FINSCH MINE TREATMENT PLANT UPGRADE PROJECT

D Olivier, F. Bornman, Bateman Engineering Projects
L Roode, A Acker, Finsch Mine, De Beers Consolidated Mines Ltd

Abstract

De Beers' Finsch Mine is situated in the Northern Cape province, 170 km northwest of Kimberley. The concentrator facility, designed and constructed by Bateman Engineering, was commissioned in 1967 and upgraded in 1979 using diamond liberation and extraction technology available at the time of design.

Since then significant advances in diamond processing and technology have been made and these have been incorporated into the new main treatment plant and recovery plant flowsheets, making diamond liberation and recovery from the Pre-1979 dumps a viable economic option at Finsch."

Significant challenges were experienced as a result of the integration of new technology and its associated infrastructure into an existing plant. Major process flow changes were implemented during the execution phase of the project. The combined effect of these issues resulted in the project being overspent by 25% and the final handover to the Client was some 18 months later than originally planned."

The paper highlights some of the difficulties experienced as a result of changes made during the execution phases of the project.

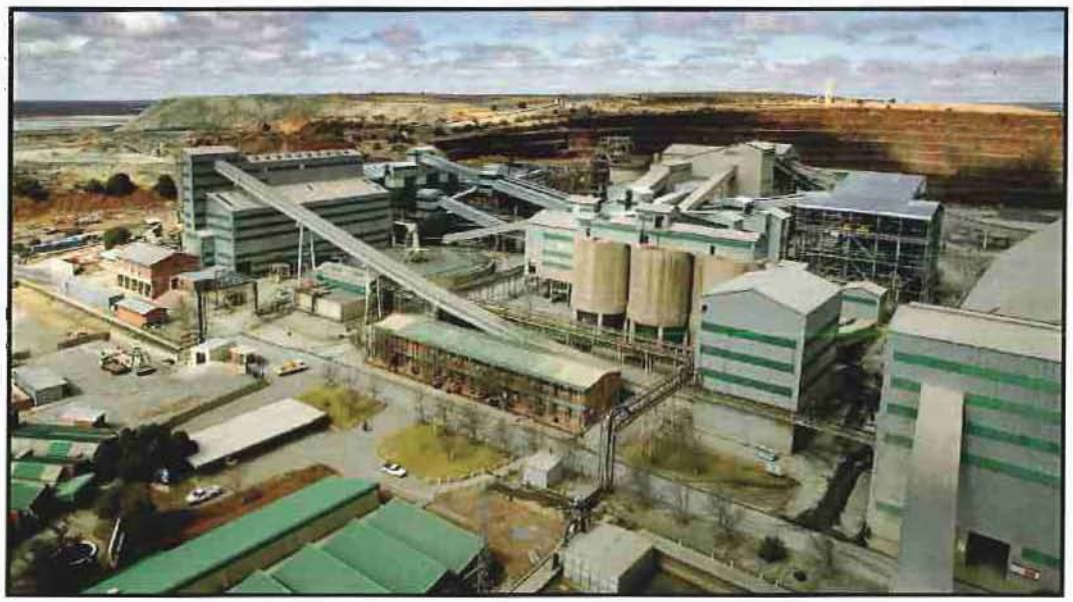


Figure 1: The upgraded Finsch Mine Treatment Plant, Northern Cape, South Africa

1.0 Introduction

The Finsch Mine Treatment Plant Upgrade (FMTPU) project was completed by Bateman Engineering in 2008 for De Beers Consolidated Mines. The project had the objective of improving overall diamond recovery efficiency as well as improving the value of the diamonds recovered by implementing available "diamond friendly" liberation processes that reduce diamond damage. In addition, the capacity of the main plant had to be increased to make provision for higher Pre-1979 wet infield screening treatment rates.

As a result of the upgrade, the feed rate from various feed sources to the plant was increased from 960t/h to a maximum of 1260t/h and the capacity of the plant was increased by approximately 25% to process an additional 1.4 million tons per year of tailings material. This means an increase in plant capacity from 5.8 million tons per year to 7.2 million tons per year.

Bateman Engineering completed the feasibility study in 2004. The contract was awarded in 2005 under a hybrid-partnering agreement, with Bateman Engineering being responsible for the design, construction and commissioning of the upgraded facility.

2.0 Main Treatment Plant

2.1 Old Process

Run-Of-Mine ore from underground was crushed on the surface and stockpiled. Ore was then scrubbed, screened and the oversize was crushed in closed circuit secondary crushing. The plant feed was processed by eight DMS modules. The DMS floats were screened at 8mm. The +8mm fraction material was then processed in a re-crush circuit using four rod mills. The DMS concentrate reported to a recovery plant which utilised magnetic separation and proprietary De Beers X-ray equipment.

2.2 Upgraded Process

The ROM ore is crushed, stockpiled, scrubbed and screened. Oversize material is crushed in closed circuit secondary crushing and transferred to the feed separation section. Here material is sized into fine and coarse fractions prior to processing in a split fines and coarse DMS.
The coarse DMS floats proceed to the re-crush plant using High Pressure Roll Crushers (HPRC). The HPRC product passes through a secondary scrubbing stage after which fines are removed and also split between the course and fines DMS. The concentrate from both the fines and coarse DMS reports to the Recovery Plant.

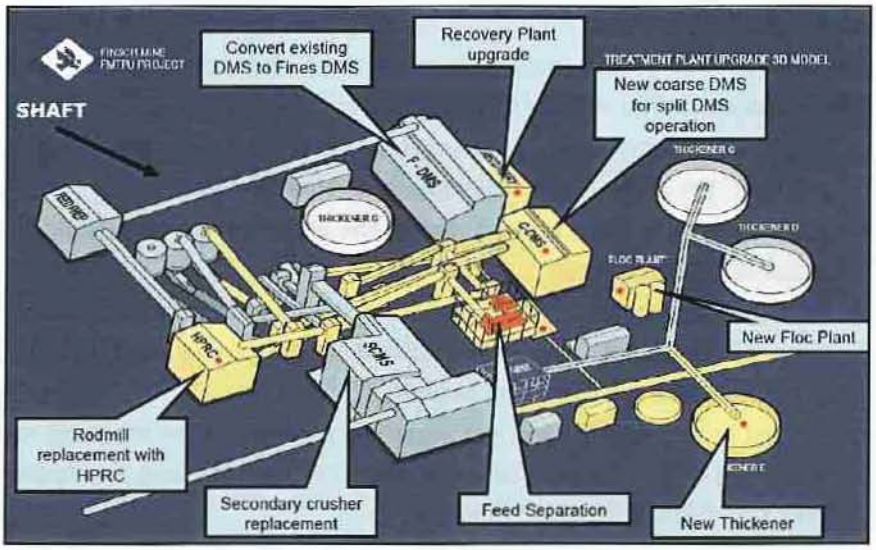


Figure 2: The overview of Finsch Upgraded Process Plant (L. Roode, 2 Sept. 2008)

2.3 New Technologies

2.3.1 HPRC

For some time prior to the commencement of the FMTPU project in 2005, it was established that the process of rod milling in a re-crush application resulted in diamond breakage. Trade-off studies were conducted to evaluate the viability of using a High Pressure Cone Crusher, but proved to be unfeasible. A more diamond-friendly process based on High Pressure Roll Crushing was therefore incorporated into the upgraded flowsheet during the subsequent study phases. This was new technology to Finsch Mine, but had been proven at Venetia Mine and other mines.

Two Polysius studded rolls Polycom 17/12-4 HPRC's were installed to replace four Rod Mills.

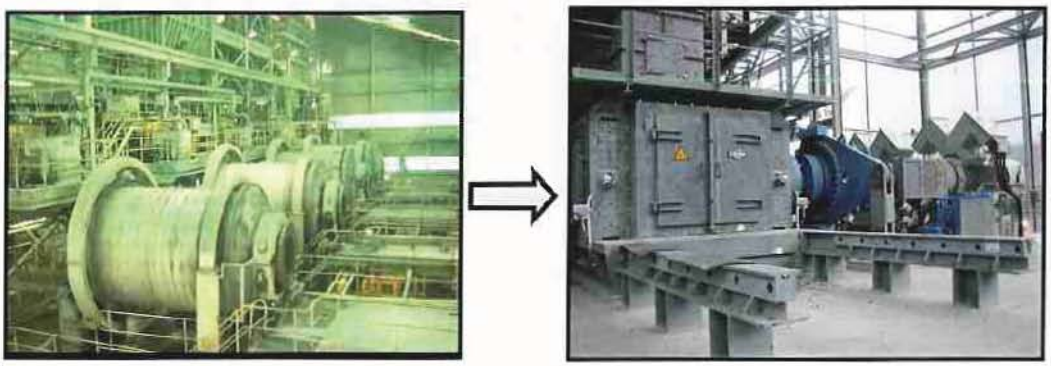


Figure 3: Four Rod Mills replaced by two High Pressure Rolls Crushers (L. Roode, 2 Sept. 2008)

The following challenges were experienced during commissioning of the HPRC's and were dealt with by the project commissioning team, the mine operations team and Polysius, the vendor supplier of the HPRC equipment:

- Machine capacity was 530t/h against an average feedrate of 320t/h – the problem was resolved by adjusting the feed inlet chute.
- High wear rates were experienced in the feed hopper – deflector plates were installed in order to reduce wear.
- Roll skewing occurred due to the drive shaft and non-drive shaft operating at different pressures - this was rectified by correcting the Nitrogen pressure and optimising the operating system.
- A high re-circulating load was experienced due to poor crushing resulting in excessive plant delays - this was rectified by adjusting the operating gap, rolls speed and feed chute opening.

After optimization of the HPRC's, the following benefits were witnessed:

- Improved production reliability, less maintenance, fully automated and better steady state operation.
- Improved diamond liberation efficiency and reduced breakage. The percentage passing -1mm in the product increased from an average of 24% to about 30% with occasional peaks at 38%.

Figure 4 below indicates the decrease in diamond breakage after the installation of the HPRC from the 16th July 2007.

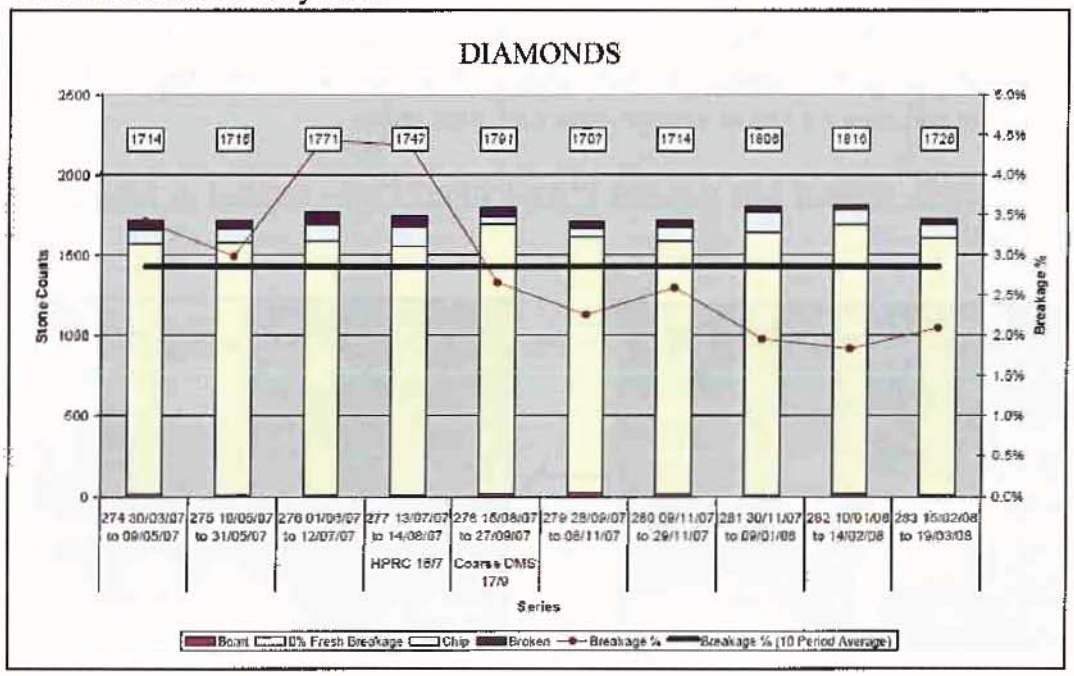


Figure 4: Bar chart indicating the diamond liberation efficiency and reduced diamond breakage (L. Roode, 2 Sept. 2008)

2.3.2 Split DMS

During the study phases of the project, an analysis was done by De Beers using the Diamond Wizard Simulation Model and it was established that for Finsch Mine, a better DMS separation and concentration efficiency will be achieved by splitting the DMS into fines and coarse fractions. The existing DMS plant was changed into a Fines DMS consisting of eight modules each using 2 x 420mm cyclones and an optimised DMS circuit. The Coarse DMS plant consists of three modules, each using 4 x 510mm cyclones with a maximum design throughput capacity of 250t/h.

The feed separation section was installed in order to achieve sizing and splitting of the feed to both DMS plants and to remove -1.4mm material to tailings. Two of the existing silos were dedicated for Fines DMS feed storage and the other silo for Coarse DMS feed storage.

Figure 5: Scrubbers and Sizing Screens in the Feed Separation Section

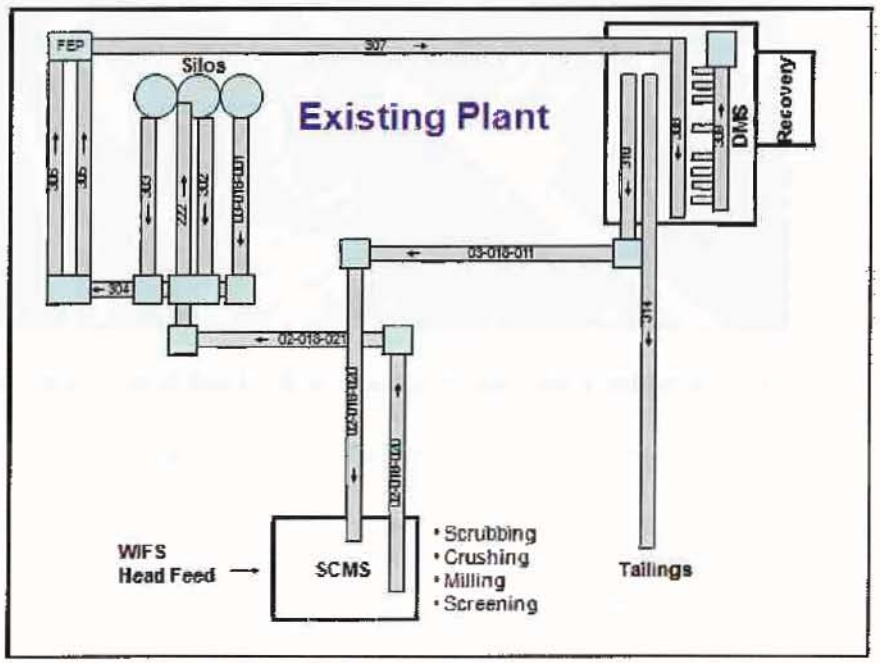
The following challenges were experienced during the DMS upgrade:

- New conveyor belts systems were erected below and above the existing ones, creating a complex maze of steelwork and concrete. Figure 6 illustrates the existing and upgraded plant layout and indicates the complexity of the brownfields upgrade.
- The Coarse DMS was a bespoke design with specific requirements that the concentrate had to be discharged onto an existing conveyor feeding the recovery plant.
- The mixing boxes in the Fines DMS were replaced and new distribution boxes installed to lower the feed pressure to the 420mm cyclones from 21D to 15D.

- The old double deck screens in the Fines DMS were replaced with single deck screens.
- An optimised control and instrumentation system was installed on the existing and new plant sections; this resulted in stabilised plant operations.
- Two thickeners were demolished in order to provide space for the erection of the new Coarse DMS plant.
- The two existing thickeners were then replaced by one new thickener. It was anticipated that the headfeed could contain more fines, mainly due to the re-treatment of weathered Pre-1979 tailings.
- A new flocculant plant was erected to serve the three thickeners.

Challenges post the optimisation phase were:

- Material flow problems through the Coarse DMS silo and chute blockages between the silo and Coarse DMS which was not anticipated during the design phase.
- High wear rates on the majority of transfer chutes.
- Feed Separation Plant efficiency and mid cut-off size optimisation initiatives were carried out.
- Optimisation of control systems to ensure steady state feed conditions from two sources.



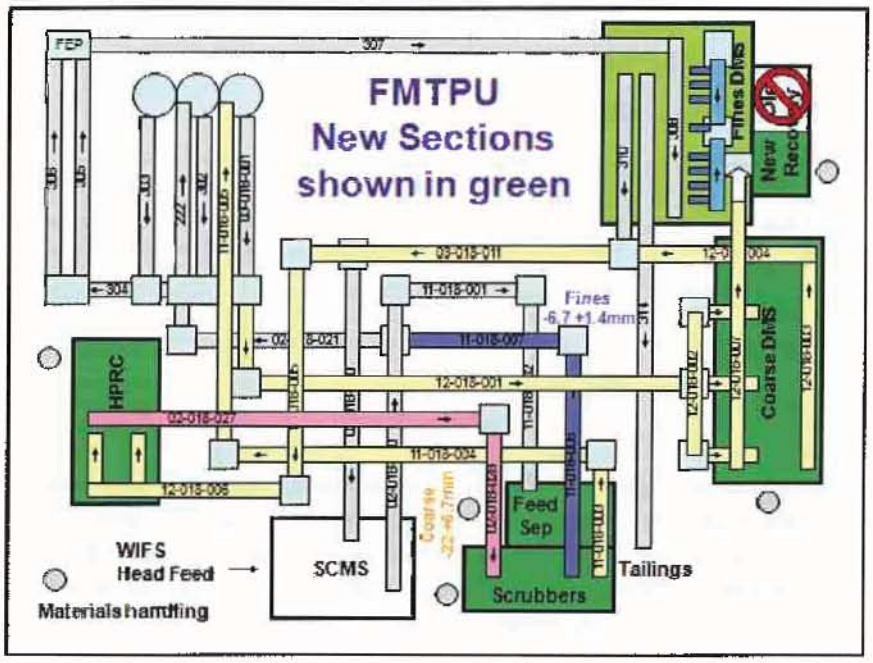


Figure 6: The schematic showing the existing and upgraded plant layout (L. Roode, 2 Sept. 2008)

3.0 Recovery Plant

3.1 Old Process

The DMS concentrate reported to storage bins in the recovery plant, from where it passed through magnetic separators to remove the magnetic contaminants such as Banded-Iron-stone in the DMS concentrate, followed by De Beers X-ray machines.

3.2 New Process

A new recovery plant was designed in order to:

- Increase capacity because the existing recovery throughput was limited to 5t/h and was not able to treat the anticipated design capacity of 10t/h.
- Improve recovery efficiency with new generation sorting equipment as existing equipment was old and became redundant.

The upgraded recovery was required to be constructed within an existing building. There were major challenges due to space constraints with respect to maintenance and operator access. The sorthouse design was improved to take cognisance of security, operational and maintenance requirements.

Although the Recovery Process Design Criteria as well as the Process Flow Diagrams were approved by all stakeholders at the end of the feasibility study, various changes were implemented in the execution phase of the project due to the client changing the

design philosophy and specifying different technology and equipment. In summary the following major changes were made:

Table 1: Summary of changes made during the Execution Phase

Item	Feasibility Study	Execution
Drier	1 x Pneumodrier	2 x Jones Driers
Bins	30	45
Feeders	27	48
Bucket Elevators	None	6
Diverters	8	28

During the feasibility study different pneumodrier options and routings were investigated and a decision was made to install one pneumodrier line. Various layout options were investigated with the option of a four bend pneumodrier line as the preferred option due to the simplicity of the systems and a few pieces of equipment. The study allowed for the recovery plant roof to be raised to ensure that all material is gravity fed through the recovery.

However, during the execution phase, the client raised concerns regarding costs and potential diamond damage and the approved design was changed to allow for the inclusion of Jones drier technology rather than using the pneumodrier. Further, the concept of raising the Recovery Plant roof was considered to be a security risk.
The preferred Jones drier option included an additional recovery feed bin and screen, two Jones driers, five additional tube feeders and four bucket elevators.

3.3 Technologies

New technology equipment installed was as follows:

- Double stage belted Rare Earth Drum Separator (REDS) machines
- New generation De Beers proprietary X-ray machines
- Raven single particle sorting machines
- Automatic audit facility (Audit optical sorter)
- Metal removal unit
- Vacuum conveying system

3.3.1 Belted Rare Earth Drum Separator machines (REDS)

Belted-REDS machines were installed to efficiently remove the magnetic contaminants in the Recovery Plant feed. The new two-stage REDS machines were more efficient that the old one-stage machines.

The design for the sizing screen and REDS remained the same as the approved feasibility design. Two tube feeders were added to feed the REDS due to layout constraints. Four splitters were added prior to the REDS to distribute the material evenly into the REDS.

3.3.2 De Beers Proprietary X-ray Machines

The sizing of the recovery plant feed into fractions is aimed at eliminating masking and increasing diamond recovery efficiencies in all size fractions.

The fines and middles size fractions are treated through CDX116CD X-ray machines through a first pass, scavenging and re-concentration step. The coarse feed fraction is treated through one stage CDX113C X-Ray machine due to higher efficiencies in recovering larger diamonds.

The number of X-ray machines as well as the X-ray configuration remained the same in execution phase. The additional future stream was removed from the Process Flow Diagram subsequent to the recovery changes and REDS testwork. One additional tube feeder was also added as a result of layout constraints.

Three diverters were added subsequent to the re-concentration X-ray machines to enable the bypass of the Raven machines, should it be required.

3.3.3 Raven

The X-ray concentrate is treated through the Raven machines which perform a primary sort before final hand sorting.

Two diverters were added to bypass the checksort gloveboxes, if required, and one diverter was added to distribute the optical sorter concentrate to different bins for metallurgical accounting purposes. One glovebox feed bin was added. A sorthouse transportation system with canisters was added to automatically convey diamonds in the export glovebox.

3.3.4 Audit Optical Sorter

The optical sorter was included in the feasibility study for the scavenging of high risk tailings streams such as the coarse primary X-ray machine tailings, re-concentration X-ray machines tailings, sorthouse tailings and contaminant removal unit tailings.

Subsequent to the feasibility study, a facility was included to audit REDS tailings as well as X-ray tailings. Seven diverters, a bin and two tube feeders were added to the flowsheet to enable auditing of the REDS tailings as well as the Secondary X-ray machine tailings. Two additional sorter feed bins were also added for metallurgical purposes as well as one tube feeder to convey the optical sorter concentrate to the sorthouse.

3.3.5 Metal Removal Unit

The purpose of the metal removal unit is to remove tramp metal still reporting to the recovery section. The unit is designed to treat both fines and coarse fractions simultaneously.
Two dry storage bins (30 tons fines and 30 tons coarse) were added after drying prior to the metal removal unit and sizing screen in the execution phase of the project.

The metal removal unit was installed subsequent to the REDS in the previous phase of the project for the following reasons:

- Feedrates would have been reduced by 75% subsequent to the REDS units. The yields would have therefore been much lower. The contaminant removal unit would not treat coarse material.

In addition to the metal removal unit's new position, two storage bins, two bucket elevators and six feeders were added.

3.3.6 Vacuum Conveying Systems

The transportation of tailings or spillage (normally in small quantities) of particulate material within the Recovery Plant requires safe handling and diamonds security. The vacuum conveying systems were installed to safely transport spillage from all the points across the recovery plant as well as X-ray machine re-concentration and sorthouse tailings. The system provides the opportunity for tailings to be check-sorted.

The dust extraction system changed when a bag filter dust removal system was selected during execution rather than the dust scrubber system that was designed and costed during feasibility.

3.3.7 Tailings

A change in the Recovery tailings disposal from a dedicated recovery tailings stockpile to a re-circulation system was motivated by the client based on practicality, construction and NPV considerations. Two diverters were added to divert tailings to the HPRC and plant tailings dump. An additional tailings bin and feeder were added for the optical sorter tailings in order to separate optical sorter tailings containing metal contaminants from recovery tailings.

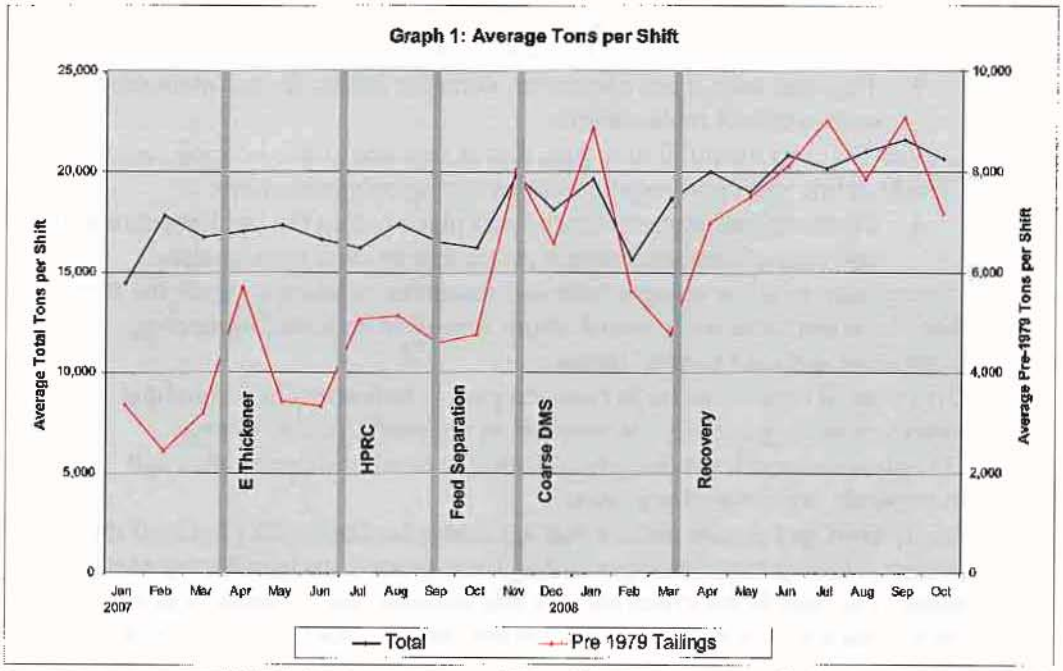
4.0 FMTPU Integration

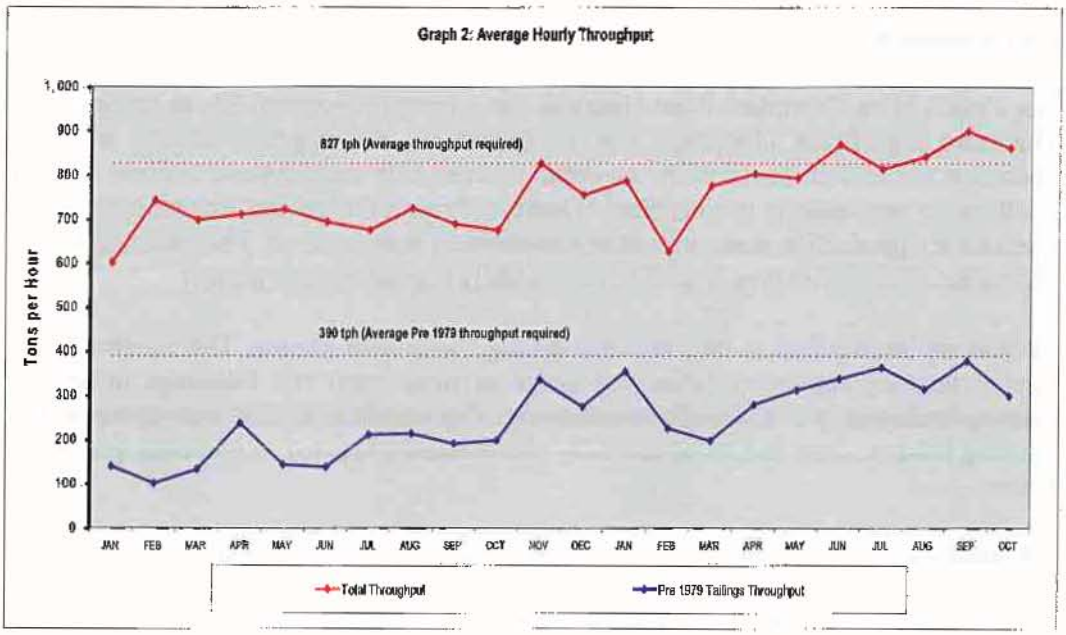
Integrating of new sections into the existing plant circuits and commissioning proved to be challenging amidst production goals that still needed to be achieved. Adding to this challenge was the continued operational and maintenance requirements of the existing plant sections which had to be balanced with training and familiarisation of staff in preparation for the transfer of responsibility.
This was achieved through proper planning and commitment from the project and operation teams.

4.1 Production Build-up

Graph 1 illustrates the production build-up that was achieved. An average of 20 500 tons per day (Run Of Mine and Pre-1979 tailings material) was achieved after the new recovery plant was commissioned, an improvement of 19% on daily throughput. Pre-1979 tailings throughput increased from an average of 5000 tons per day to 7 900 tons per day.

Graph 2 depicts the average hourly throughput for the Total and Pre-1979 tailings. The improvement in throughout was incremental and came about as various optimisation initiatives were completed, together with an improvement of the plant utilisation as operational and maintenance personnel became more familiar with the new processes.





5.0 Considerations for Brownfield Projects

1. Involve front line teams from concept phase through to implementation phase of the project.

   a. Change management is essential to ensure smooth transition of responsibility.
   b. Have front line teams represented on Operational Readiness Team.
2. As far as possible incorporate front-line team's recommendations into design and have designs audited.
   a. Audit and evaluate chute designs, liner specifications, material flow and material characteristics to identify problem areas before implementation.
   b. Together with front-line teams, consider access for maintenance, e.g. conveyor belt replacements.
3. Standardizations essential to reduce spares cost and stores holding requirements.
4. Clearly define roles and responsibilities during commissioning:
   a. Contracts and agreements to be in place before the implementation phase and sign-off and acceptance process to be clear to all parties.
5. Project team to allow enough time and resources to address punch list items.
6. Keep core team and try to avoid labour turn-over on both Engineering Contractor and the Owners' teams.
7. Give careful consideration to ramp-up plan commitment as throughput improvement is generally incremental as opposed to a step change.
8. Do not over complicate designs and stick to good basic principles and incorporate *proven* best practises.
9. Apply clear and agreed change management practices in all phases of the project. Making major changes to approved process designs during execution phases has significant effect on cost and schedule and effectively moves the project back to feasibility phase. This has major impact on project risk.

6.0 Conclusion

The Finsch Mine Treatment Plant Upgrade was a complex brownfields upgrade project. The most significant challenge was to implement the upgrade project while the operation remains in production. In order to meet this requirement, a close working relationship between the project team (Owners' Project Office and Engineering Design Contractor), production team and other stakeholders was required. The planning and co-ordination of activities was crucial to successfully implement this project.

Several difficulties had to be overcome during the project phases. The construction of steel structures, conveyors (over and under existing ones) and buildings in between existing buildings was especially challenging. The interface of new conveyors into the existing infrastructure had to be carefully planned and executed to minimise production losses.

7.0 References

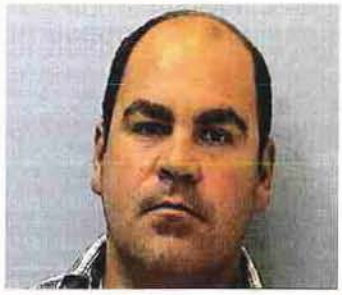
1. L. Roode, Finsch Mine Treatment Plant Upgrade, Installation of High Pressure Grinding Mills, 2 September 2008.
2. W. Hoffmann, Finsch Mine Treatment Plant Upgrade Project, Recovery Upgrade (M7110), Process Execution Report, Document No. M7110-P720-001, 2007.

3. W. Hoffmann, Finsch Mine Treatment Plant Upgrade Project, Recovery Upgrade (M7110), Process Design Strategy, Document No. BAM7110-P370-002, 2005.
4. Bateman Project Profile, Finsch Mine Treatment Plant Upgrade Project, 2008.

The Authors

Darrell Olivier, *General Manager*, Bateman Engineering Projects

Darrell commenced his career in the gold mining industry where he spent 11 years in production before moving to diamonds when he joined the De Beers Research Labs or DebTech in 1997. In 2004, after spending almost 7 years with De Beers, including 2 years with De Beers Marine, and a short spell in offshore marine mining operations, he joined Bateman Engineering Projects. Since then Bateman has completed a number of diamond projects including the Venetia Primary Crusher Project, the Finsch Main Treatment Plant Upgrade Project, the SASA Marine Mining Vessel Project for De Beers Marine, Damtshaa Double-up Project, and the Letseng No 2 Plant Project. Darrell is currently General Manager in the Process Engineering Department of the Sub-Saharan Africa business unit of Bateman Engineering Projects.



Anton Acker, *Ore Processing Section Leader – Production*, De Beers Consolidated Mines – Finsch Mine

Anton started his career in the gold mining industry in 1995. After spending a year at Randfontein Estates Gold Mine - Doornkop plant, he was transferred to the Consolidated Murchison antimony and gold mine where he was involved in production and commissioning of the plant expansion project.

In 1998 Anton joined De Beers Namaqualand Mines where he was involved in various projects and production in the Buffels Marine, Buffels Inland and Koingnaas mining complexes. He joined De Beers Finsch Mine at the end of 2006 as a Production Section Leader responsible for the Ore Receiving and Preparation section, and the Pre-1979 mining and treatment operation. During the time he was involved in the FMTPU project mainly from a commissioning, integration and operational readiness perspective.