Raise-boring experiences in the gold mines of the Anglo American Corporation Group

by J. W. WILSON and P. C. GRAHAM

Published in the Journal, October, 1972.

Discussion by F. H. Guise-Brown*, B.Sc. (Min. Eng.) (Member)

INTRODUCTION

Messrs J. W. Wilson and P. C. Graham are to be congratulated on an excellent paper containing several thought-provoking remarks. The concept of allocating a machine and equipment valued initially at some R300 000 on an experimental basis is courageous, and the results obtained could be of interest to the mining industry as a whole.

The Gold Fields of S.A. Group approached this problem differently. In pioneering the start of this work in South African gold mines, they considered that expenditure of this magnitude would be warranted only if the proposition was viable right from the start. To this end, a Robbins R41 was purchased expressly to assist in the duplication of part of the No. 1 shaft system of the Doornfontein Gold Mine. Mr M. J. Koorts[1] has summed up the initial results of this work and given some preliminary costing, but inflation since that period has made these figures somewhat out of date. Although purchased for a specific purpose, the machine has been kept fairly busy and up to the end of November, 1972, had drilled some 3580 converted metres. (The term converted metres is explained later.)

Of equal importance was that the performance of this machine indicated a considerable potential for work of this nature. No particular mine at that time foresaw the necessity for such a large capital outlay, but, as several showed some interest, Gold Fields of South Africa Group nominated Gold Fields Cementation Mining Co., Ltd, to buy a machine and operate it on contract with a guarantee of very limited work only. Two further machines were purchased late in 1970, one subsequently being replaced by a more modern machine. It must, however, be admitted that a considerable amount of the 10 000 and more metres reamed by Gold Fields Cementation Mining Co., Ltd, since the start of contract raise-boring has been done for mines other than gold mines.

DECISION TO RAISE-BORE ON CONTRACT

In deciding whether or not raise-boring should be done on contract, several points were considered, and it was felt that the following advantages would accrue.

To the Client

(1) No capital costs, all items being paid for on a 'pay as you use' basis.
(2) No personnel problems.
(3) No utilization problems.
(4) No worry about machine maintenance, and ordering and delivery of spares and equipment.
(5) No worry about long idle periods when, strictly speaking, the machine should be amortized.

To the Contractor

(a) He would make a profit if he could operate economically on a competitive basis.
(b) There was a fairly broad field from which to solicit work.
(c) By choosing his team judiciously, during idle periods he could use his personnel for work other than raise-boring.
(d) Operations in as wide a field as possible would eventually lead to improvements on performance and costs.
(e) The possession of more than one machine would give rise to experimentation.

Of the above, (1) and (a) were the crux of the argument and decided the issue in favour of contractor ownership.

CHOICE OF MACHINE

A Robbins R41 machine, which is limited to 1,22 metre dia. holes, was considered too small. Robbins's only commercially available larger machine at that time was the R61, designed to drill 1,83 metre dia. holes. Several other makes were available, but, because the R41 had proved mechanically reliable and capable of meeting the maker's claims, it was decided to buy the R61.

It is of interest to note that Doornfontein Gold Mine have extended the use of their R41, whereby 122 metre dia. holes are being successfully sliped from a conveyance suspended inside the original hole. The design and concept of this operation are entirely their own.

CHOICE OF CUTTERS AND RODS

Unfortunately (for the consumer), each type of cutter is made only for its own specific head, and choice of cutter therefore involves choice of head also. The most practical head assembly appeared to be a 1,22 metre head with 1,52, 1,83, and 2,13 metre bolt-on sections. Such a configuration is commonly called a Christmas Tree. No hardrock disc was available, and button cutters using a single 'Cat' seal (necessitating lowering almost daily for re-greasing) were all that could be bought at that time. Reed heads and cutters, on past performance, were accordingly chosen.

'Drillco' 10 inch dia. rods were specified and have been found entirely satisfactory, especially as reversal of the threaded ends is possible.

CHOICE OF PERSONNEL

The operation of any one raise-borer requires the immediate daily overall supervision of one operator per shift, and, from time to time only, riggers, fitters, and electricians.

Because an investment of more

*Gold Fields Cementation Mining Co. Ltd.

than a quarter of a million rands demands at least adequate return, staff having the following characteristics were chosen:

(a) intelligent enough to understand the workings of this new 'toy',
(b) capable of understanding and carrying out instructions,
(c) sober and reliable,
(d) if not qualified, at least mechanically minded, and
(e) with sufficient drive and initiative to get on with the job and exhibit some pride of achievement.

The choice of supervisor (and subsequently supervisors) fell on individuals known to the Company for more than 20 years who met at least the above requirements.

The present staff for three machines consists of a Superintendent capable of advising on and negotiating contracts, assisted by a qualified Engineer; a Foreman and three Operators for each machine; and a specialized electrician and a fitter, who undertake repairs when and where necessary, carry out routine and periodic overhaul, and perform all cutter repairs at a centralized depot near Carletonville, Transvaal. It should be mentioned that the Foreman and the Operators are capable of carrying out minor repairs, and they do all the initial repair work to cutters and the changing of cutters, greasing, and so forth; it is necessary to send for the qualified fitter or electrician only in case of breakdown or of routine or periodic overhauls.

The operators' backgrounds vary but they include ex diamond drillers and riggers, who are employed as such during idle machine periods. This assists in the controlling of overall costs.

It is possibly worth mentioning that the suppliers of the machines consider that the calibre of the Gold Fields Cementation crew is at least equal to anything they have encountered anywhere in the world.

COMPARISON OF OUTPUT

Of interest is a comparison of results between Doornfontein, Anglo American Group, and Gold Fields Cementation machines.

Owner	Machine months	Converted metres*	Converted metres per machine month
Anglo American Group	12	1282	106,9
Doornfontein Gold Mine	45	3580	79,6
Gold Fields Cementation	82	10375	126,5

**Note* It is axiomatic that the reaming of a 2,13 metre dia. hole must be more costly (not only as far as cutters are concerned) than that of a 1,22 metre dia. hole in similar ground, and it would be incorrect to add arithmetically a series of different size holes and arrive at a common cost. Gold Fields Cementation have therefore attempted to rationalize the various sizes of hole by applying conversion factors to reduce each size to a common denominator, i.e., the 1,22 metre dia. hole. It is freely admitted that these factors are not necessarily correct, but, when applied, for example, to the Anglo American Group tabulation, they do give a basis for comparison.

BUILDUP OF A CONTRACT PRICE

Prior to the purchase of the machine, it was realized that the borer consisted of two distinct entities: the machine itself and its components, and consumables, both of which should be costed to produce a true figure.

The machine and its components

Basically, this consists of a machine, its power pack and console, a series of equipment cars, and, possibly, a transporter.

The total cost of all this equipment for an R61 model is about R170 000, and is ignored by both Mr Koorts and Messrs Wilson and Graham except in so far as current maintenance is concerned.

It is anticipated that these components have a finite life and should be amortized over a given period. The actual length of this period can only be estimated, and it was accepted as being 5 years, after which it was felt that the machine would probably be obsolete and unduly fatigued. In point of fact, since the initial purchase nearly 3 years ago, two new models have come onto the market from this maker alone, namely the R71 and the R83 (currently being made). This has not meant that the R61 is obsolete but has lessened its value as an operational tool and added weight to the argument that a 5-year amortization period is not unduly conservative.

Strictly speaking, this amortization cost, amounting to something of the order of R3000 a month, should be added to the costs given by Messrs Wilson and Graham (and to a lesser extent to those of Mr Koorts).

Consumables

(a) Apart from normal machine maintenance and repair, there should be some provision for major overhaul.
(b) *Rods.* Again, the previous authors make no reference to the very important cost of rods. It is difficult to assess rod life and when the stage will be reached for discard, but this must eventually happen. Total costs of 150 metres of R71 rod (1,51 metres long by 254 millimetres dia.) today is of the order of R80 000.
(c) *Heads.* Again, no provision was made by these authors for the purchase or repair of heads. Some indication of cost is that a 28 centimetre by 1,22 metre head costs about R7000, whereas a bolt-on 2,13 metre stage would add another R12 000 to this cost.

In the assessment of a contract price, allowance is made for all these items and a much truer cost arrived at than that given by Messrs Wilson and Graham, who included basically only the cutter and labour charges.

Note: The assumption made by these authors that the average cutter costs of R356 per metre in their holes 1 and 2 be accepted as contractor costs is completely wrong. The true figure for quart-

zite has never exceeded R150 per metre (inclusive of rebate and pilot costs) for button cutters and is somewhat less for disc cutters.

(d) The buildup of a contract price is therefore as follows:
Monthly: amortization; labour; insurance; and allowances;
Per metre: cutters (including repair); pilot bits; lubricants; repairs; rod and head wastage; plus a small profit margin, which may or may not be realized. For convenience, this is all converted to a cost per metre and charged as such.

UTILIZATION OF CUTTERS

One of the real advantages of contractor employment is that cutters partially used on one contract can be absorbed somewhere else, e.g., cutter life in hard rock is somewhat limited but may be extended by subsequent use in softer rock with a saving for all concerned. When it is realized that dressing a 2,13 metre dia. head costs something of the order of R30 000, this factor can be appreciable.

COMPARISON OF PAST AND PRESENT CONTRACT COSTS

An examination of contract charges today compared with those of three years ago reveals that, in spite of severe inflationary effects in every aspect of raise-boring, the overall contract cost has actually decreased and in many instances is now approaching normal development costs.

FLAT HEAD versus CHRISTMAS TREE

Gold Fields Cementation's experience with flat heads is somewhat contrary to that of Anglo American Group's for the following reasons:

(a) There appear to be imperfections in design in that flat heads vibrate more.

(b) Costs of a disc cutter with a 1,22 metre flat head were more than twice those for buttons on a conventional head in similar ground.

(c) A flat head has two real advantages: fewer cutters, and no expensive stage bolts.
It is not economically sound at this time to discard perfectly good Christmas Tree heads in favour of flat heads. This is even more apparent when it is realized that some makes of Christmas Tree can be fitted with discs as well as buttons.

DOUBLE 'CAT' SEALS

The development of the double 'Cat' seal has made an enormous difference to costs, not only as regards cutter life but also in overall reaming time.

Before the introduction of the double 'Cat' seal, it was thought that the majority of cutter failure was due, not to button wear, but to the fact that cutters seized on their bearings owing to insufficient lubrication.

The lubrication of such cutters was unduly onerous, and it is freely admitted that this was probably skimped. The type of cutter commercially available today is built to withstand a pressure of something like 100 kN. This relatively low pressure (well within the limits of the machine itself) means that the power of the machine is not fully utilized, and it is hoped in the near future that cutters will be available to withstand much greater loads.

TYPE OF DISCS

Three types of disc cutters are available at present:

(a) a hardened metal disc,

(b) a metal disc with replaceable rings, and

(c) a disc with a few button inserts around the periphery.

After the initial success of (b) in quartzite, (a), which was previously accepted as a soft-ground cutter, was tried and found to work surprisingly well. However, Gold Fields Cementation have found that (c) is the most economical in hard rock.

There is little doubt that in the not too distant future the use of discs (of one type or another) will be standard for ground having the characteristics of quartzite.

DEVIATION

If sufficient care is taken in setting the machine, deviation should be at a minimum, provided that the correct techniques of piloting are employed. Deviation is invariably less than $\frac{1}{2}$ per cent (in fact is normally guaranteed within this limit).

Sharp changes of ground, strong faults or dykes, and even pronounced bedding planes can affect straightness but can be allowed for if known about before piloting is started.

REAMING AND PILOT RATES OF DRILLING

Gold Fields Cementation's experience is somewhat at variance with Anglo American Group's in this respect, and it has been found (even in hard ground) that reaming rates are governed to a great extent by the ability to remove spoil so that reaming and pilot rates of advance vary between 1:1 and 1:3.

In soft ground, reaming can sometimes be done faster than piloting because the speed of the latter has to be controlled to maintain straightness.

UTILIZATION OF RODS

One of the problems facing the prospective purchaser of a machine is just how much rod to buy. The machine may be capable of reaming a 300 or 400 metre hole, but a 100 metre hole would probably be a more common length. If only 100 metres is purchased, the machine is limited to this length of hole, whereas, if 400 metres of rod is purchased, it means that the bulk of this rod will certainly be idle for most of the time, thus constituting a waste of capital investment. One of the advantages of contractor usage is that, where the contractor owns two or more machines, he is able to spread his rods from one machine to the other as and when this becomes necessary. Gold Fields Cementation at the moment are actually reaming a 380 metre hole.

UTILIZATION OF HEADS

The argument used in the previous paragraph applies to the purchase of heads.

Should only one machine be purchased and this machine is going to drill three or four different-sized holes, it is necessary to purchase all

the various combinations of heads for these holes, whereas, for the contractor owning two or more machines, it is necessary to purchase the basic size, namely the 1,22 metre head, and possibly one of each combination for the other heads, and to work on the assumption that the one size will not be necessary at all his machines at the same time. In point of fact, this has proved to be the case in practice.

EXPERIMENTATION WITH CUTTERS

One of the criticisms levelled at the contractor is his lack of initiative in using different types of cutter. To some extent this criticism is warranted. A pilot bit today costs approximately R1600; a button cutter costs up to R2000 and, with the 2,13 metre dia. hole, there are 16 such cutters. It therefore stands to reason that the amount of money involved makes it difficult, from a contractor's point of view, to experiment, particularly where he is working to guaranteed price. The main value of Messrs Wilson's and Graham's paper from a reader's point of view is the attention given to detail and the presentation of this detail.

From a contractor's point of view, this is very rarely done. Also, it must be remembered that the head for a particular type of cutter is likely to be in use for a considerable period, and the contractor therefore considers very carefully before deciding what head to purchase, and having done so he is not able to experiment with other types of head.

LAVA

No comment on raise-boring on Witwatersrand gold mines would be complete without some reference to drilling in lava. Lava as found in the west Witwatersrand area appears to have at least 7 degrees of hardness and, although it was found to be physically possible to ream 2,13 metre dia. holes to depths of approximately 100 metres, the cutter cost was prohibitive.

Button cutters cost almost three times as much as in quartzite, and a set of discs that was tried did not ream even one metre.

ACKNOWLEDGEMENTS

The author wishes to acknowledge his gratitude to the Board of Gold Felds Cementation for permission to publish this contribution and to Mr G. T. Fenton, Manager, Doornfontein Gold Mining Company Limited, for his constructive criticism.

REFERENCE

1. KOORTS, M. J. 'Initial results with the raise-borer on Doornfontein Mine.' *S.A. Association of Mine Managers*, 1968-69.

AUTHORS' REPLY

The authors wish to thank Mr Guise-Brown for contributing to their paper. His comments are particularly appreciated because he represents a firm of contractors who have considerable raise-boring experience. Mr Guise-Brown's contribution has naturally defended the role of the contractor in the raise-boring field. It must be clearly understood that on no occasion was it the authors' intention to detract from the valuable contribution made by raise-boring contractors to the gold-mining industry. On the contrary, it was intended to encourage an increase in the use of the raise-boring technique in the South African mining industry.

Although the authors agree with many of the advantages cited by Mr Guise-Brown for contractor operation, there are a number of points raised in his contribution that require some clarification and cannot go unchallenged.

In the first paragraph of the contribution, reference is made to the "courageous" nature of our experimental programme. This decision was not made without considerable thought by the technical management of Anglo American Corporation Gold Division. At that time the costs of contract raise-boring in the Orange Free State and other areas was prohibitively high and the future of raise-boring on the Anglo American gold mines looked rather bleak. The cost of boring the first two holes in the Research and Development programme are indicative of the magnitude of cutter costs in Orange Free State quartzites using the "then best" commercially available cutters.

Comparison of Outputs

In comparing the results of the various raise-borer operators, he makes use of the unit "converted metres" but has omitted to mention the factor required to change actual metres into converted metres. After careful examination of all the facts concerning our operation, it was not possible to determine logically how Mr Guise-Brown arrived at the "converted metres per machine month" quoted for the Anglo American machine. He does, however, state that converted metres are related to 1,22 m dia. holes. It follows that 1,22 m dia. holes are easier and less costly to drill than 1,82 and 2,13 m dia. holes. Therefore, it is to be expected that the converted metres for holes of these diameters would be greater than their actual lengths. For the period covered in the paper, the Anglo American machine drilled a total of 941,2 m of 1,82 and 2,13 m dia. raises. If the ratio of diameter is used as a basis for comparison, this length converts to 1496 converted metres of 1,22 m diameter raise or 124,7 converted metres per machine month and *not* 32,6 m as reported by Mr Guise-Brown. Incidentally, it is worth noting that the diameter ratio is the least advantageous conversion factor. It is interesting to note that at the time of writing we have drilled a total of 1856 m in 22 months of operation, which works out to 119,6 converted metres per machine month.

Amortization Costs

At no point in our paper was it intended to compare our total costs with the costs used for contract purposes. We do agree, however, that amortization costs, if they can be derived in a meaningful fashion, should naturally be included in contracting total costs. Our reservations in deriving amortization costs are based on the fact that our machine has been operating for over 6 years (it was the first 61R machine to arrive in South Africa) and is currently in excellent condition. There is no indication to date that our machine is requiring any more or less maintenance than it did two years ago, when it was acquired.

The method of calculation for amortization costs is surely a matter of company policy. In the case of the Anglo American Corporation "in-house" raise-boring operations, we can justify amortizing the boring equipment in a different manner from that used by outside contractors.

Maintenance Costs

Machine maintenance, head maintenance, consumables, etc., are all included in the figures given in Table IV in our paper. In fact, Mr Guise-Brown's assumption that our costs are "basically cutter and labour charges only" is not correct. Apart from depreciation (or amortization) costs and profit margin, our costing of raise-boring operations is comparable with contract raise-boring operations.

Flat Head versus Christmas-tree Head

In his comments under this heading, Mr Guise-Brown has apparently confused our definition of these heads. Sketches of the different reaming heads were given in the paper and the terms were used accordingly in the discussions. The modern trend in reaming head design for button cutters is towards flat heads for the reasons stated. However, it has also been our experience that disc reamers with flat profiles vibrate excessively—so much so that, in the light of current experience, it has been a severe setback to disc-cutter manufacturers.

Costs Associated with Holes No. 1 and No. 2

When challenging the costs reported for holes 1 and 2 given in our paper, Mr Guise-Brown should remember that these holes were drilled prior to the advent of "double Cat" seals and in very tough Free State quartzites. Boring in these conditions necessitated the use of more than one set of cutters in each hole, resulting in excessively high costs. There is no doubt that these costs are accurate, and a fixed contract price would have "burnt the fingers" of any contracting company at that point of time.

Cutter Experimentation

We appreciate Mr Guise-Brown's comments on the value of our paper; however, he should note that, despite the fact that a new crew was trained from scratch and detailed observations and measurements were taken throughout the programme, our machine utilization compares favourably with the much more experienced operations of Goldfields Cementation. Furthermore, as was noted in our paper, experimentation with new cutter designs and new products is carried out as often as is considered warranted—in the light of reducing operating costs.

Reaming and Pilot Rates of Drilling

Mr Guise-Brown suggests that his company's experience is at variance with ours in regard to reaming and pilot rates of drilling. We fail to detect the variance. However, we would say that only on odd occasions has the reaming cycle been held up by cleaning operations at the bottom of the hole. By far the most common reason for slow reaming rates is the nature of the rock being bored.

It may be of interest to mention here that in recent months the Anglo American raise-boring team completed a 1,22 m dia. hole through Ventersdorp lava in the Orange Free State. Although we hesitate to say that this lava is as tough as the lavas encountered in the West Wits. area, we successfully completed the hole with acceptable cutter costs. We feel that the application of high loads per cutter may have attributed to the success; however, we appreciate the nature of the problem when larger diameters and lengths of hole are required in such geological conditions.

In conclusion, we should like to thank Mr Guise-Brown for his contribution to our paper. We have welcomed this opportunity of exchanging ideas with another operator of raise-borers who has to contend with similar hard rock conditions and at the same time continue to strive for reduced unit costs.

COLLOQUIUM AND GENERAL MEETING

Developments in gold recovery processes

A General Meeting and Metallurgical Colloquium on the above topic were held on Wednesday, 14th March, 1973, at Kelvin House, Johannesburg.

Dr J. P. Hugo (President) was in the Chair.

The colloquium was attended by 170 delegates, and was opened by the President at 9.15 a.m.

OBITUARIES

The President: It is my sad duty to announce the death of the following:

D. R. Campbell, J. Daniel, J. M. Pike, and T. Pryor, Life Fellows; W. Drake and M. P. Pearce, Fellows; J. G. van der Nest, Member, and G. T. Rimmer, Associate.

As a mark of respect to the memory of the deceased and in sympathy with the bereaved, I would ask you all to rise and observe a few moments silence.

MEMBERSHIP

The Presidnet: I have much pleasure in announcing that the undermentioned candidates, whose names have been published in accordance with By-Law 5.2.2, have been elected by Council to membership of the Institute in the following grades:

Fellow: C. C. la Grange, N. Orsmond, K. Reim, S. S. Selmer-Olsen.

Member: A. F. Goetzsche, J. R. Caddy.

Associate: J. W. Broschk, R. H. McArthur, D. F. Cleary, P. J. Heyneke, R. H. B. Miles, F. G.