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Does mechanized drilling pay?

by P.J. KINVER*

SYNOPSIS

The paper presents details of the costs and outputs being achieved by South African mechanized tunnelling and stoping drillrigs. The information was gathered from various hard-rock mining and tunnelling operations ranging from deep-level gold mines to shallow base-metal mines. The survey included older pneumatic rigs and the newer electro-hydraulic rigs, but excluded shaft drilling and the stope drillrigs that were developed recently for narrow reefs. The information presented is intended as a guide to those having to decide whether to use mechanized drillrigs and, if so, what type and quantity.

SAMEVATTING

Die referaat verstrek besonderhede van die koste, en die lewering wat met Suid-Afrikaanse gemeganiseerde tonnelbou- en afbouboormasjiene verkry is. Die inligting is ingewin vanaf verskillende harderotsmynbou- en tonnelbouwerksaamhede wat wissel van diep goudmyne tot vlak onedelmetaalmyne. Die opname het ouer druklugboormasjiene en die nuwer elektrohidrouliese masjiene ingesluit maar skagbouwerk en die afbouboormasjiene wat onlangs vir smal riwwe ontwerp is, is uitgesluit. Die inligting wat aangebied word is bedoel as 'n leidraad vir diegene wat moet besluit of daar van gemeganiseerde boormasjiene gebruik gemaak moet word, en, indien wel, watter soort en hoeveelheid.

Introduction

With the continued need for greater productivity, an increasing number of mines and tunnelling operations are using mechanized drillrigs or intend to use them. In this paper, detailed costs and outputs are presented for the more commonly used mechanized drillrigs, together with associated fixed costs and other overheads. The information is intended as a guide to anyone addressing the typical questions that arise.

(a) Are trackless layouts with mechanized drilling suited to the particular reef or orebody, and what level of dilution can be tolerated?
(b) What is the planned output of the rigs?
(c) What type of rig is most suited to the requirements?
(d) What is the expected output of the drillrig?
(e) What mucking equipment is necessary to match the required output of the drillrig?
(f) What are the expected running costs of the drillrig?
(g) What additional capital and working costs can be incurred?
(h) What are the savings in labour, capital, and fixed costs that can be achieved?
(i) What are the skilled labour and training requirements?

Mining Layout and Extraction Method

Prior to a decision of whether trackless or conventional methods are preferable, the suitability of trackless layouts for the development and extraction of a particular reef or orebody must be examined.

Many base-metal mines use trackless layouts, and more recently deep-level gold mines have successfully planned and established trackless-mining layouts showing significant reductions in overall development requirements. In the latter case, this saving arises mainly from the fact that the raise interval in main levels and the associated crosscut spacing can be increased.

An existing operation has shown, and feasibility studies indicate, that a trackless layout for a reef that is well faulted may require 50 per cent less development. An associated greater face productivity of 30 per cent can be achieved as a result of improved access for men and material and for reef removal. However, the smallest on-reef development end that can be effectively mucked requires a face area of roughly 7 m^2, and it is therefore essential to estimate the effect of this increased dilution and to establish whether this is acceptable in terms of the financial returns.

Planned Output for the Drilling

The information given here is derived from a survey that was completed for rigs operating early in 1987.

Two questions have to be answered before the number of drillrigs required can be estimated:

(a) What level of drillrig availability can be economically justifiable?
(b) What output would be economically justifiable?

Availability

Even with a good maintenance programme, drillrig availabilities may be as low as 75 per cent. To improve this, considerable additional costs would be incurred, which may not be justified. A summary of availabilities for various hydraulic and pneumatic drillrigs is presented in Table I.

Wherever possible in the survey, *availability* was defined as the total breakdown and service hours subtracted from the maximum permissible hours and expressed as a percentage of the latter. Utilization was based on power pack hours for hydraulic rigs and percussion

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TABLE I
OUTPUTS OF MECHANIZED DRILLRIGS

Drillrig type	Made by	Hyd. or pneu.	Drifter × number	Length drilled per month m	Monthly production m³	Roofbolts	Av. hole length m	Penetration rate m/min	Availability %	Utilization %
Minimatic	Tamrock	P	L400×2	4 500	2000	Yes	3,0	0,5–0,6	76	50
Paramatic	Tamrock	P	L400×2	7 100	2800	Nil	3,0	0,5–0,7	89	56
Paramatic	Tamrock	P	L500×3	2 140	1500	Nil	3,0	0,5–0,7	83	36
Zoomtrack	Tamrock	P	L500×1	2 300	–	Yes	–	0,5–0,7	80	69
AC Promec T466	Seco	P	536	9 500	1680			0,5–0,6		
Minimatic H207L	Tamrock	H	HLR438TS×2	6 300	4700	Yes	3,5	1,0–1,2	73	61
Buffalo H38DC5	Atlas Copco	H	Cop1038HD×2	7 800	5800	No	3,5	1,0–1,2	70	48
Boomer H128	Atlas Copco	H	Cop1032HD×2	6 600	4900	No	3,5	0,8–1,0	76	50
Boomer H127	Atlas Copco	H	Cop1032HD×2	11 000	3700	Yes	3,2	0,8–1,0	75	55
Monomatic	Tamrock	H	HLR538×1	3 900	2900	10×2,1m/shift	3,7	1,0–1,4	74	66
Zoomtrack	Tamrock	H	HLR438TS×1	4 000	–	Yes	1,8	0,8–1,2	70	30
Seco Jumbo	Seco	H	BoartHD125	6 430	2600	22/shift	3,0	1,2–1,4	81	31
Monomatic	Tamrock	H	HLR438×1	11 000	2420	Yes	3,7	0,8–1,2	N/A	N/A
Minimatic H207L	Tamrock	H	HLR538×2	11 000	5400	No	3,7	1,0–1,4	70	48
Secoma Pluton 1	Eimco	H	Hydrastar 300 × 2	11 000	2500	No	3,8	1,1–1,9	90	45

hours for pneumatic rigs.

Economic Output

Drillrig performance varied from mine to mine. Most rigs completed an equivalent of 110 m of development per month, but others had a smaller output because of inflexible layouts and shortages of available ends for drilling. Some rigs were required to complete roofbolting operations prior to face drilling, but mostly it was felt that bolting reduced the overall efficiency of the rig and either a bolting rig or follow-up jackhammers were used. The rig's performance is primarily a function of its utilization, the length of round to be drilled, and the availability of clean ends for drilling.

The best possible working efficiency must be ensured by the drilling of the length of round most suited to the effective shift time, by which an optimum cycle of cleaning, support, drilling, and charging–blasting cycle can be achieved. The length of round may be limited if roofbolting is to be completed by the rig, unless a telescopic boom–slide arrangement is used. Where rock conditions were suitable, the most popular drillrod was 3,5 m, giving an effective hole length of 3,2 m.

The average drilling rates for the various rigs are included in Table I. The drilling rates for the hydraulic drifters are greater than for pneumatic drifters but, unless the hydraulic drillrig is given a large number of clean ends in close proximity to one another, the output for the more costly hydraulic rig will not be significantly higher than the pneumatic equivalent.

A reason for this is that the operator will tend to drill one round per shift, whether it is hydraulic or pneumatic, unless there are adequate incentives for the second round to be drilled during the same shift on a regular basis.

The number of ends that should be allocated to a rig is a function of the geography, the degree of interlevel access, and other restrictions such as the support provided for the mucking equipment that has been allocated to the rig.

The base-metal mines featuring in the survey generally had more concentrated working areas, allowing for greater flexibility. In all mines, it is highly recommended that the main levels be connected by a ramp system and, where possible, have a central workshop area that serves several production areas.

Shift times basically fell into two categories: double shift and treble shift. The effective shift time for base-metal mines was normally longer than for deep-level gold mines. A treble shift was generally used only for high rates on major development. Treble shifts are not used more widely because of the lengthy re-entry periods.

A drillrig is only as efficient as its associated cleaning equipment. The output for various load–haul dumpers (LHD), front-end loaders, and haul trucks is readily available. The measured machine outputs are generally close to the manufacturer's claims for given availability and degrees of utilization. The following are the main factors affecting the machine output:

(a) mechanical availability
(b) effective utilization
(c) operator ability
(d) size of bucket and its configuration
(e) distance from a rock pass
(f) condition and gradient of roadway
(g) degree of fragmentation.

It was found in the survey that the main cause for poor rig performance was a lack of available cleaned and prepared ends. It is essential that the mucking equipment that is required to provide adequate ends should be determined.

Expected Output of a Drillrig

Table I presents the average outputs for various pneumatic and hydraulic drillrigs. Most operations that have purchased drillrigs in recent years have opted for the two-boom hydraulic unit. The output of the hydraulic units was in the range 4000 to 13000 m drilled per month, whereas that of the pneumatic rigs ranged from 2000 to 7000 m per month drilled.

Although the penetration rate of the hydraulic drifter is roughly twice that of the pneumatic equivalent, many results in the survey did not show the corresponding increase in output.

The availability of pneumatic drillrigs was found to be in the 80 to 85 per cent range, which is appreciably higher than the 70 to 80 per cent availability for the hydraulic equivalent. This is attributed mainly to the fact that more of the established operations had pneumatic rigs, and their planned maintenance systems, workshop facilities, and operational ability were generally good. In addition, the complex hydraulic systems are more prone to failure and more difficult to maintain and repair.

For a rig output in the range of more than 10 000 m drilled per month, a rig availability of at least 75 per cent is required together with a utilization of 60 per cent of the available hours. The survey revealed that most of the rigs were operating on two 8-hour shifts only, and that 100 per cent utilization was related to 16 hours rather than to 24 hours.

Running Costs

Because the hydraulic rigs drilled more metres than the pneumatic rigs, the corresponding unit costs were considerably less. In general, a mechanized drillrig should achieve at least 7000 m per month to justify the capital outlay.

Table II, which shows working costs, excludes provision for capital replacement. It is essential in any analysis of drilling costs that financial provision should be made for the replacement of a rig. This annual provision is equivalent roughly to a unit price of 15 per cent of the original purchase price of the rig. To make this provision, roughly R10 000 per month must be added to the cost of the rig. For an efficient rig, this would add R1 per metre drilled.

Capital Costs

In addition to the large capital outlay for the purchase of drillrigs (approximately R750 000 for a two-boom hydraulic rig), significant costs are involved in the provision of adequate workshop facilities. The workshop area must enable a well-organized planned maintenance and repair programme to operate efficiently. Where possible, a main central workshop should be provided that is capable of completed major work on the rigs, and sufficient clean parking areas must be provided. It is important that a well-stocked store be kept of all major items of equipment.

A major complaint from many operations was that their satellite workshops were cramped and inadequately designed for the large drillrigs and associated mucking equipment.

The capital cost of a workshop will vary according to the ground conditions and the size and amount of equipment to be installed. A workshop–store for one development suite of equipment, i.e. 1 drillrig, 1 LHD, 2 haul trucks, and 2 ancillary vehicles, would need to be roughly 120 m^2 by 6 m high with a parking area of 100 m^2 by 4 m. The total cost of this development, plus support, civil-engineering requirements, and equipment could be around R1 000 000.

Offset against these large capital outlays, a significant reduction in the other capital requirements may be possible:

(a) reduced development costs due to more efficient layout,
(b) reduced hostel and other infrastructural requirements due to a reduction in labour,
(c) reduced compressed-air requirements, and
(d) reduced ventilation and chilled-water requirements, because the working areas are more concentrated.

In regard to (b), major savings are possible, with some R6000 per person in capital expenditure necessary to provide hostel amenities.

As for (c), many operations have reached or are close to their maximum output of compressed air. As a mine expands or gets deeper, additional compressors may be required. This need is eliminated where electro-powered hydraulic drillrigs are used.

TABLE II

OPERATING COSTS OF MECHANIZED DRILLRIGS (1987 COSTS)

Drillrig type	Made by	Hyd. or pneu.	Drifter × number	Maintenance cost of drifter* R	Operating labour cost* R	Engineering labour cost* R	Maintenance cost of stores* R	Water cost R/m	Power cost R/m	Diesel cost* R	Total cost* R
Minimatic	Tamrock	P	L400 × 2	0,19	0,23	0,16	1,12	0,10	1,19	0,05	3,04
Paramatic	Tamrock	P	L400 × 2	0,19	0,12	0,08	1,12	0,10	1,19	0,05	2,95
Paramatic	Tamrock	P	L500 × 3	0,55	0,40	0,28	1,40	0,10	2,13	0,05	4,91
Zoomtrack	Tamrock	P	L500 × 1	0,55	0,38	0,26	1,54	0,10	2,13	–	4,96
Promec T466	Seco	P	536 × 2	0,85	0,40	–	0,90	0,10	1,20	–	3,45
Minimatic	Tamrock	H	HLR438TS × 2	0,56	0,14	0,10	1,40	0,06	0,11	0,05	2,42
Monomatic	Tamrock	H	HL538 × 1	0,56	0,22	0,15	1,40	0,06	0,11	0,05	2,55
Zoomtrack	Tamrock	H	HLR438TS × 1	0,60	0,50	0,34	2,56	0,06	0,11	–	4,17
Buffalo	Atlas Copco	H	Cop1038HD × 2	0,27	0,11	0,08	1,40	0,05	0,11	0,05	2,07
Boomer H127	Atlas Copco	H	Cop1032HD × 2	0,12	0,13	0,09	1,40	0,05	0,11	0,05	1,95
Seco Jumbo	Seco	H	HD125 × 2	R0,16	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Monomatic (H107L)	Tamrock	H	HRL438LS × 1	1,40	0,22	N/A	0,60	0,60	0,11	–	3,10
Secoma Pluton 17	Eimco	H	Hydrastar × 2 300	0,09	0,15	0,10	0,62	0,06	0,11	0,05	1,18

* Per metre drilled

Personnel

Where a drillrig is used for the stoping of massive orebodies or for development purposes, significant reductions in labour are possible. These reductions are difficult to summarize but, for a drillrig operation, 1 operator and 1 assistant are generally used, together with 3 or 4 persons to assist with the construction and charging-up process. It was found that, on average, 2 drillrigs required 1 artisan and 2 assistants. A fleet of 5 rigs would also require a full-time boilermaker and electrician. In a completely trackless-mining system, the ratio of production to engineering staff was roughly 6:1 for a narrow-reef layout and 3:1 in a massive type of orebody. It must be stressed that the charging, mucking, equipping, banning, and support cycles must also be mechanized to enable significant reductions in labour to be made.

A comparison between the output and the cost of different methods of drilling in narrow- and wide-reef environments with ordinary development is given in Table III. These costs exclude the initial capital cost and the equivalent replacement cost and are in terms of mid-1987 money.

TABLE III
COSTS OF DRILLING

Item	Monthly production* per person m^3	Mining cost† per m^3 R
Drillrig—development	40–60	60‡ – 120
Drillrig—stoping, wide reef/orebody	40–75	75§–100
Jackhammer development	22–38	200–250
Jackhammer stoping—narrow reef	14–20	110×–150

* Including engineering
† To surface and mill
‡ Shallow base-metal mine, 20 m^2 development end
§ Equivalent to R80 per ton milled
× Equivalent to R100 per ton milled

Replacement of Drillrigs

Since the initial purchase price of a rig is large, provision should be made in the financial analysis for its replacement. Many operations have successfully operated a rig for 12 years or more, but all that remains of the original rig is usually the carriage assembly. The replacement cost may not be a 'one off' replacement cost, say in 8 years after the purchase of a rig, but allowance must be made for the replacement of major items on the rig from as little as 3000 hours for an engine, or 60 000 m for a drifter if the machine has been abused.

In general, within a period of 6 or 7 years after the rig's initial purchase, all the major components have to be replaced. Many operations started with major overhauls of their rigs at 3 to 4 years, which cost 40 to 75 per cent of the current purchase price of a new rig. It is now established that, if an extensive service is completed at 2-yearly intervals in which only the items requiring replacement and the items with a high risk of failure are replaced, the operating costs of the rig are minimized. To ensure that a planned maintenance system is effective, it is essential to follow a system that uses historical data and predicts the optimum interval between minor and major services based on predicted theory.

Training of Staff

An operation that starts with sophisticated drillrigs requires an equally sophisticated and advanced training programme. A new operation will, with sufficient incentive, attract already-trained staff from other operating companies. However, most of the positions required will have to be filled by personnel unaccustomed to the operational and engineering skills necessary to allow the full potential of the rig to be achieved.

There are no short-cuts to the training of operators and staff. Because of the high cost, it is usually not possible to have a rig on surface in the training-school environment, which means that a large proportion of the training has to take place on the job in the work environment.

Some operations have developed advanced training modules for both operators and maintenance staff. These courses are the result of experience gained, and the management of a new operation would be advised to visit established mines and benefit from their extensive and comprehensive training systems.

Operations that have started with mechanized drillrigs have found that at least 2 to 3 years are necessary before a competent team of operators and maintenance staff is developed.

Safety and Environmental Aspects

Mechanized mining, it has been noted, has reduced the number of injuries. This can be attributed mainly to less exposure to hazards, together with a reduction in the number of hazardous operations that have to be carried out. Collaring is an example in that the drill operator sits on the rig and is remote from the working face.

The noise levels of hydraulic rigs are substantially lower, about 12 dB, than their pneumatic equivalents. Hydraulic rigs do not suffer from fogging, and most rigs have good lights that contribute to greater visibility by both operators and supervisory staff.

Conclusions

There is no simple answer to the question 'Does mechanized drilling pay?'. Two different scenarios emerged from the survey: drilling primarily in a massive reef or orebody, and drilling primarily in development. The survey reveals that the output of a rig in the former case is far more efficient, the rig being capable of drilling 11 000 m per month. It is therefore more cost-effective than conventional drilling techniques. However, in a tunnelling environment, rigs are less efficient, and conventional jackhammer methods are more effective unless the rig drills more than 7000 m per month (equivalent to 120 m of a 12 m^2 tunnel). The survey reveals that hydraulic drillrigs are quite capable of exceeding these levels and are reliable in their operation. It should be noted that, where the scheduled development rate is less than 7000 m drilled per month, a pneumatic rig is more cost-effective.

An operation that is using jackhammers for its development would find it difficult to justify the prohibitive purchase price of a drillrig, workshop facilities, and cleaning fleet, and to allow for the infrastructure, the shafts, and the main stope layouts. However, at the onset of a new project or a major extension to a mine, significant capital savings can be made in hostel layouts, infrastructure, compressors and development requirements, together with reduced operating costs.

The drillrig is more than just an alternative method of drilling holes for blasting and support. The mechanized drillrig, together with its cleaning equipment, is capable of producing more effective mining layouts that lead to improved stope productivity.

The efficient mechanized drillrig is at present marginally more cost-effective than conventional drilling methods. However, with the ever-increasing labour costs, it may become necessary for more new mines, and even some existing operations, to introduce mechanized drillrigs.

Acknowledgements

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New Director of Hot Dip Galvanizers*

Arising from the acceptance by Mr Denis Twigg, Executive Director of the South African Hot Dip Galvanizers Association for the past seven years, of an academic post at the Port Elizabeth Technikon, Mr Walter Barnett has been appointed Executive Director with effect from 15th January, 1990.

Mr Twigg continued in an advisory capacity prior to commencing his new position on 1st April, 1990. Mr Stan Roberts will continue in his present position as Marketing Director of the Association.

Mr Walter Barnett, a leading corrosion expert, was a joint founder of the SA Hot Dip Galvanizers Association in 1961, and has been Chairman of this body for 22 of the past 27 years. The establishment of the Association was motivated in the late 1950s and early 1960s by the feeling in the market place that galvanizing did not have a very good name because standards were very low. By working together, those involved in the industry were determined to improve its image and advance the technology.

One of the Association's first activities was the development of a local standard specification system, and to this end the SABS, Eskom, other end users, and the young organization worked together. The result was what is today regarded as one of the best galvanizing specifications internationally—SABS 763.

Mr Barnett joined Sturrocks in 1948 in the administration and sales department. Over a period of ten years, Sturrocks moved into local manufacture and became involved in corrosion protection, particularly hot-dip galvanizing. This is how Mr Barnett's main-stream career was launched.

In time he worked his way up the ladder, literally from office boy to director of several companies and Managing Director of the corrosion-protection company Rietfontein General Galvanizers, one of the largest jobbing galvanizing companies in the southern hemisphere. In December 1987, Monoweld of the Barlows' Group bought this company out.

In December 1988 Mr Barnett became a private corrosion consultant.

In 1988 the South African Corrosion Institute awarded its gold medal—an honour bestowed only twice before —to Mr Barnett in recognition of his major contribution to corrosion protection both locally and internationally.

* Press release from South African Hot Dip Galvanizers Association, P.O. Box 77, Wits, 2050 Transvaal.

Engineering in South Africa*

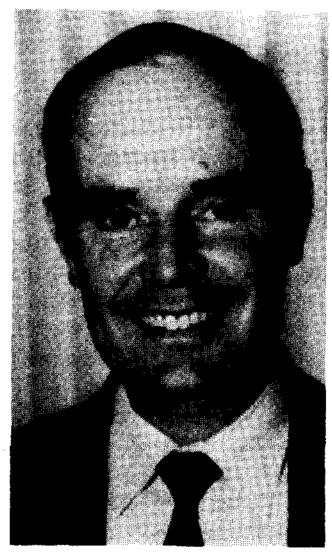
'If South African society does not begin to recognize the importance of engineering as a career, our ability to compete internationally and to generate wealth will continue to decline.'

This was the message voiced by Professor Alan Kemp as he started his three-year term as Dean of the Faculty of Engineering at the University of the Witwatersrand this year.

'Successful countries today are those that can compete industrially and technologically in an international free-trade arena', he added.

Engineering Education

Professor Kemp is Professor of Structural Engineering at Wits and Deputy President of the South African Institution of Civil Engineers. He plays a leading role in the furthering of engineering education, and was one of three academics to undertake an international study of civil-engineering education last year, visiting 40 institutions in 10 countries.



Professor Alan Kemp, Dean of the Faculty of Engineering at the University of the Witwatersrand

'South African society does not appreciate the contribution of engineering to its well-being, largely because of the low priority technology receives at Government level,' said Professor Kemp. 'In wealthy countries engineering is recognized as being the prime mover in wealth and job creation, and engineering education is treated as a national priority.'

He pointed out that enrolment figures in many South African engineering faculties had not improved significantly in the past ten years, and added that, if this trend persisted, the country would continue to drift from first- to third-world status and become progressively poorer.

Co-operation

Discussing the Engineering Faculty's objectives for the coming years, Professor Kemp said that the development of active long-term working relationships with the engineering industry and profession would be continued. He described this co-operation as mutual support in partnership for mutual benefit.

'We have a strong academic staff, are actively involved in fundamental and applied research, and run highly proficient post-graduate and continuing-education programmes in nearly all engineering disciplines. These strengths provide numerous opportunities for industry, professional bodies, and trade groups to benefit by closer long-term co-operation with the Faculty.'

He pointed out that, whether or not the Government changed its priorities, the future success of engineering education depended on continued support from the private sector.

Extra Year

Improvements to the scope of engineering education are also high on the Faculty's agenda. One move in this direction advocated by Professor Kemp is the development of an optional Master of Engineering qualification after the existing four-year undergraduate degree.

'This should be a one-year full-time or two-year part-time course focusing on engineering management or technical specialization. It should provide a broader education linked to the need for the engineer to play a stronger leadership role in industry.

'Because of his ability to interpret technical information, the engineer of the future will lead other professions in reaching key decisions in society.'

He explained that this additional year of study, recently pioneered in the UK, would require close collaboration with industry and the Wits Business School in order to achieve its aims.

Professor Kemp said he hoped to institute a system, also based on international trends, enabling top science graduates to obtain engineering degrees with an additional two years of study.

School System

He stressed, however, that the training of more and better engineers also depends on an urgent overhaul of the school system.

'South Africa's proportion of engineering graduates per million of population is about 10 per cent of those in other Western countries. This is not surprising when one considers that only 1 per cent of matric students are completing maths and science at an acceptable level for university study in engineering. Scholars should be advised to include career-related courses in their high-school studies, while private-sector initiatives should be directed increasingly at bridging education in maths and science.

'The report of the De Lange Commission has gathered dust on Government shelves for ten years in the mistaken belief that national priorities in education and training are unnecessary', said Professor Kemp. 'The result will be massive levels of unemployment of school-educated people in the 1990s and beyond.'

* Released by Lynne Hancock Communications, P.O. Box 1564, Parklands, 2121.