and are designed to complement each other, to ensure optimum sorting machine performance.

Another challenge facing all emerging technologies is the requirement to develop the required support infrastructure to ensure their successful introduction. These would include laboratory test equipment, standardisation performance procedures and simulants to enable the users to test and optimise the new technologies, without having to use the product which they are intended to identify, namely diamonds.

3. Material characterization

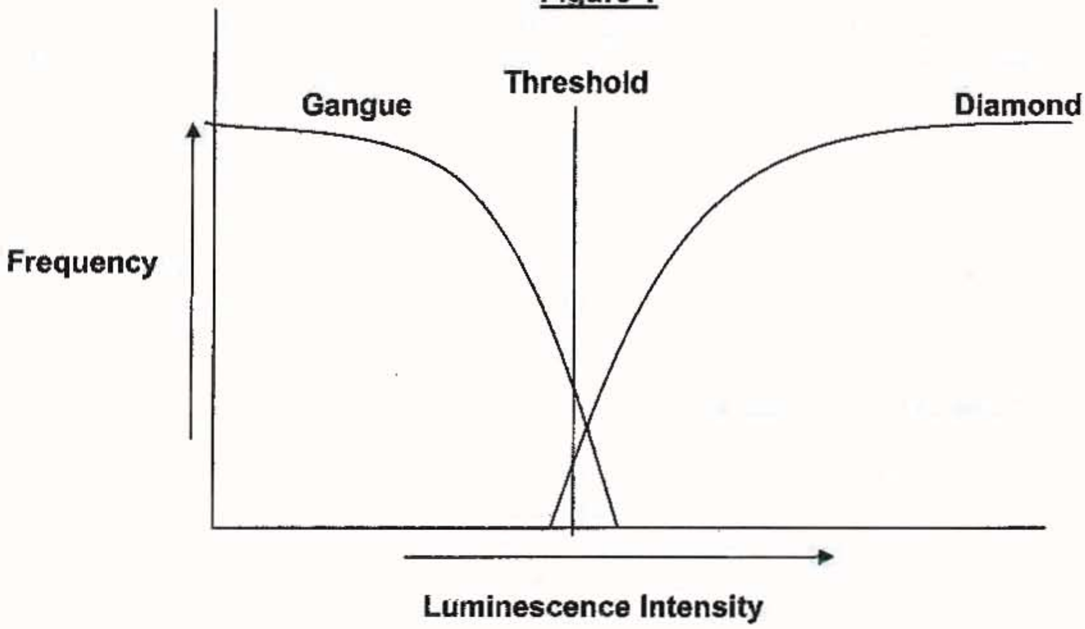
Maximum recovery efficiency is achieved, when the capability of the employed technology is matched to the targeted material property. In comparison with the more mainstream extractive mining activities, most diamond deposits are of such a low grade, that the cost effective collation of information about the diamond characteristics is difficult to obtain. However this information is essential to understand how well the equipment selected in the recovery plant will perform at identifying and separating the diamonds from gangue.

All sorting machines have been designed around technologies that have a certain performance curve when used in a diamond sorting environment. This performance is based on the response of the diamonds and the gangue to that particular technology. However, due to their complex composition, neither diamonds nor gangue have a uniform response when exposed to a particular type of discrimination technology, be it X-Rays or magnetics.

To ensure that the equipment operates at its optimum level, it is imperative that there is a good understanding of the diamonds and the gangue in the orebody. The characterisation should be done with a representative sample of both diamonds and gangue, and must be done in such a way, that the characterisation results can be translated into the operational performance of the equipment used. It is common that two different embodiments of a particular technology might produce significantly different results in a similar setup as a result of differences in the method by which the two machines exploit the technology. This could compromise the interpretation of the results obtained from a characterisation exercise in a laboratory. Currently both X-ray Luminescence intensity (LI) and Magnetic characterisation is done extensively.

- Particle luminescent intensity
  Generation of the LI profile for both diamonds and gangue, as an aide to determining sensitivity settings on X-ray machines. The LI machine is functionally similar to an X-ray machine, and characterises one particle at a time. The output is a luminescent distribution of the two competing species and can be used to set the production machines for the optimum cut point at which diamond recovery is maximised while simultaneously reducing gangue recovery. An example of this is shown in figure 1.

Figure 1

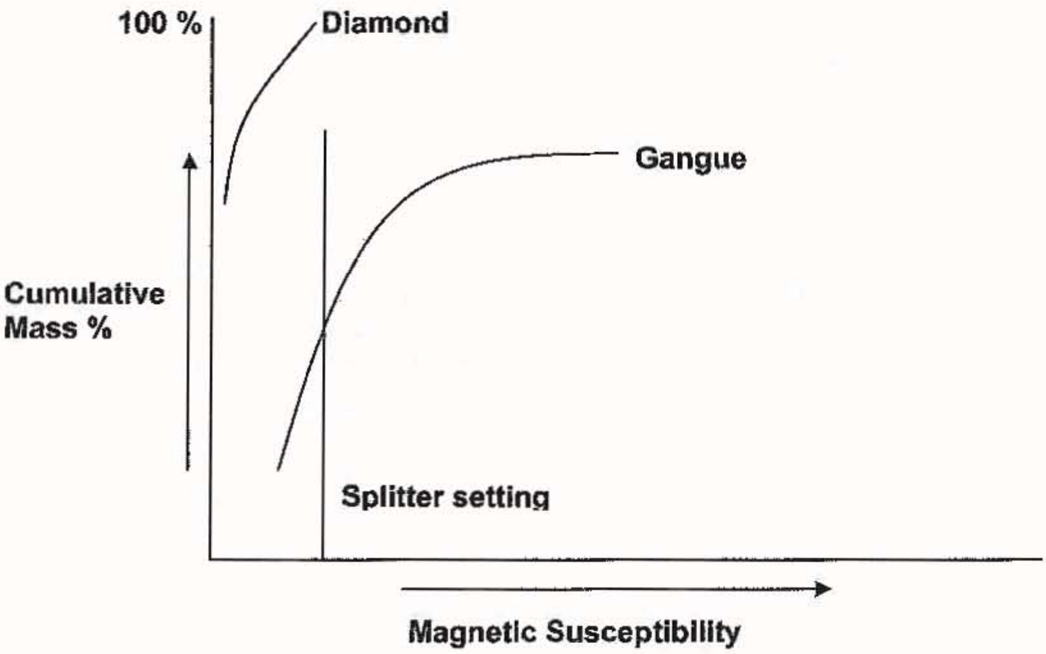


- Dual wavelength
  This is an extension of above, whereby the response of the competing species to X-Rays is measured at two wavelengths (blue and red), allowing for an extra level of discrimination to be applied. The net effect is to increase the difference in the discriminating parameter and decrease the recovery of the gangue species. From the graph above this technology should reduce the intersection area of the two curves.

- Magnetic characterisation:
  Measurement of the magnetic susceptibility is done either at particle level using a Kappa bridge, or by characterising material response to a magnetic separator. The magnetic susceptibility curve of the competing species allows the operator to set the machine for optimum recovery, similar to X-ray machines.

Figure 2 shows a typical Magnetic susceptibility characterisation graph.

Figure 2



The other small but key support technology used in a recovery plant is that of simulants. This is to aid the setup and continuous performance monitoring of the equipment. It is important that these simulants have an identical response to that of diamonds once exposed to the technology to be used. This response needs to be viewed in light of previous comments regarding the embodiment of the particular technology. The response of the simulants needs to be viewed with respect to the design of the particular product, as the response can vary significantly. The availability of reliable and stable luminescence intensity and magnetic tracers; that are matched to the design of a product, has been a key contributor to the success of X-ray and magnetic separation technology in recovery plants.

4. Optimising the Flowsheet

A flowsheet is a two dimensional pictorial representation showing material flow, mass balance, equipment types and process connectors. It is part of the design process and is ultimately transformed into a three dimensional plant. A successful plant is the combination of the best process flowsheet with best physical layout. At design time adequate time should be spent to arrive at the best of both, given that they are interdependent, but not necessarily conflicting.

The diamond recovery plant typically starts with receipt of DMS (dense medium separation) concentrate, and ends with export of diamond filled canisters. The main sub-circuits include sizing, bulk reduction, primary concentration, reconcentration, final sorting and tailings disposal

The first decision to be considered is whether the process will be in the majority dry or wet. Previously, there were significant differences in the performance and type of technology embodiments depending on whether the material was to be treated wet or dry. As described earlier, the majority of those differences have now been overcome with exactly the same products being available in a wet or dry configuration. It is important therefore to determine, through ore dressing studies, the type of material produced by the DMS plant. The other important factor is the throughput required and the size distribution presented to the recovery plant. Again this information needs to be obtained through proper ore dressing studies.

Based on the information obtained the use of bulk reduction equipment can be determined. The key question is whether the material is amenable to the bulk reduction technology to be used, and that reduction having a material impact on the capital and operating costs of the plant. Typically, magnetic separation is used and therefore it is important to have a good understanding of the magnetic susceptibility characteristics of the diamonds and gangue, prior to the design and construction of the plant. The current availability of wet and dry MagRolls allows for the use of a combination of BaFe and NdFe based magnetic separators, which offer the best performance.

The primary recovery process is mostly accomplished using electronic sorting based on X-ray technology to affect maximum diamond recovery. A common circuit design consists of a two pass operation where the tailings stream from the first machine reports to the second machine, and the concentrate of both machines report to a reconcentrate machine. Understanding of material properties provides the opportunity to set up the machines in such a way, as to optimise overall diamond recovery efficiencies rather that optimise the machines individually, which might compromise the overall performance of the plant. This optimisation involves balancing the individual machine recovery efficiency and yield.

Furthermore, depending on the particular characteristics of the material, it may be beneficial to introduce a different technology in either the second pass or the reconcentrate stage. This can only be successfully achieved if the diamond response to this technology is not in conflict with the response from the X-ray technology. Otherwise the overall recovery efficiency will be compromised. Again the proper characterisation of the material to be sorted by any technology is crucial, so that the combination of technologies to be used is correct, as well as the configuration of the implementation.

The final sorting of the product is mostly done by hand sorting. Currently there are a number of operations that use single particle sorters based on laser Raman technology and complement this with hand sorting to defalsify the concentrate. The requirement for the successful implementation of this process is to identify the technology that produces the highest recovery with the minimum yield for the particular characteristics of the diamonds in the ore body.

5. Way forward, the future optimum flowsheet

The optimum plant is a combination of the best technical flowsheet and layout architecture. The importance of other drivers such as security, utilities availability, and plant economics is recognized, however, the focus is on the benefits of improving plant architecture. To date recovery plant architecture has been characterised either by capital intensive superstructures, or small mobile containerised plants. What is proposed for the future is a hybrid model separating the feed preparation unit processes (sizing, drying, magnetic reduction and bulk storage) into one space, radiating out to small modular plants.

The modular plants will be characterised by a high degree of flexibility, but more importantly the ability to increase or decrease capacity at minimum capital cost. They will be connected by common utility and transport lines as necessary, while being able to also operate independently when the situation arises. More importantly within each modular plant, the specific flowsheet will be optimised to suit that size fraction in terms of technologies and product output (maximum efficiency or maximum product grade). The internal modular layout is independently optimised, with minimum cross over impact. Current superstructure layouts do not offer such flexibility.

Figures 3, 4 illustrate this hybrid principle that combines the benefits of current plant layout philosophies. The first step in the quest for the ultimate recovery plant.

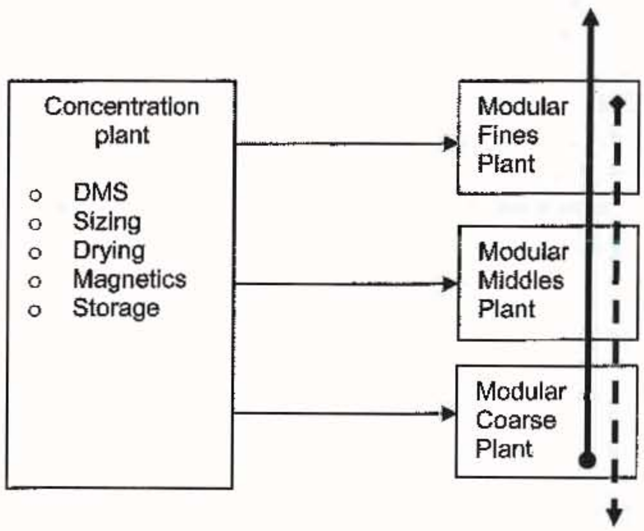


Figure 3 – Common destinations hybrid plant layout

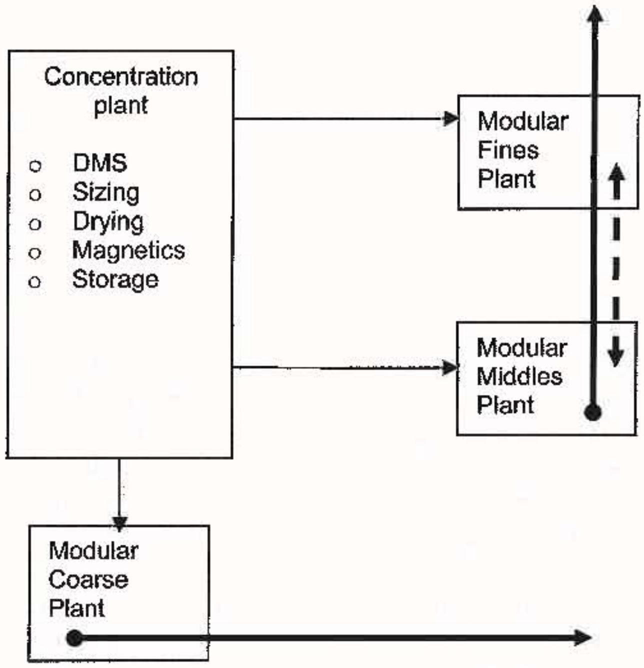


Figure 4 – Hybrid plant layout with separate destinations

6. Conclusion

There have been a number of important developments in technologies used in the recovery process of diamonds. Some of these technologies offer significant advantages in terms of cost and performance. However it is important to note that for those advantages to be realised there has to be a good characterisation exercise to understand the response of both the diamonds and gangue to the particular technologies to be used. It is also crucial that the characterisation is done with a good understanding of the configuration and embodiment of the technologies to be used, so that the conclusions drawn from the characterisation exercise are applicable the final embodiment or actual machine chosen. Once the plant has been built the monitoring and testing tools such as audit processes and simulants / tracers need to be available and used as recommended, to ensure the continuous sustainable performance of the recovery plant.

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