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Financial evaluation of electric rock drills for in-stope mining in platinum operations

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Financial evaluation is necessary to investigate the viability of implementing and/or utilising new technology in mining projects. It establishes a techno-economic base for decision-making and justifies capital expenditure.

This paper aims to present a monetary appraisal of the electric rock drilling system in a typical feasibility project, whose purpose is to increase the production rate. The *in situ* environment is a platinum orebody, and the stoping operations occur in UG2 reef. The results are a function of production requirements, technical parameters and financial outlay of the drills.

The costs involved in implementing and operating electric rock drills are assessed to the current method of drilling, namely the compressed air operation. A comparison of the electric and pneumatic rock drills in terms of financial outlays for drilling and service requirements, peripheral equipping and training is discussed.

Other factors that affect the business case are technical advantages, safety and risk management and the environmental objective of the company.

Introduction

Current small- and large-scale mining projects focus on expansion or ongoing capital activities, expenditure to improve safety, health and environment, and financial outlay to reduce risk. Consequently, the present purpose of the majority of desktop to feasibility studies is to investigate the viability of increasing the production rate of existing operations, to include all these activities, simultaneously.

The opportunity has risen to investigate alternate drilling methods for mining projects aimed at expanding production or replacing tonnage. The main requirements of these projects include determining the capital for the drilling equipment, and the costs incurred during the life of the project. Other prerequisites involve reducing or eliminating expenses as a result of detrimental operational factors. These include health conditions experienced by rock drill operators (RDO) and negative consequences to the environment.

The existing and conventional rock drilling methods achieve production levels that are dependent on the supply and condition of compressed air reticulation systems. The efficiency of the pneumatic drills is reduced as more remote stopes are brought into production. Problems with excessive air losses, due to leaking air columns and poor maintenance, render future operations less successful and lessen profitable.

The strategic business plan (SBP)[3] driven by senior executives in Anglo Platinum includes technology that is consistent with the concept of 'fit for future' (FFF). A drilling system that is independent of air supply, namely electric rock drills, is being tested and implemented at its various mining operations.

Scope of case study

In this typical case study, it is proposed to increase the production rate of UG2 from 20 ktpm to a steady-state rate of 130 ktpm. The present mine establishment consists of a decline shaft system and supporting surface infrastructure. The project is labelled 'greenfields', meaning that production is being expanded in a new reserve block.

The in-stope panels will be mined with electric rock drills. The targeted tonnage requires full production from five levels, below the return airway (RAW). The drill requirements on the half-levels are assessed from the identified production outputs.

Mining environment, layout and method

The unique geological factors of the tabular orebody and the reserve estimate are considered in developing this mining scenario. A UG2 band with an average thickness of one metre, including the leader seam is allowed for. The main reef is a chromitite seam with mostly widely spaced shallow dipping curved joints. Blocky conditions, dykes and bedding faults also occur within this layer. The footwall is undulating, but has a variation of less than one metre.

The mining method and length of stable production spans is chosen from quasi-static and dynamic loading conditions. Since mining is to take place at shallow depths, a high k-ratio, greater than unity, is selected to cater for the extent of the tensile zone in the immediate hangingwall of the stope[1] and layered thrust faults. Consequently, the planned method of mining is conventional breast/dip mining. Support takes place with room and pillar operations. Footwall development is included.

The mining layout consists of breast panels, 31 m wide, stoped from predeveloped raises spaced 210 m apart, as shown in Figure 1. Individual panels are separated by 4 m by 8 m inter–panel pillars with 2 m holings. The panels are cleaned into boxholes emptying into cross-cuts at each level. Stability pillars with a width:height ratio of ten are required when a depth of 200 m below surface. These pillars take over the regional support function from the interpanel pillars, as the factor of safety reduces.

Production parameters and schedule

The average stoping panel lengths is set up to suit 35 m gully centres. A working face length of 31 m is available, when measured between the pillars (skin to skin maximum span). The design makes provision for a change in the dip of the reef (15 degrees) which alters the back length. This variance is taken up on the panel traversing the cross-cut access and travelling way area.

A geological loss of 19% is assumed due to potholes, faults, dykes and replacement pegmatite. The UG2 rock properties and the mining dimensions at the stope panels are presented in Table I.

From this mine design criteria, raise line lengths of 245 m require three stoping crews active in a standard block of fourteen panels maximum. The mining schedule indicating production time dictates the production pattern to reach the required tonnages, and is shown in Table II.

The the in-stope drilling configuration and requirements to maintain the 130 ktpm are presented in Table III.

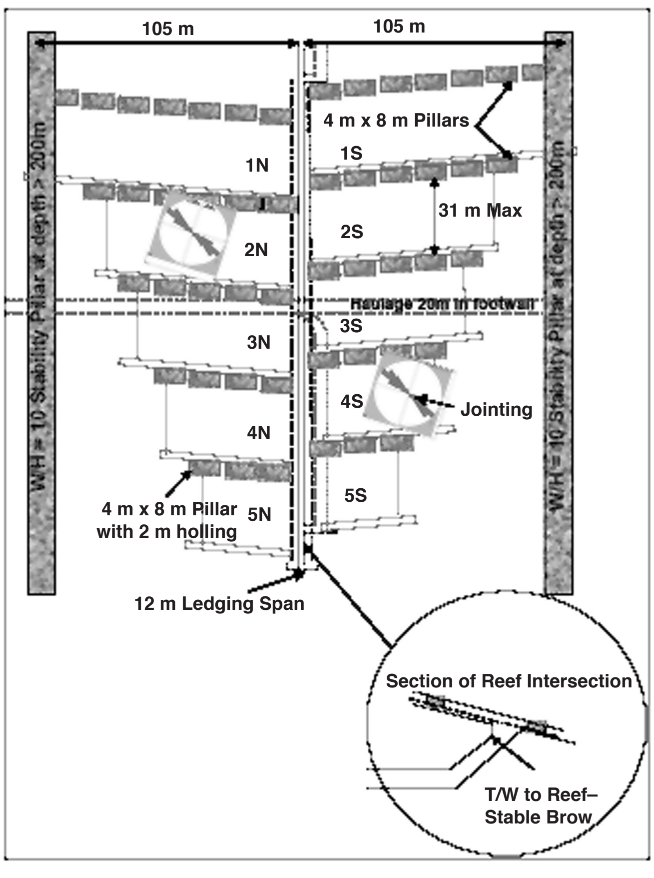

Figure 1. Schematic plan of proposed mining layout with dimensions[1]

Financial evaluation of the electric rock drill

The primary objective of the implementation of electric rock drills is to improve the drilling cycle in terms of safety, eliminate dependence on compressed air and reduce the costs in operating and maintaining the drilling equipment.

Business case

This case study uses a typical shaft that has the ability to increase production, without the installation of a surface compressed air station. The business case is based on drilling operational data, namely:

- Life cycle cost of rock drills
- Maintenance procedures
- Component replacements
- Energy consumption
- Training
- Implementation.

A cost analysis model is developed to determine the overall capital and operational expenditures for the electric rock drills. The results are compared to those for establishing infrastructure for pneumatic drilling operations.

Table I
Average stoping panel

Average stoping panel	Ore	Ore bulk density	Stope length	Stoping height	Drills per panel	Face advance
	UG2	4.08 t/m^3	31 m	920 mm	3 drills	1.05 m

Table II
Production schedule

Production days in one month	23 days
Number of drilling shifts	1 shift/day
Shift duration	8.0 hours/shift
Effective work time	6.25 hours/shift
Working efficiency	78.1%
Electric drill availability	100%
Annual programme	52 weeks/year
Shifts programmed	260 shifts/year
Shifts lost (assumed)	30 shift/year
Available shifts	230 shifts/year

Table III
In-stope and mine production parameters

Distance per holes on horizontal	1.0 metre
Distance per holes on vertical	0.7 metre
Number of rows	2
Number of columns	62
Drilled holes per face	124
Hole length drilled	1.05 metre
Rock drill operator (RDO)	Trained
Average drilling time	5 min 35 sec
Number of levels	4.5
Half levels per level	2
Raise lines	2
Number of panels	14

Throughout the study, some operational parameters must be assumed, and others are aligned to ensure an acceptable degree of comparison can be made. Generalizations for life cycle costing include:

- The physical drilling time per shift per drill
- Operational results are based on the same geology and reef type
- Electricity tariffs are charged on day shift/on-peak rates
- Logistics are matching
- All pneumatic rock drills are purchased
- All electric rock drills are leased
- Costs will be divided into fixed and variable items
- Costs for compressed air includes air required for pre-stressed supports, Anfex loaders, timber chain saws, refuge chambers and gulley pumps
- Base-dated costs are sourced from recent information available from feasibility studies, and equipment suppliers.

Quantification of stope panels and rock drills

The number of drills required for any 'greenfields', or replacement/expansion project is obtained from the mine plan or mine design criteria, respectively. The parameters are a function of the production tonnage to be mined monthly/yearly. This is quantified by the number of panels to be mined monthly, for both development and mining activities. Typically, three paired panels per stope are in the full production phase. In this exercise, it has been decided to equip four raises on five levels.

Consequently, the number of drills required is calculated for the dimension of the panel. For platinum operations, on average, each panel includes a minimum of three drills per stope. A total of 756 drills is calculated. The pneumatic drills currently used on the mine are the muffled SECO S215 for stoping. The electric drill is a 250 rpm, 240 V, with 2.2 kW power input.

Costing

Capital cost

The capital cost of the pneumatic drills is a function of the surface compressors and includes the compressor station and cooling towers, civil and structural costs, electrical infrastructure, piping underground and the drill costs. This is an upfront cost of R44 milllion, but may increase as more remote stoping operations are reached.

For electric drills, a total capital cost of R21 million is calculated. The capital cost includes equipping the stopes on all working levels, with some modifications of the surface electrical infrastructure, minor alterations to gully boxes, inclusion of small-scale compressors and some compressed air piping underground (for ventilation and refuge chambers).

A single-phase reticulation system is priced instead of three-phase reticulation system, because of its lower cost. Furthermore, no more than twelve drills are operational per raise at any one time. The cost is approximately R17 000 per panel or R4 250 per drill[2]. In November 2004, the capital cost for a three-phase power system for 18 drills was ±R205 000 or R68 000 per panel (R11 389 per drill)[2].

Extra minor costs are incurred to establish a workshop/store for the leased units. The storage space can be anything from a disused cubby to the underground workshop storeroom. Options to replace the need for compressed air (timber chain saw, pod intensifier, gulley pumps, hoist and Anfex loader) is considered in this study by including costs for small-sized rotary screw compressors.

Electric cost

The variation in power rating of the operating machines has a significant impact on consumption costs. The pneumatic drills are rated at a total compressed air power consumption of 2600 kW in this specific case, compared to 2.2 kW for each electric drill unit.

The electric consumption is dependent on the power per drill, the utility cost and the daily drill usage. An effective working time of 6.25 hours generates limited power usage compared to the continuous daily running of a compressed air system. However, for comparison purposes, the compressor running time is equal to the effective drilling time. It has been estimated that only 8% of input power is lost for electrical reticulation system, compared to an 85% loss for a compressor installation[5].

Applying a standard utility cost of R0.18 per kW/h, the electric operating cost for the drills and compressor for ancillary equipment is half of the pneumatic equivalent. The yearly utility bill for a pneumatic operation is R1.07 million, while R0.52 million is payable for the electric counterpart. In this study, a single-phase reticulation system is priced since twelve drills, or less, will be operating simultaneously.

Additional costs are incurred with the pumping of the water used by the drills. The drilling operation consumes and produces water that must be pumped away from the working area by gulley pumps. Although the pumping cost is negligible, it is included.

Operating cost

The operating cost for the pneumatic drills increases over time. It is mainly a function of the maintenance of the drill and supporting system, and replacement required. The assumption is made that the surface compressors operate on maximum demand continuously. This is not entirely correct because when the compressed air demand is low, some compressors could be shut down.

A yearly maintenance cost of 5% of the compressor station, per year is assumed for the compressed air system.

Other costs include lubrication. In 2004, Anglo Platinum used 1.053 million litres of drilling lubricant for pneumatic rock drills. This represented an annual expenditure of R8.109 million[2]. The electric rock drills do not use grease/lubricant, generating savings on drilling costs.

Information supplied by a pneumatic drill supplier suggested that drills need to be replaced on average every four years with three major overhauls during that period. This was compiled from maintenance data. An annual maintenance/replacement cost of approximately R5.726 per drill is estimated.

The noise exposure of the RDO results in compensation costs for hearing impairment or hearing loss. Noise induced hearing loss (NIHL) costs the mine ±R83 200 per month. Consequently, the addition of all operating costs with pneumatic drills amount to R8.6 million.

The operating cost of the electric drills is the rental charge of R3 103 (including the knock-off bit and drill steel) and the electrical cost of operating the drills and compressor for ancillary equipment. Replacement components costs are included for knock-off button bits, drill steels, plugs and cabling. Similarly, from results

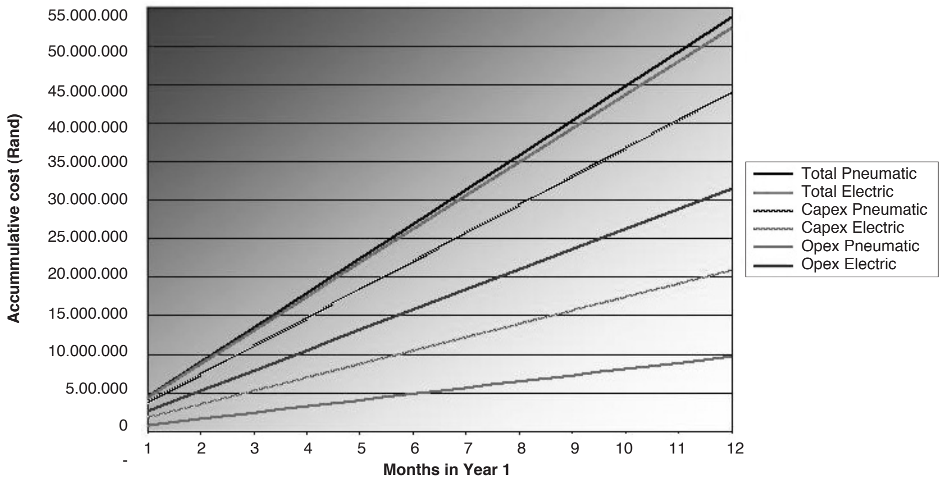

Figure 2. Comparison of total accumulated costs of drills over Year 1

obtained in independent studies, the acceptable sound pressure levels, emitted from electric rock drills, means that no NIHL claims are contemplated[4]. The exchange rate factor is not included in the rental cost. A total annual operating cost of R30.1 million is ascertained.

It is advisable that, initially, the electric drills are not purchased, because the mine does not have specialized and qualified technicians to maintain/repair these types of drills. To ensure quick servicing of the machines, a variety of essential spares are kept, for the supplier, at the underground mine workshops.

Comparison of expenditure

Figure 2 shows the fixed, variable and total cost comparison for both rock drill type over the span of twelve months. Since no operations have consistently used electric drills for more than one year yet, the graph does not extend beyond this period.

Case study results

Cost of drilling equipment

The financial parameters modelled in the business case are developed to determine the capital, electric and operational expenditures for the electric rock drills. The results are compared to those for establishing infrastructure to begin pneumatic drilling operations. Over one year, the purchase of pneumatic drills and associated infrastructure substantially outweigh the cost to lease the electrical rock machines.

The value of the lease contract for the supply and maintenance of the electric rock drills is assessed in comparison to the purchase of muffled pneumatic machines, for a typical expansion/replacement project. The cost of running an efficient compressor at a distance from the portal and the maintenance of the overland pipe line and underground air columns is included. The electric reticulation system to provide power for the electric rock drills, the establishment of an underground maintenance workshop and RDO training are incorporated.

Although the electric costs are lower for the electric rock drills, the operational costs are substantially higher in the first year of operation. This is attributed to the rental cost of the electric units and the cost of components. Training the RDO also contributes to variable costs. These rates and costs can be substantially reduced through the 'economy of scale' principle. The decision by Anglo Platinum to pursue full electric mining will result in lower operational costs.

Conclusion

The study entailed the establishment of a financial model to determine the expenditure requirements for the implementation of new drilling technology in a platinum operation. Although the financial outcome is not the only consideration in deciding whether new technology will be implemented, it does provide a measure for future consideration. Its projected return on investment and other cost controls are decisive factors for determining its feasibility in mining operations projects.

Other factors must be considered when selecting and initiating operational projects with new technology. The technical performance of the equipment will affect the initial and continued costs of production and operations. The drilling option is also determined by considering the safety aspects during machine handling. Equipment-based risk management reveals costs incurred to resolve identified risks. The environmental effect of the technology also contributes to the operational expense. Reducing electricity consumption and carbon emissions results in lowering costs in the project life cycle.

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