A REVIEW AND COST COMPARISON OF THE THREE MAIN METHODS OF UNDERGROUND COAL MINING IN SOUTH AFRICA

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A Project Report submitted to the *Faculty of Engineering*, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

WITBANK, 1989

DECLARATION

I declare that this project report is my own, *unaided work*. It is being submitted for the Master of Science in Engineering in the University of the Witwatersrand, *Johannesburg*. It has not been submitted before for any degree or examination in any other University.

K.W. FALCONER

10 TH day of MAY 1989

ABSTRACT

This project report reviews the present state of the art of the main methods of underground coal mining in South Africa, namely, conventional mechanised, continuous miner and longwalling. Comparisons are also drawn between these systems as operated by the other major coal mining countries.

The current situation with regard to local and export coal production in South Africa is reviewed. The potential and limitations of each of the mining systems are analysed with a view to improving their [illegible] and effectiveness.

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The current situation with regard to local and export coal production in South Africa is reviewed. The potential and limitations of each of the mining systems are analysed with a view to improving their suitability and efficiency.

The operating costs for each method are calculated and compared on an equivalent cost per ton basis, from which it was found that conventional mining still remains the cheapest system. The additional benefit of its greater simplicity, requiring a lesser skills level for maintenance and operation was also considered to be important.

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C O N T E N T S

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NOMENCLATURE

B.J.D.	British Jeffry Diamond
c/m	Continuous Miner
ESKOM	South African Electricity Supply Commission
F.O.B.	Free on board
ISCOR	South African Iron and Steel Corporation
L.H.D.	Load Haul Dump Truck
P.F.	Pension Fund
R.O.M.	Run of Mine
R.P.A.	Replacement per Annum
S.C.R.	Silicon Control Rectifier
S.E.I.F.S.A.	Steel and Engineering Industries Federation of South Africa
T.C.O.A.	Transvaal Coal Owners Association
W.C.S.	Working Cost Suspense

CHAPTER 1

INTRODUCTION

INTRODUCTION

1.1 COAL RESERVES IN SOUTH AFRICA

In order that a nation achieves the maximum benefit from mining operations, it is necessary that an accurate picture be available of the extent and quality of the reserves.

The determination of export quantities can then be fixed to ensure that the different grades of mineral are extracted at rates which do not jeopardise the country's own long term needs.

Many estimates have been made of the coal reserves in South Africa since the first official survey was carried out by the Department of Mines in 1913. These figures change as exploration increases and more efficient mining methods evolve. Different investigating bodies will also use different criteria when calculating reserves.

One of the latest reports conducted by the geological survey in 1981, indicated that the insitu mineable reserves of bituminous coal was 113 326mt with the recoverable portion being 57 541mt. These results formed the basis on which the government in May 1981, allocated 80mt per year for export over the next 30 years. This increased the previous quota of 44mt per year significantly. De Jager (1).

The adjustment was as a result of an increase in recoverable reserves of raw bituminous coal of 32 172mt from the previous calculations presented by the Petrick report of 1975, due to the vast amount of exploration carried out since then.

Factors which influence the evaluation of a coalfield are both physical and economic :

a) The extraction percentage used in planning which is influenced in multi seam deposits by the choice of seam to be mined first.
b) The mining cost as determined by the geological nature of the field.
c) The cost of beneficiation necessary to attain the desired product.
d) The availability and extent of the existing infrastructure.
e) The transport costs to inland market or export terminal.
f) Rand/dollar exchange rate.
g) The selling price.
h) The political situation, particularly involving sanctions.

As the volume of economically recoverable reserves is influenced by various external factors, these reserves cannot be regarded as being fixed, but are dynamic with regular updating being essential in order that planning can be adjusted if necessary.

1.2 PETROGRAPHIC QUALITIES OF SOUTH AFRICAN COALS

South African coal characteristics vary from those of Europe and North America. Equipment designed for European conditions has often experienced problems when tried in South Africa. This has at times, been due to the unexpected differences in terms of mechanical cutting, breakage, crushing and abrasion. A result of this has been the production of high quantities of dust and reduced amounts of the sized product.

The rank of the coal refers to the degree of metamorphism undergone by a coal seam due to time, temperature or pressure. In South Africa, the influence of rank has not yet been quantified in relation to the mechanical properties of coal. This is due largely to the methods used in the northern hemisphere being unsuitable for South African coals. Falcon (2).

a mechanism to determine the cuttability of the coal is necessary in order to gauge the effects on mechanised mining. The cuttability can be termed to be a combination of the undermentioned mechanical properties :

a) Hardness, which affects the penetration at the point of cutting.
b) Strength, this affects the resistance to sustained compression.
c) Friability affects the capacity to break up once penetrated.
d) Abrasion affects the erosion and wear on the equipment.

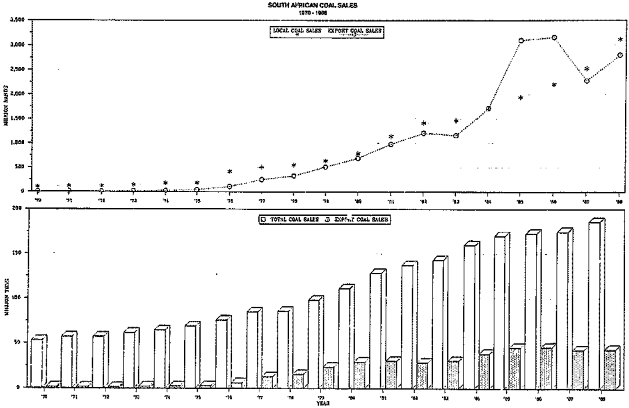
These primary classifications explain the variances in the characteristic mechanical behaviour of the coal in the various coalfields of Southern Africa.

1.3 COAL PRODUCTION IN SOUTH AFRICA

South African coal sales have grown dramatically in the last 20 years. Since the oil crisis of 1970, local sales have shown a 6% growth rate per annum.
See Fig. 1.1 - South African Coal Sales.

In 1986, local sales were worth R1,8 billion with exports worth R3,2 billion or 14% of S.A.'s mineral export earnings, making it second only to gold. From a total sales of 169,7 million tons, exports amounted to 44,8M with the local market absorbing 124,8 million tons. In 1987, total sales had increased by 7 million tons, although exports fell by 2,5M tons. There was, however, a substantial decrease in export revenue, which fell to R2,3 billion, while revenue from local sales increased to R2,5 billion.

Provisional figures released for 1988 show export tonnages virtually unchanged at 42M tons, although revenue has increased by R0,4 billion to R2,7 billion. This can be attributed to the weakening of the rand against the U.S. dollar and a firming of international coal prices towards the end of the year. Local coal sales continued to grow, up 4M tons to 139,7M tons, with the large increase in revenue (R3 billion), being largely attributable to the internal rate of inflation.



SOUTH AFRICAN COAL SALES
1970 - 1988
LOCAL COAL SALES
EXPORT COAL SALES
MILLION RANDS
TOTAL COAL SALES
EXPORT COAL SALES
MILLION TONS
YEAR

Fig 1

Major coal exports started around 1970, when an agreement was signed between T.C.O.A. and the Japanese steel mills for the export of two and a half million tons of low ash blend coking coal.

Since the opening of the Richards Bay coal terminal in 1976, S.A. has grown to establish itself as one of the world's major coal exporters.

As the quality of the insitu coal is not high, a considerable amount of ingenuity and engineering expertise is needed to produce coal suitable for world markets. In order to meet the demands of the end user, selective mining is being practised together with two-stage beneficiation yielding low ash metallurgical coal and power station steaming coal.

Typically, Witbank 2 seam coal could be beneficiated to yield 26% low ash coal and 54% steam coal.

Run of mine tonnages amounted to 210 million tons in 1987, with 53,760 production workers being employed, which gave an overall output per man shift of 13 tons. This compares with 16 tons for Australia and 10 tons for the U.K.

In the last 10 years, S.A. has managed to secure about 25% of the internationally traded steam coal market. It is unlikely that this figure will ever be exceeded, as prudent buyers normally limit their purchases from any one country to not more than 30% for reasons of security of supply.

The market is now becoming more competitive, as new operations in Colombia and China enter the export market. In order to be competitive, these countries are having to sell their coal at virtually cost price. Colombian coal from El Cerrejon is being sold at prices which cannot even service the capital committed to this project. China would be prepared to make a loss on its coal sales for the more valued foreign currency which it derives. This forces other exporters to follow suit, dropping their prices to below economic levels simply to remain competitive.

In order that S.A. maintains its present market share it is necessary that it :

a) Maintains a reputation as a secure and reliable supplier through harmonious industrial relations and internal stability.
b) Produces coal of an acceptable quality for large coal users.
c) Continues to mine coal cost effectively and safely.
d) Maintains an efficient transportation infrastructure which enables coal to be offered at a competitive delivered price.
e) Provides effective technical services, i.e. quality control, pre-sales and after sales services.
f) Controls the inflation rate and keeps price rises below this level.
g) Maintains a credible rate of internal reform so that sanctions fail to become an important issue.

The imposition of sanctions by France, Denmark and the United States and the present world glut of coal, continue to affect the export market. Export tonnages have dropped by 6% (2,5M tons) over the previous year ('86) with revenue being down a staggering 0,9 billion due largely to a stronger rand/dollar exchange rate.

In the past 3 years, the total labour force has been reduced by 8000 to 92 000. Increasing mechanisation and rationalisation on the collieries is expected to reduce this figure by another 5,000 this year.

The international coal markets are now extremely sensitive to cost with a situation of oversupply developing due to the new market players. S.A.'s double figure inflation, in contrast with other exporters, has blunted her competitive thrust.

The other serious aspect is the increase in rail tariffs to Richards Bay. Since March last year, these costs have risen from R12,90 a ton to R23 a ton from the Witbank area. This now accounts for almost 40% of the price to the consumer. The result is greatly reduced profit margins making many mines marginal or uneconomic. Over the same period, export competitors such as Australia have managed to reduce their tariffs.

On the domestic coal market, the rate of expansion has decreased with the realisation that energy requirements are not increasing at the rate they were forecast to a decade ago. The building of new coal fired generating capacity is being slowed down as the economic growth rate has decreased and more efficient use is being made of the available power.

A breakdown of local sales reveals the following :

Electricity generation	51,6%
Industrial and synfuels	32,2%
Metallurgy	6,4%
Merchants and domestic use	4,4%
Transport	0,8%
Mining	0,6%

The local market for steam coal and the synfuel industry are secure with large, tied collieries supplying their needs. Their development is jointly financed by the coal user and the mining house. This market security allows them to sell their coal at a reduced profit margin. Boiler technology has now advanced to the stage where those installations can burn very poor quality coal as low as 16MJ.

Further expansion of the synfuel market cannot be justified at present on economic grounds because of the low crude oil prices. It is likely however, that this will provide an increased market for future coal sales.

ISCOR is the largest domestic consumer of metallurgical coal, using approximately 5M per annum. About three quarters of their needs are supplied by their own collieries.

Their quality parameters are much more stringent and are achieved by selective mining and careful beneficiation. They are planning expansions at some of their smaller coal mining operations, as well as their largest, Grootegeluk, where additional coal will be supplied to E.S.K.O.M.

1.4 QUALITY CONTROL IN THE MINING OPERATION

The users of coal can be split into 3 different categories :

a) Heating and steam-raising.

b) Carbonization to form cokes and chars.

c) Conversion to synthetic gaseous and liquid hydrocarbons.

Its most important chemical and physical properties are therefore those that determine its response to oxidation and reduction.

The selection of the mining method has a large influence on the quality of the product which is produced in terms of :

a) Ability to which a product of uniform chemical composition can be produced.

b) The amount of removable impurities which are mined.

c) Control of size and size ratios.

d) Control of moisture.

The petrography of the coal in the seam does not remain uniform, and therefore, the quality of the coal marketed depends upon intelligent foresight, planning, execution and supervision.

The problem of preventing contamination of the coal at the working face during mining is greatly increased if the roof or floor material is soft or irregular. This can be compensated for by coal being left in the roof or floor. Unless the fraction which was left was of an inferior quality, then the expected extraction ratio is reduced.

Skilful operation and supervision in the application of conventional or continuous mining equipment govern the successful elimination of floor or roof impurities. Coal cutters may be used to cut above or below undesirable coal.

Systematic checking of the thickness of roof and bottom coal or the following of a marker band can be used to ensure selectivity. Such selectivity may not be possible where the seam is very narrow.

Continuous miners can be employed to extract a selected portion of the seam, but only if it does not undulate too much. Their effective operation depends to a large extent on the skill and attentiveness of the machine operator. They have a tendency to churn up a weak floor, and the cutting horizon is difficult to control with the high levels of dust which are produced. With pillar extraction, contaminants are often loaded where the coal comes into contact with the goaf.

Most often, continuous miners and longwalling is used where the mining is non-selective and is practised over the full seam.

With longwalls, the opportunity for the exclusion of roof and floor material depends largely upon the correct selection of the equipment. This will ensure that no roof or floor is cut to allow for the passage of the machine and supports. If weak floor conditions prevail, the facepans and supports must be selected so that they do not exacerbate the problem. With poor roof conditions, retractable sprags can be provided on the supports.

Where sizing of the product is important, the selection of the continuous miner and shearer will play an important part. Differences in size between coal produced by conventional mining and that cut by machine, is most pronounced in the coarser size ranges.

Continuous miners produce a substantially smaller amount of plus 50mm sizes than are produced by blasting though there are only slight differences in the under 6mm fraction.

The moisture content of raw coal varies considerably from seam to seam. It has numerous undesirable effects such as increasing transportation costs and causing handling problems. Preparation is made more difficult when it is sticky. Any additional increase in water during the mining operation can usually be cut down by careful mine design and operation.

The selection of a suitable system of underground mining is influenced by a large number of factors. Geological conditions and the targeted market which d... the quality of the coal, are but a few. The bottom line must h... er, be cost, but when considering this parameter, it is necessary ... ake cognizance of the long term implications of both resource depl... ion and price escalation.

1.5 OPENCAST MINING

Opencast mining is relatively new to South Africa. The first large scale opencast mining project commenced in 1971. Previous to this time, coal seams with an overburden of less than 25m were often very difficult to mine, either by surface or through underground mining.

Initially, coal reserves which had an overburden of less than 35m, were considered to be mineable by opencast methods, but as equipment has improved, stripping depths have become deeper. In some instances up to 70m.

The main technological restraints imposed with increased depth are the reduction in the extraction rate due to the amount of overburden which has to be handled.

The geology of the coal field is important when considering opencast mining, especially in so far as the thickness and type of overburden is concerned. This influences the overburden-to-coal ratio, the stripping ratio, which along with the quality of the coal, determines the economics of the operation. The type of overlying strata influences the cost of overburden removal by dictating the required spacing of the shot holes and the amount of explosives necessary.

An important advantage of opencast mining where a multiple seam deposit is concerned, is that all the seams down to the stripping limit can be taken.

Some form of beneficiation may often be required due to the difficulties of ·arating the coal and rock in the pit.

This project report will concern itself only with underground mining methods.

CHAPTER 2

CONVENTIONAL MINING

CONVENTIONAL MINING

2.1. THE DEVELOPMENT OF MECHANISED CONVENTIONAL MINING

2.1.1 Introduction

The first moves to mechanise a room and pillar mining operation into the conventional mechanised mining system of today, were made around the turn of the century when coal undercutting machines were produced in Britain and America. It was not until the 1940's however, that self propelled machines were developed to perform the various functions of the conventional mechanical coal winning process. Although newer mining systems have superseded the conventional system,it is still popular in the U.S.A and South Africa in particular.

2.1.2 Handloading

Handloading has remained viable for small operators of high grade coal seams who cannot afford to invest in mechanised equipment. The production potentials for such sections are small, with a maximum of 4,500 tons per month being realistic from a complement of 45 section workers. Due to the labour intensiveness of handgot sections and continuous haulages, rising labour costs are making this mining method less viable. A further important aspect is that the manual loading of coal is becoming unattractive due partly to the higher accident rate which is involved. Where stooping operations are conducted, the slower advance rate results in a decreased percentage extraction.

2.2 THE ADVANTAGES OF CONVENTIONAL MINING

Conventional mining offers the most flexible mining system for the production of high tonnages, given a competent roof such as is present in the South African coalfields.

The conventional mining system offers the following advantages :

a) Geological disturbances in the coalfield i.e. dykes and faults, can most easily be worked through with conventional machirery.
b) The machines can successfully negotiate gradients and poor underfoot conditions that would stop a continuous miner.
c) Conventional mining *offers the best opportunity* of mining a large sized product making preparation costs cheaper. The reduced amount of fines result in less discard at the preparation plant.
d) The conventional section in contrast to the continuous miner section makes use of *a number of production* machines, each with a separate function i.e. cutting, drilling and loading. These one function machines are comparatively less complicated and therefore less likely to malfunction.
e) By keeping the machines operating a few faces apart where *sufficient working places* are available, small breakdowns can be attended to without disrupting the production cycle.
f) Should a serious fault arise, a backup machine can quickly be brought into operation.

The loading machines normally have a loading capacity in excess of normal loading requirements, giving it the ability to make up at least a part of its lost time resulting from breakdowns to itself or outbye equipment.

2.3 SAFETY

2.3.1 The Advantages of Conventional Mining

The advantages of conventional machinery are as follows :

a) Less dust is created by the machinery. The better visability makes for a safer working environment with less risk of lung disease to the workforce.
b) The smaller machines allow for a larger passage of ventilating air in the faces.

c) There is no prolonged working of a machine against the roof making an ignition less likely.

d) A comparatively smaller advance is gained with each blast, which exposes less roof for support.

2.3.2 The Disadvantages of Continuous Mining

The disadvantages of conventional mining from a safety point of view can be listed as follows :

a) A blasting section leaves a rougher roadway profile than a continuous miner.

b) The roof can be damaged due to careless drilling which will require additional support work.

c) The rougher profile offers greater resistance to the ventilating air though multiple entries and returns make this less important.

d) The dangers associated with blasting operations.

e) The working of multiple entries makes the job of supervising the section more difficult. A greater responsibility is placed at the hands of the individual operators to ensure that their work is performed correctly.

2.4 MACHINE DEPLOYMENT

2.4.1 American Mining Practise

American mining operators favour small sections with five to seven roadways. The smaller section ensures that less time is spent on tramming, which makes operations easier when less personnel are employed in the sections. Fewer section roadways offer less margin for machine downtime as a breakdown at one part of the cycle will very quickly bring the operation to a standstill. U.S. operators tend not to have backup machines available. This requires that the working machinery is kept in top condition. Their machine maintenance takes place during special maintenance shifts at night or weekends.

2.4.2 South African Mining Practise

South African operators favour larger sections with many headings. Extra labour is employed in the sections to speed up the operation.

Backup machines are usually available in the section as machines are generally taken off for maintenance on the day shift when more supervision is available. Large breakdowns occur when the preventative maintenance is not as good as it should be, often because of a high turnover and shortages of engineering staff. The backup machine then plays an important role in keeping the section operational. With better engineering standards, problems can be addressed in their infancy and regular maintenance and servicing ensures that breakdowns occur less frequently, as worn components are identified before failure occurs.

2.5 THE IMPORTANCE OF CONVENTIONAL MINING IN SOUTH AFRICA

Conventional mining is still the most popular underground mining system in South Africa.

The relatively shallow coal seams allow for high extraction ratios as small pillar centres can be left which increase the productivity of the system. In medium seam heights, conventional mining offers the highest production rates in bord and pillar operations.

2.6 SECTION CONFIGURATIONS

Traditionally, single header sections working a large number of roadways have been operated. The slower rate of advance with this type of section reduces the frequency of belt extensions, and the large number of working places enable geological problems to be negotiated without production being seriously affected. This layout does have the disadvantage of slowing down the production rate, as longer tramming distances are involved when working the flanks. The barriers may not be worked every time, especially, if there are problems with the loading operation. This results in their falling behind and affects the proper ventilation of the section.

When tramming distances are reduced, a higher rate of production can be maintained. This can best be achieved by reducing the number of working places to the minimum that are required for each piece of equipment. This would be :

1) Roofbolting.
2) Cutting.
3) Drilling.
4) Charging up/blasting.
5) Loading.

To eliminate any waiting time which the different machines may be subjected to, an additional face should be available for blasting, allowing fumes to clear and for duffing (where necessary).

With a seven road configuration, a small time interval is available to cater for delays to the production machines. This would allow for minor repairs to be carried out as required.

2.7 LABOUR REQUIREMENTS OF A CONVENTIONAL SECTION

2.7.1 Foreign Practice

American, European and Australian labour costs determine that section complements should be trimmed to the minimum.

A typical American conventional section would comprise of 12 persons. Harrold (3).

2 Loader operators
1 Coal cutter operator
1 Drill rig operator
1 Charger/shot firer
2 Shuttlecar operators
1 Ventilation man
2 Roofbolt operators
1 Mechanic/Electrician
1 Foreman

This would represent a 30% increase over that of a compatible continuous miner section.

Although the S.A. complements are larger, a higher production rate is expected from the sections. The complement is deployed such that no job sharing is required to be done.

2.7.2 Manning Requirements of a South African Section

2.7.2.1 Face Drills

Face drill rigs are now replacing hand held coal drills in most conventional sections. The resulting increase in production potential and reduction of section labour justifies the capital expenditure.

2.7.2.2 Coal Cutters

Floor cutting is practised where the coal to be mined overlies a poorer quality coal. The coal cutter then maintains the cutting horizon. This technique can result in a slower cutting rate when hard stone is encountered at the marker band.

Where the required floor is a stone band or a hard seam floor, the cut is taken in mid seam to avoid the pick contact with the hard cutting horizon. With this technique, the coal cutter can select the most easily cuttible coal within it's boom reach. The disadvantage is that the duff has to be cleared before the bottom holes are drilled or charged up (if they were pre-drilled). Very often the bottom holes are drilled with a hand held drill which enables the coal to be blasted away from the contact more cleanly. The mechanical difficulties of operating the face drill successfully when the boom has been swiveled by 180° have not been fully overcome. Drilling is made more difficult where a floating stone floor exists.

2.7.2.3 Duffing

Cleaning the duff so that the face can be drilled (or charged up), requires that a further stage be added to the production cycle.

The methods available are by hand loading, mechanical shovel or gathering arm loader.

Hand loading is slightly slower, and requires 3 people while a mechanical shovel requires only 1 driver who can sweep the section when he is not duiling. As an alternative, the spare loader can be used to remove duff, an operation which would require two operators. One loader could load and remove duff, but the reduction in the production potential of the section would not merit this.

2.7.2.4 <u>Labour Complement of a Single Header Section</u>

A typical complement for a South African single header conventional section would be 25 where the following equipment was employed :

1	Roofbolt machine	
1	Gathering arm loader	and 1 spare
2	Shuttlecars	and 1 spare
1	Coalcutter	and 1 spare
1	Drill rig	and 1 spare
1	Feederbreaker	

The labour would be made up as follows :

1	Section miner	1	Fitter
1	Team leader	1	Fitter aide
2	Roofbolt operators	1	Electrician
2	Coalcutter operators	1	Electrician aide
2	Drill rig operators		
3	Charging assistants	(4)	
1	Pinchbar attendant		
2	Loader operators		
3	Shuttlecar operators		
1	L.H.D. operator		
2	EDD operators		
1	Tip attendant		

(21)

Such a section has the potential to produce 80,000 tons of coal per month on a *double shift basis,* given good mining conditions and a medium seam height.

2.8 CONVENTIONAL STOOPING

2.8.1. Pillar Extraction

Conventional mechanised stooping sections are operated in competition to continuous miners by several S.A. mines. Smith (4).

The use of conventional equipment is restricted in stooping operations, to the pillar extraction method. In contrast to continuous miner sections where each pillar is systematically extracted along the stooping line, the nature *of operations* in a conventional set up determine that several working places be made available. For this reason, each pillar in the stooping line is worked, taking care that no one pillar is extracted faster than the next. The most popular stooping line is maintained at 45° to the direction *of retreat.*

Experience has shown a five pillar panel to be the most practical for a stooping section. This ensures that the rate of retreat is maximised, giving the best opportunity for the extraction of the snooks.

2.8.2 Mining Equipment

As the pillar extraction section is *already developed,* a minimum amount of equipment is required to work it. This could comprise of :

1 Coalcutter
1 Roofbolt machine and 1 spare
3 Front end loaders and 1 spare
4 Electric coal drills

As an alternative to the front end loader, a mechanical loader and two shuttlecars may be operated if there is sufficient space to manoeuvre between the temporary supports.

2.8.3 Labour Requirements for a Stooping Section

Labour requirements for a stooping section would typically be greater than for a conventional development section. This is despite the fact that less equipment is operated and due to the greater amount of support work required. A typical labour complement would be :

1	Section miner		1	Fitter
1	Team leader		1	Electrician
2	Coalcutters		2	Aides
2	Roofbolter operators		2	Helpers
3	Front end loader operators			
4	Electric drill operators	(6)		
3	Timber attendants			
1	Pinchbar & water attendant			
1	Duff attendant			
2	Box attendants			
1	*Ventilation & stonedust attendant*			
1	Tip attendant			

(27)

Production rates in medium seam heights are unlikely to exceed 35,000t per month, which is no more than could be expected from the development section. The effective tons per man is reduced with stooping, due to the extra presonnel. The installation and withdrawal of supports limits the production tempo.

2.9 THE OPERATION OF LHD'S IN A PRODUCTION SECTION

Diesel front end loaders have the advantage of being able to double up as supply vehicles to the section, though they require higher ventilating quantities.

Electric front end loaders lack the flexibility of the diesel units, but are a cleaner machine and their quieter operation enables a better monitoring of roof conditions in the stooping area.

The factors influencing the cost efficient operation of LHD's are :

a) Tramming distance.
b) Tramming speed.
c) Bucket capacity.

Tramming distances in a production section are usually kept below 100m due to practical section configurations. This ensures that the machine is used within its most efficient haul range. The difference in cost per ton for various bucket capacities are less marked at lower tramming distances. So too, is any variation in tramming speed. Major (5).

An increase in efficiency resulting from higher tramming speeds is often overshadowed by the detrimental effect that this has on the machinery. Smaller machines have the advantage of manoeuverability in the underground section which offsets their increased cost per ton.

Figure 2.1 (after Major), shows a comparison of cost per ton, for consumables only, against tramming distance for various machine sizes.

2.10 THIN SEAM MINING

Seam heights of less than 1,5m are generally referred to as thin seams. The practical working heights for such seams extend down to 0,9m with conventional equipment and 0,75m with a continuous miner.

With narrower seam heights, the economics of the operation are adversely affected, as the reduced output causes an increase in the cost per ton.

COST PER TON OF CONSUMABLES

FOR VARIOUS SIZED LHDS

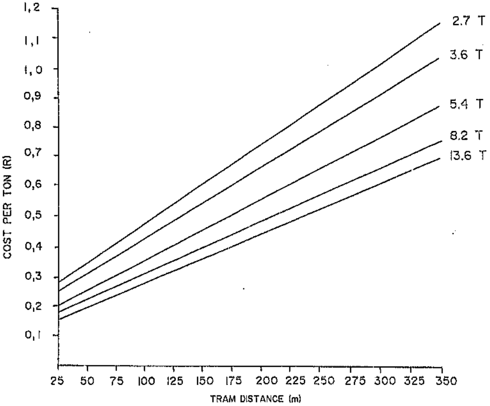


Fig 2.1 (after Major)

Productivity simulations and practical experience have shown the most productive thin seam primary extraction method to favour the use of conventional equipment rather than continuous miners. From studies carried out by the Chamber of Mines of South Africa, the average equipment availabilities for the various machinery pla· d an important part in determining the realistic monthly pro. ·tion. Conventional equipment was found to average 83% availabilities, while continuous miners averaged 62% and 58%, when used in conjunction with continuous haulages. Trueman (6).

A double header *conventional section has the best production* potential for thin seam mining. Production rates of 40,000t per month could be expected with seam heights of 1,5m, given favourable mining conditions. The best loading equipment for thin seams is the scoop tram, as the lesser tonnages which are produced per blast can most easily be loaded out, with a self propelled load haul dump unit. Shuttlecars are unable to transport large tonnages due to the height restriction. The manoeuvering of a loader around the section delays the operation to the extent that cannot be made up when loading.

Although a section can produce more coal using scoops or shuttlecars than with LHD's, the equipment would be chosen, after consideration of the mining conditions prevailing.

Scoop trams can out perform LHD's due to their larger carrying capacities, but they are less able to operate where unfavourable floor conditions exist. The smaller bucket capacities of the LHD's are suited to uneven floors or gradient work and where both coal and stone are to be handled.

2.11 DOUBLE HEADER CONVENTIONAL SECTION

2.11.1 Mining Conditions

A double header section has a number of important advantages which can increase the production of coal. It is best suited to good underground floor and roof conditions.

This is necessary in order that both sides of the section can advance at an even rate. It is also important that the tramming conditions around the tip are favourable and areas of poor roof do not prevent the splits from being holed. This would increase the tramming route and slow down the loading operation.

The optimum size for a double header section with single conveyor belt is 15 roads. With large pillar centres, the number of roadways may need to be reduced, thereby affecting the flexibility of the section.

2.11.2 <u>Advantages of a Double Header Section</u>

The advantages of a double header section are :

a) The concentration of two single header sections increases the level of supervision.
b) Spare machines from one section can easily be swapped to compensate for breakdowns in the other.
c) Artisans from one section can readily assist in the other.
d) A single miner could cover both sections if necessary.
e) The supply of materials, stonedusting and maintenance of service roads, conveyors and ventilation controls is simplified.
f) There is less chance of running out of mining and engineering consumables.
g) A measure of competition exists between the two gangs which fosters better standards and production.

With split ventilation, each section is supplied with fresh air so personnel are not subjected to any increase in airborne dust levels.

2.11.3 Double Header Section with Twin Conveyor Belt

A double conveyor system increases the production potential from the section. This can be achieved by having two section belts which feed onto the trunk, or a single section conveyor, with a portable conveyor delivering onto it via a cross cut conveyor. The cross cut drive could be eliminated if a belt bender were employed.

2.11.4 The Advantage of a Twin Conveyor System

The advantages of a twin conveyor system are :

a) Each section can work more roadways for a decreased tramming section.
b) The tipping area is less congested, giving each section 3 tipping points, which results in less shuttlecar waiting time, especially where a feeder breaker is required to regulate the flow.
c) This increase in working places is important in maintaining a continuity of operations. It allows for a natural spacing out of the machinery as the various cycles operate at different speeds depending on the conditions which are encountered in each face. As breakdowns occur, a greater time margin is allowed for before production is brought to a halt.

2.11.5 Double Header Machinery Deployment

Machinery deployment for each side of the double header section would be similar to that of the single header section, though savings in spare equipment could be made if desired.

2.11.6 Double Header Manning Requirements

Manning configurations would also be similar. A reduction of one tip attendant where a single conveyor is operated would be unlikely, due to the increase in the amount of spillage.

CHAPTER 3

CONTINUOUS MINERS

CONTINUOUS MINERS

3.1 THE GROWTH OF CONTINUOUS MINERS

Continuous miners began to be introduced in the U.S.A. around 1948 and gained popularity through the 1950's and 1960's. In 1968 they became the largest underground production method in the U.S.A and today 3 000 continuous miners are producing two thirds of that countries total underground production. Harrold (3).

In their evolutionary process they progressed from fairly primitive versions with ripper chains and swinging cutter heads to the present configuration with a solid, chainless or nearly chainless cutter drum. The machine mass and installed power has generally increased over this period so that they can more effectively cope with more demanding conditions.

Continuous miners started to become popular in S.A. during the mid seventies and since that time their numbers have risen steadily. The fact that they were easily manoeuvrable meant that they fitted well into the conventional system of moving from heading to heading. They incorporated the under-cutting, drilling, blasting and loading steps of conventional mining and left the hauling and roof control steps nearly unchanged.

In their early days they were regarded as being something of a specialist machine to be used in areas of poor ground control but today with around 125 deployed in 18 collieries they are firmly established as an alternative production system.

Much research has been undertaken to increase the performance of these machines and the Chamber of Mines has played an important role.

Since 1978 they have been correlating information which has been supplied monthly by the collieries.

3.2 CONTINUOUS MINER OPERATIONAL FACTORS

3.2.1 Productivity of the Continuous Miners

The Chamber of Mines of South Africa Coal Mining Laboratory define production time as the available section time minus the downtime.

The machine availability is a relationship between the output per operating time (the time that the machine was cutting during the shift) and the output per total time (the time during which the operators were in the section). Hardman (7)

The average machine availability calculated from the data which was submitted by the collieries was found to be 67,1%. There was however, a wide range of production rate values due to the large data set. This averaged out to be 76t per operating hour and 51t per total hour.

3.2.2 Production Time Vs Production Rate

From analysis of the submitted figures it was found that there was little variation in production time per month for the various types of machines at the different collieries.

When machines which operate under similar conditions were compared, large differences in the performance statistics were found. This would indicate that the differences were due to the operational and engineering procedures.

The mining method has a very important influence on the production rate.

Studies made at one colliery where the management and engineering procedures were consistent, with little variation in seam conditions showed considerable variation in production rate as the mining method varied.

This is due largely to the effect of section geometry on the shuttlecar and continuous miner tramming times in addition to the cuttability of the coal being affected by the additional stress levels involved in rib-pillar operations.

TABLE 3.1 shows the difference in output between different mining operations.

MINING SYSTEM	PRODUCTION TIME	OUTPUT PER OPERATING HR	OUTPUT PER TOTAL HOUR
Bord & Pillar	59%	82t	47t
Rib-Pillar	78%	96t	75t
Longwall Development	73%	50t	33t

This amounts to approximately one third of South African deep mined coal. Continuous miners applications tends to be restricted to medium height seams although there are a few operating in narrow and thick seams.

Of the total number of machines operational in S.A. the following represents a fairly accurate breakdown of the height of seams in which they are operated.

TABLE 3.2

SEAM HEIGHT	% IN OPERATION
< 1,5m	1%
1,5m to 2,4m	16%
2,4m to 3,0m	36%
3,0m to 3,4m	28%
3,4m to 4,2m	18%
> ,2m	1%

3.2.3 Cutting Height

Cutting height has an important influence on in-section performance. This is due to a number of reasons :

a) The sumping operation is less productive than that of shearing therefore in higher seams a greater part of the operation is constituted by the more productive operation.
b) In lower seams a greater proportion of the machine's time is spent on tramming due to the cutting operation being that much shorter.
c) The lower seam height also inhibits good supervision of the section and makes the work more demanding. This results in the necessary preparatory work not always being completed ahead of the machine and jobs such as cable handling becoming more ardous.
The drilling of roofbolt holes may require the use of three different size drill steels.
d) The availabilities of the machine in lower seam heights also tend to suffer from the less pleasant conditions under which the engineering staff operate. Persons are less liable to undertake preventative maintenance, get around the section less frequently and hence fail to take corrective action before a breakdown occurs.

3.2.4 Variation in Actual Performance to Rated Performance

Although the continuous miner cutting drum may be rated between 600 and 250t/h the actual results which are achieved fall considerably short of this (on average 92 to 48t/h). This is due mainly to section designs and the machine operating procedures, with machine downtime having a lesser effect.

To determine the overall production rate it is necessary that the cutting rate be considered.

The cutting rate is the first essential value which determines the overall production rate of the machine cutting at the face. It is a weighted average of the sump and shear cutting rates.

$$\text{cutting rate} = \frac{\text{tons/sump} + \text{tons/shear}}{\text{time/sump} + \text{time/shear}}$$

the factors which affect this are:

a) The mechanical characteristics of the machine i.e. mass and installed power.
b) Cutting mechanism factors i.e. pick configuration, their type and condition of wear.
c) Properties of the coal seam i.e. hardness, frequency of cleats, fractures, mineral inclusions and confining pressure.
d) Face cutting sequence - where the drum is sumped and the direction of shear.
e) Advance per cycle.

3.2.5 Cutting Force

Cutting force refers to the force acting on the pick in its direction of cutting. The average cutting force multiplied by the distance cut gives the work done by the pick. The norm' force acts perpendicularly to the cutting force and is the force which must be overcome in order to keep the pick at the required depth of cut.
Roxborough (8).
See Figure 3.1 (after Roxborough).

The specific energy is the work done per unit volume or weight of coal cut and is the principal measure of cutting efficiency. Any decrease in specific energy means an improvement in cutting efficiency.

PICK CUTTING FORCE

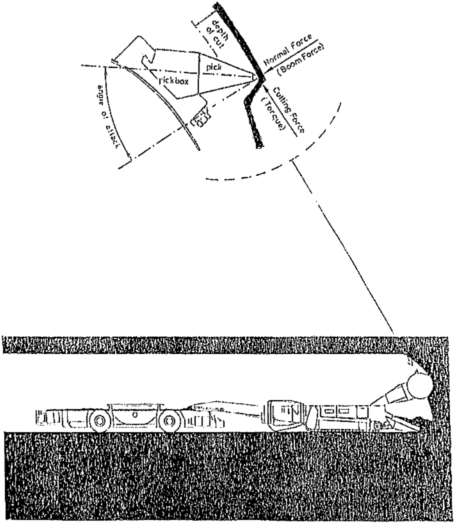


Fig 3.1 (after Roxborough)

3.2.6 The Effect of Pick Spacing

This is an important design consideration of the manufacturer. It influences the boom force and torque required at the cutting head. As there is a strong correlation between depth of cut and pick spacing it is important that the most efficient combination is found. Boardman (9).

While the widest spacing is potentially the most efficient the picks must be able to cope with the higher forces generated in cutting deeper so that an interaction of the picks can occur.

As there is a geometric similarity in the groove formed by a pick cutting to different depths, spacing can conveniently be expressed as a multiple of cutting depth.

3.2.7 Pick Influence

Most mines have conducted their own investigations into which pick type was best suited to their conditions. Despite claims of the various manufacturers the differences as far as cutting rate is concerned are very small, though the benefits of pick life against cost may be attractive.

The sharpness of the pick is important and worn picks can reduce the cutting rate by over 40% whilst increasing the make of dust. Rataj (10) The most popular method of maintaining the picks in a sharp condition is through an anchorage such as the tri-tite system where the picks are allowed to rotate in their fastenings promoting a self sharpening action.

3.2.8 Advance Per Cycle

When the cutter drum sumps into the face a decrease in tramming speed is affected by the control circuitry as resistance increases. When the drum has been sumped into half its diameter and the maximum number of picks are now in contact with the coal no further decrease occurs and the sumping speed remains relatively constant.

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The forces required for sumping are significantly higher than the required downw·rd force on the boom for shearing. It is vital therefore that floor conditions and the condition of the cat tracks is good to prevent any loss of traction. Alrhough there are fewer picks engaging the coal when shearing the action of sumping has opened up a second free face which is exploited by the cutter drum.

3.2.9 The Optimum Depth of Sump

From underground studies, the following results have emerged:

a) Cutting torque increases linearly with depth of cut for both sumping and shearing.
b) Specific energy reduces with depth of cut. Larger sizes are produced with less energy being wasted through the production of fines.
   See Figure 3.2 (after Roxborough).
c) The cutting rate increases linearly with shearing depth.

It is therefore apparent that sumping in the boom to its maximum will maximise the cutting rate.

3.2.10 Face Cycle Rate

This is the average rate which a continuous miner would produce coal disregarding the interruptions which are caused with its transportation. Rataj (10).

It is defined as the ratio between the amount of coal obtained from a cutting cycle and the face cycle time.

$$\text{face cycle rate (t/min)} = \frac{\text{tons per cutting cycle}}{\text{face cycle time}}$$

The operations which comprise the face cycle are that of sumping and shearing (the cutting cycle) plus the non-productive operations of raising the cutting boom and manoeuvering between cutting cycles. Also included is the time spent trimming the roof and floor.

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SPECIFIC ENERGY VERSUS DEPTH OF CUT

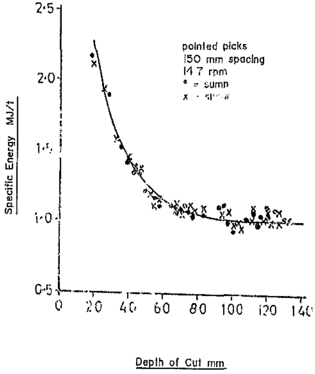


Fig 3.2 (after Roxborough)

Increasing the face cycle rate therefore, can be achieved by paying attention to the following operations:

a) Increasing the cutting rate.
b) Trimming the roof and floor at pre-determined distances in order to maximise efficiency.
c) No unnecessary floor sweeping being done with the c/m.
d) Efficient face cutting sequence.
e) Cutter boom lift speed not being allowed to fall below manufacturers specifications.
f) Efficient handling of cable when tramming between headings.

Output per operating time takes consideration of shuttlecar change out delays and time spent tramming the continuous miners which are affected by the particular section geometry. The overall production rate or output per total hour can then be calculated which includes all the delays in the production of coal.

3.3 HUMAN FACTORS WHICH INFLUENCE PRODUCTION

From experiments conducted by the Chamber of Mines it was found that all other factors being equal the rate of production from a given depth of sump was not consistent for different c/m operations. This became apparent in numerous observations with different types of machines. The sequence in which the roof was being trimmed also had an important bearing on the efficiency of the cutting cycle. Sumping in adjacent to the roof and effectively trimming it would reduce roof trimming time, though in areas where the roof was uneven a further roof trimming cycle may often be required.

There is a high skills level which needs to be attained by the driver in order that he operates the machine at its most efficient.

The imparting of this knowledge *can be greatly helped by training.* The development of various other control features on the continuous miner could also assist in this regard i.e. :

a) Sump depth indicator.
b) Shear down rate as compared to the optimum.

Obviously, the mechanical condition of the machine is very important and the tramming circuitry and boom lift rate are two prime factors which have a direct influence on the efficiency with which the machine cuts coal.

Notwithstanding the fact that a malfunction of the machine leading to downtime directly influences the available cutting time, the consequences are often more far reaching. Some machine downtime is usually allowed for when calculating the expected production rate but if this starts to become excessive then the morale of the production team can be affected. This results in the machine failing to perform at its potential cutting rate during the period that it is available. The engineering department is therefore an integral part of the production team. Preventative maintenance which stems from careful observation by knowledgeable personnel plays a critical part in the efficient and cost effective running of a production section. Potentially large breakdowns can be quickly rectified before they become serious and result in the breakage of further components. Scheduled maintenance plays a very important part in picking up these problems. There can be no doubt that regular stoppages for such work pays dividends.

The efficiency with which the section is managed is also a key aspect in its productiveness. There are great benefits to be gained by having a well qualified supervisor running operations at the face as a well planned operation is invariably subjected to less delays.

Observations were undertaken in America by various industrial engineering companies to investigate the large numbers of unnecessary delays which appeared to be affecting the production cycle. When the performance characteristics of the haulage equipment and the roofbolting cycle were looked at more carefully it became apparent that it was almost always the continuous miner which was the critical element affecting section productivity. The skill of the operator was again paramount in determining the efficiency with which the machine operated. In the U.S.A. many machines are operated remotely, often due to low seam conditions and to protect the driver from dust. This makes good operation difficult as the driver does not have the same feel of his machine though considerable advantages are derived from the safety point of view. Harrold (3).

3.4 THE EFFECT OF THE HAULAGE SYSTEM

3.4.1 Shuttlecars

With an intermittent haulage system the most critical area is the time required to change out cars at the face. Vehicle capacity is also an important factor with speed, haul distance and the use of a feeder breaker being secondary. When tramming distances increase, speed, capacity and the use of a feeder breaker become important. By having larger capacity cars and ensuring that the shuttlecar change out was within one cross cut of the face, haulage delays were held at a minimum. While diesel and battery equipment offers advantages over cable vehicles as far as flexibility is concerned, the initial capital outlay is greater.

3.4.2 Continuous Haulages

As their technology improves continuous conveyor transport systems are gradually replacing the shuttlecar. Often they comprise an extendible or fixed mobile conveyor mounted on rubber tyres. By interlocking these haulage units a flexible connection is formed between the continuous miner and the section belt.

Belt benders have now been perfected which can turn the belt by any angle up to 90 degrees allowing one continuous conveyor belt to transport coal from the continuous miner on to the section conveyor. Despite early problems with spillage these units are becoming more popular with many operators now claiming benefits in productivity and reduced cost per ton.

3.5 PRODUCTION CONFIGURATION FOR CONTINUOUS MINERS

3.5.1 Mining Methods Employed

The application of continuous miners in South African Mines is varied. They are engaged in a wide variety of coal getting operations in differing seam heights and conditions. Their present distribution can be summarised below:

Bord & pillar development	54%
Longwall development	20%
Rib pillar section	16%
Pillar extraction	10%

3.5.2 Bord and Pillar Development

Board and pillar developments typically vary from five to eleven roads with pillar centres averaging 25 metres.

Sections are commonly worked with either 1 or 2 production units. With coarsed ventilation it is becoming more common for only one unit to be operated at a time due to the high levels of dust to which personnel on the return side machine are subjected.

3.5.3 Cutting Sequence

Various cutting sequences are practiced depending on the preference of the operating company and numerous studies have been conducted to optimize the cutting cycle.
Wheeler (11) and Posniak (12) produced a computer program that simulated the cutting cycle in a continuous miner section.

The cutting sequence when one machine is available varies from that of a double header section. With one machine operating at a time the opportunity arises to tram the other machine to its next cutting position or pull it out of the face being cut to allow for roofbolting, examination and changing of picks, where necessary.

In areas of bad roof, roofbolting is the biggest constraint to continuous production. Although some of the larger machines have on board roofbolting systems, independent, self propelled roofbolt machines are still preferred. These ensure that the operator is not working in the return air while the continuous miner is cutting and enable bolting to be carried out right at the face if conditions so require. An on board roofbolting facility would also stop the coal winning process completely should it develop a fault.

Future developments indicate that "Hands off" bolting is likely to come to fruition in the near future. This would be an automatic bolting facility which would allow the operator to bolt from the safety of his cab.

The Joy "Link Sump" miner (12CM 10-13 ADLS) has now been developed which enables the cutting jib to be sumped forward 0,75m without the body ~ the machine moving. This allows the machine to remain stationary for a longer period of time while producing coal, so that on board bolting operations can be completed.

3.5.4 Calculating the Optimum Cutting Cycle

The Chamber of Mines of S.A. have developed a program which calculates the production potential of continuous miner section layouts. Numerous different configurations, straight line, herringbone and designs which ensure one part of the section is kept in advance, have been evaluated. The input required by the program are the section dimensions including number of headings, pillar size, bord width, mining height and distance of advance for each lift in straights and splits.

The position of the faces from the tip-end with number of through roads and the proposed position prior to the next belt extension are also input. See Figure 3.3 Machine information includes roofbolting time and machine tramming time, continuous miner *loading rate and tramming speed.*

The number of shuttlecars operating, their pay load and tramming speed both full and empty, together with their discharge time are entered. The shift time and combined machine availability calculated for the operation as a whole is also an input and the following results are obtained :

a) The available face minutes per shift
b) Tons per face minute
c) Tons per shift
d) Total tons for the planned mining cycle up to the next belt extension.

The continuous miner utili[illegible]ation, shuttlecar change out and *wait on shuttlecar t*[illegible]ulated. Shuttlecar change out distances, tot[illegible]nces and tons per km of travel are worked [illegible]her with various factors pertaining to the shuttleca[illegible]tilization.
See Fig. 3.4 (from Chamber of *Mines of South Africa*).

3.5.5 <u>Program Limitations</u>

Results can be compared for different section layouts in order that the most efficient be determined. The influence that the cutting sequence has on section ventilation is however not taken into account and has to be considered separately. This is important in order that the desired tramming roads are not blocked by ventilation control barriers.

The continuous miner, which can flit at 20m/min, is restricted by the time it takes to move its trailing cable and therefore the cutting sequence should be planned to reduce this to a minimum.

PROPOSED CUTTING SEQUENCE FOR COMPUTER EVALUATION

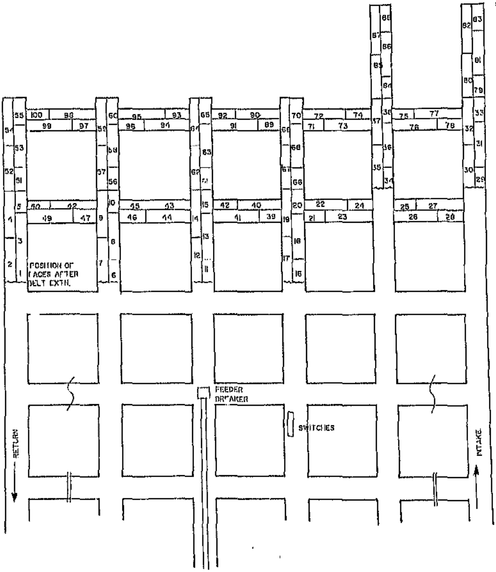


Fig 3.3

CHAMBER OF MINES COAL MINING LABORATORY

SIMULATION RESULTS OF CONTINUOUS MINER BORD AND PILLAR MINING

COLLIERY .... SEAM .... SECTION .... DATE ....

INPUT DATA		RESULTS	
SHIFT TIME (mn)	552.1	AVAILABLE FACE MIN/SHIFT	444.8
MACHINE AVAILABILITY (%)	108.1	TONS PER FACE MINUTE	2.77
		TONS PER SHIFT	1535.1
NUMBER OF HEADINGS	6	TOTAL TONS MINED (CYCLE)	6697
PILLAR SIZE (ADVANCE)(m)	18.7		
PILLAR SIZE (L-S) (m)	18.7		
BORD WIDTH (m)	6.3	TONS PER CUT (ADVANCE)	94.1
MINING HEIGHT (m)	2.00	TONS PER CUT (SPLITS)	50.9
DEPTH TO FLOOR (m)	0.0		
SAFETY FACTOR	2.0	CONT. MINER UTILIZATION:	
		-CUTTING %	61.3
DEPTH OF CUT (ADV.) (m)	6.3	-TRAMMING %	5.4
DEPTH OF CUT (SPLITS)(m)	6.2	-WAIT S.C.CH.-OUTS	24.0
S.G. OF COAL	1.50	-WAIT NO S.C %	8.2
INITIAL ADVANCE FROM S-P	32.1		
No OF INTL. THROUGH RDS	1	R.B. UTILIZATION %	2.5
SELF EXT. (LIKE PILLARS)	2		
R.B. TIME (mn/10m)	0.1	SHUTTLE-CAR(S):	
R.B. TRAVEL SPEED (m/mn)	50.0	TONS/KM OF S.C. TRAVEL	62.0
		TOTAL CH.-OUT DIST. (km)	42.7
C.M. LOADING RATE (t/mn)	4.5	TOTAL ROUTE DIST. (km)	105
C.M. TRAVEL SPEED (m/mn)	6.0		
NUMBER OF SHUTTLE-CARS	2	S.C. UTILIZATION:	
S.C. PAYLOAD (RATED) (t)	10.0	-WAIT FOR NEXT CUT %	10.4
S.C. PAYLOAD (ACTUAL)(t)	9.0	-LOAD & DISCHARGE %	40.6
		-CHANGE-OUT %	12.6
S.C. SPEED EMPTY (m/mn)	75.2	-WAIT MAIN CH.-OUT %	15.0
S.C. SPEED FULL (m/mn)	72.5	-WAIT OTHERS CH.-OUTS	0.0
S.C. DISCHARGE TIME (mn)	0.7	-TRAVELLING %	17.6

Fig 3.4

(after Chambers of Mines of South Africa)

The positioning of the section switches is important in this regard, as well as ensuring that the desired roadways can be cut with the standard cable length, usually 200m. A typical cutting sequence is shown for a seven road double header section. See Figure 3.5 The sequence ensures that each machine does the same amount of cutting. The first splits are cut to the right in order that the ventilating air can be channelled through the newly opened roadway when the adjacent splits are cut. The switches are positioned so that the cable movements are minimised and the maximum reach is attained. Machine maintenance and breakdowns disrupt the cutting sequence and result in increased tramming distances by the continuous miner. This has to be accepted otherwise the proper ventilation of the section will suffer as the roadways are cut out of sequence.

Often the most desirable layout cannot be worked due to design constraints imposed by the overall mine plan i.e. :

a) Large pillar centres have to be worked when a increased safety factor is desired. (the more advantageous squat pillar formula is not yet generally permitted).
b) Barrier pillars have to be left to protect the roadways from subsequent total extraction resulting in large pillar centres.
c) The conveyor may not be positioned in the centre road as this would not allow belt drives to be established for subsequent developments.

3.5.6 Chain Road Developments

Continuous miners are ideally suited to working chain road developments. These are driveages which are advanced with the minimum number of roadways for the development of either longwall or rib pillar extraction sections. The small number of faces that are worked with this type of driveage make a blasting section inefficient.
See Figure 3.6.

CUTTING SEQUENCE FOR A 7 ROAD DOUBLE HEADER SECTION

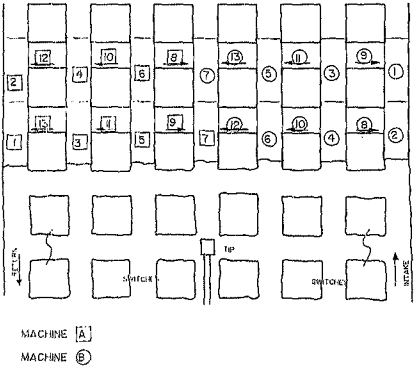


Fig 3.5

CUTTING SEQUENCE FOR A CHAIN ROAD DEVELOPMENT

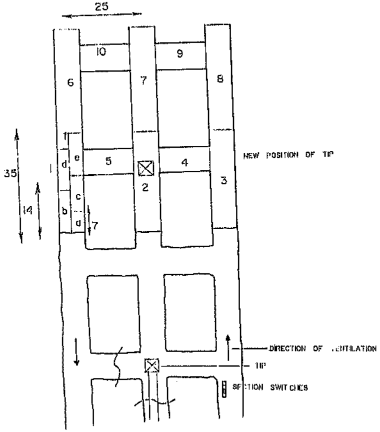


Fig 3.6

In South Africa the development of one single roadway is not popular and the luxury of developing more than one can be afforded due to the relatively light support work which is necessary. Multiple roadways make for easier ventilation during development and ensure unrestricted access for free steered vehicles, a much more versatile transport system.

A three road chain road development can be advantageous with longwalls. The conveyor is sited in the middle road so that one of the pillars is extracted as part of the face line and a mid gate is formed next to the maingate roadway. This allows an easy access to the face machine for service and repairs.

The development may leave small pillars which are partially extracted and become crush pillars or leave large stabilising pillars.

3.6 TOTAL EXTRACTIVE METHODS OF MINING

3.6.1 Total extraction can be achieved with continuous miners when the following mining methods are practiced. This will be conditional on the necessary permission being received from the surface land owners and the inspectorate due to the subsidence which results.

3.6.2 Rib Pillar Extraction

Rib pillar extraction involves the systematic removal of coal between the goaf and the development roads using the solid as yet intact rib of coal to provide the major support. The method is fairly new to South Africa with most of the pioneering work having been carried out in Australia since permission was granted for the mechanical extraction of pillars in the 1950's.

One popular system which was developed in Australia is the Wongawilli method. It provided a single working place which reduced the possibility of leaving remnant pillars in the goaf. This enables the coal to be extracted in a "stress relieved" area. Various derivations of the Wongawilli method are practiced depending on local conditions. Typically chain roads are driven out to form a central panel of coal which is to be extracted. From the chain road, splits are systematically driven across the panel to the barrier which may be a goaf or another chain road.

Between the split and the goaf a rib of coal is formed which is subsequently pocketed on retreat. The small snooks which are left are crushed by the goaf. Usually the pillars of the chain road are also taken. The next split is very often being developed in advance of the stooping operation by a second continuous miner allowing one machine to be dedicated to stooping. The width of the rib will vary according to conditions. If the ground conditions are bad the rib may be narrowed allowing the continuous miner to extract it while the driver remains under the supported split. The machine could also be operated by remote control.

It is important that every effort be made to complete a lift and partially taken lifts should not be left at the end of shift otherwise large snooks may be formed which cause weight to be transferred to the development roads, resulting in deteriorating mining conditions. The single split can lead to ventilation problems if the goaf seals off the ventilation. It may not be desirable to ventilate through the goaf if the coal is conducive to spontaneous combustion. In this instance an exhaust column is carried in the split. Where the goaf is sealed off the dangers of methane emissions arise with a fall in barometric pressure. With the long single entry the travelling time for the shuttlecar in the split is too long.
See Figure 3.7 (after Fauconnier).

THE WONGAWILLI METHOD OF RIB PILLAR EXTRACTION

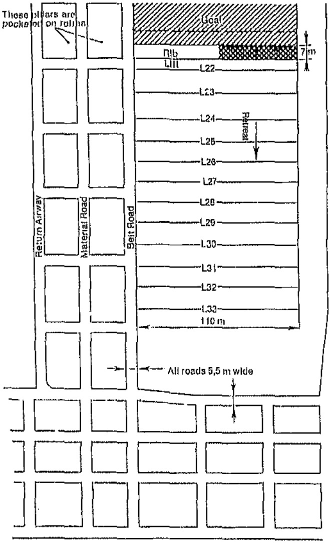


Fig. 3.7 (after Fauconnier)

Extraction ratios can be as high as 90% when good mining conditions prevail.

3.6.3 *The Munmorrah Method*

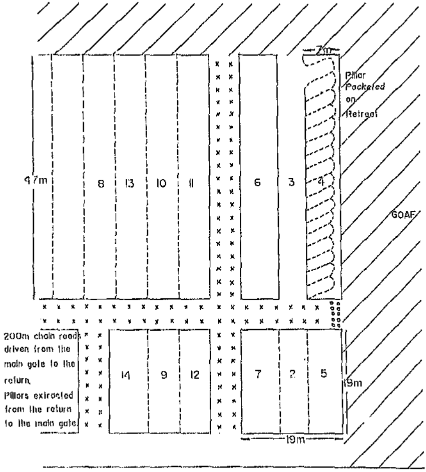
The Munmorrah method which was also developed in Australia is very similar to the Wongawilli method in the way that the chain roads are driven and the area blocked out. The rib of coal which is left after the split is driven, is wider, over 20m. This rib is then split into pillars. From the roadway which is formed the machine cuts pockets (lifts) into the pillar thus extracting it. The pillar is often determined such that the continuous miner operator works from under the protection of the roadway supports.

As the pillar is extracted from the goaf towards the split a breaker line of timber or hydraulic supports is installed after each lift to protect the roadway from a goaf overrun. Ventilation can be coursed around the continuous miner with the aid of extraction fans or if conditions allow channelled through the goaf making for a cleaner working environment. Average production rates of 500 tons per shift are similar to the Wongawilli method with 90% extraction ratios being achievable given favourable conditions. Fauconnier (13) See Figure 3.8.

3.6.4 *South African Rib Pillar Stooping*

South African collieries have favoured the Munmorrah method of rib pillar stooping and methods similar to it have been tried at Sigma, Kriel and New Denmark collieries. In each case bleeder roads were established through the goaf. The system operated at Kriel and New Denmark ensured that two splits with connecting laterals was driven across the panel which allowed the shuttlecar change out point to be positioned close to the continuous miner.
At New Denmark one machine was used to develop the splits, while the other was used solely for stooping. Cross belts were installed to reduce shuttlecar tramming distances.

THE MUNMORRAH METHOD OF RIB PILLAR EXTRACTION AS PRACTISED AT NEW DENMARK COLLIERY



× ROOFBOLTS

ooo BREAKER LINE

SCALE 1: 500

Fig. 3.8

This higher rate of extraction which was achieved helped to maintain better face conditions due to the faster rate of retreat. Both machines could produce a total of 40 000t of coal per month from a 2m seam height with an 85% extraction ratio.

The design of the panel width has to taken into account the thickness and caving characteristics of the rock strata overlying the coal seam and the section must be designed to handle an increased make of water and gas due to caving. The local roof strata must be able to safely bridge the bord and the increasing diagonal working span without falling. Early and regular caving of the upper and local roof strata must occur at a steep angle to relieve the stress on the roadway without overrunning the breaker lines. The increased stress to which the pillars are subjected ensure that the energy exerted by the continuous miner in cutting the coal is greatly reduced and the coal is loaded at a faster rate.

3.6.5 Pillar Extraction

Pillar extraction has been practiced in South Africa for many years being more popular in the thinner seams of Natal. Where thick seams exist top or bottom coaling is preferred, the apparent abundance not being conducive to the development of pillar extraction. Generally pillar extraction is easier at greater depths as better caving is induced in a reasonably competent roof, which is necessary in order that it may be held by temporary supports. The supports must be readily removable and remnants able to be crushed in order that weight is not transferred onto the working area.
The reason for pillar extraction is often to provide additional reserves once an area has been worked out rather than as a planned conclusion to primary mining. With the latter case the pillars can be extracted before the roadways are allowed to stand and deteriorate allowing the conveying system and services used in primary mining to be reused.

Larger safety factors in excess of 2,2 are designed for primary mining and panel dimensions often with reduced bord widths are calculated with due regard to the rock mechanics of total extraction. Pillar extraction increases the loading on pillars in the vicinity of the goaf edge and hence the strength must be greater than that required to support the static load imposed in primary mining. As the pillar is reduced in size during the mining process so stress increases. The success of recovering it before failure depends on the rate of removal. Continuous miners therefore have an important edge in this respect and afford a greater degree of protection to the operator with less people being exposed to risk at the working face.

3.6.6 The Mining System

Pillars are commonly extracted by either of two methods 'open end' or 'pocket and fender'. These two techniques are the most commonly used to systematically reduce the pillar in size.

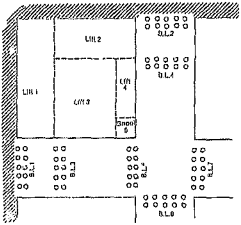
See Figure 3.9 (after Fauconnier).

The 'open end' system ensures that slices are taken from the side of the pillar next to the goaf with the remainder of the pillar complementing the artificial support.

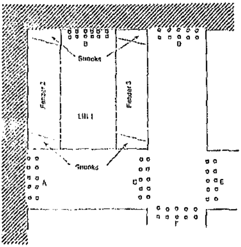
In the 'pocket and fender' system the pillar is reduced by taking a pocket out of its centre. The fenders give good support and can supplement either props or roofbolts. If possible they too are recovered.

This method is often preferred with continuous miners. With either method it is important that the pillars are removed in a sequential manner to avoid protrusions into the goaf and formation of highly stressed areas. For this reason an extraction line angle of 45% is often chosen. In order to optimize the tramming distance the conveyor road is situated nearer the trailing edge of the stooping line.

PILLAR EXTRACTION MINING METHODS



USUTU COLLIERY - EXTRACTION SEQUENCE OF LIFTS IN OPEN - END PILLAR EXTRACTION.



USUTU COLLIERY - EXTRACTION SEQUENCE OF LIFTS IN THE POCKET AND FENDER METHOD OF EXTRACTION

Fig 3.9 (after Fauconnier)

Support can be by either hydraulic props, timber or roofbolts. Given that the roof is not too friable roofbolts are preferred in mechanised sections du: to their rapid installation and non interference with tramming routes. A practical height limit of 3,5m is imposed in the workings due to the breaker lines which have to be installed. Fauconnier (13).

3.6.7 Continuous Miner Pillar Extraction

South African conventional mining pillar extraction operations have largely been replaced by continuous miners due to the following reasons :

a) Higher productivity of the system.
b) Reduction of costs per ton mined.
c) Greater safety.
d) Less labour intensive.
e) Greater concentration of supervision as only one pillar is extracted at a time.
f) Greater control over the goafing of the roof.

The percentage extraction in panel is slightly lower for a continuous miner, 85% as opposed to 90% because a solid rib of coal is left on the goaf side edge of the pillar. The production equipment normally consists of one continuous miner and three shuttlecars.

This "total extractive" method of mining can readily be undertaken with continuous miners for very little extra capital outlay. A large degree of flexibility can be catered for as variations in the mining system can be developed to cater for quite differe· mining conditions.

3.7 DUST SUPPRESSION

3.7.1 The dust problems created by continuous miners are more serious than those produced by either conventional or longwall mining. This is due to the difficulties of ventilating headings adequately, to dilute the large amounts of dust which are produced whilst cutting. The cyclic nature of the operation requires that support work sometimes takes place on the return side of the machine exposing those personnel to high dust levels. With longwall mining better ventilation and new technology ensure that fewer people are exposed. The increased health hazard which high airborne dust concentrations create has prompted the government mining engineer to implement stricter legislation as the number of continuous miners have grown. The proposed mean dust exposure concentration for any mining operation shall not exceed 3,0 mg/m³ over an eight hour shift period. The implementation of effective counter measures are therefore a prime consideration of the operator.

Dust [illegible]ncentrations have been most successfully reduced by use of the following dust allaying equipment:

a) Spray nozzles which are mounted above, below and to the side of the cutting drum and can deliver up to [illegible] of water at 7,5 MPa (75 bar) via a high pressur[illegible] pump.
b) Hydraulic or electric fans which draw air from beneath the boom via intake ports through a flooded bed scrubber prior to exhausting on the return side.
c) Water powered venturi systems which produce finely atomised spray while moving large quantities of air across [illegible] cutting head.

These mach[illegible] systems, when used in conjunction with the more manoeuvrable hydraulic fan and light weight fibre glass ducting, are successfully reducing the dust concentrations in continuous miner sections.

3.8 INCREASED EXTRACTION WITH BORD AND PILLAR MINING

3.8.1 The Squat Pillar Formula

This formula allows for a higher primary extraction ratio to be designed for at greater working depth. Salamon (1982), saw the need to cater for mine pillar designs where the width to height ratio was greater than five, this being beyond the range of the original analysis. Madden (14).

The squat pillar formula is an extension of the pillar formula which was developed by Salamon and Munro (1967), and which has been used successfully since then for coal pillar design.

The formula was developed from statistical analysis of collapsed and intact pillar geometrics, and states :

$$\sigma_p = KV^{-0,067} \quad R^{0,593}$$

Where V is the pillar volume m^3
R is the pillar width to height ratio
σ_p is the pillar strength (kPa)
K is the strength of a unit of coal (kPa)
Pillar strength is a function of the geometry and composition of the pillar. The deformation behaviour of a pillar changes with increasing width to height ratio.

Materials that exhibit brittle violent failure at low width to height ratios can exhibit plastic or even ductile behaviour at large width to height ratios.

The squat pillar formula takes into account the increase in the strength of a pillar as its width to height ratio increases. Various researches have stated that the pillar formula probably underestimated the pillar strength when the width to height ratio exceeds 5 or 6. The limitation of the pillar strength formula is that it assumes that the strength of a pillar increased proportionally with a power of the width to height ratio. ($R^{0,593}$).

Salamon proposed that when the width to height ratio, R of a pillar exceeds the critical width to height ratio, Ro, then the strength should be expressed in the form.

$$\sigma_s = KV^a \; (\gamma \varepsilon + \delta)$$

Where γ, ε and δ are dimensionless parameters and σ_s is the strength of a squat pillar.

Parameters γ and δ can be determined from two conditions of continuity.
It is postulated that at R = Ro

$$\sigma_p = \sigma_s \text{ and } \frac{\partial \sigma_p}{\partial R} = \frac{\partial \sigma_s}{\partial R}$$

From these relationships the following ca be derived which has two unknown Ro and ε

$$\sigma_s = KV^a \; Ro^b \; \left\{ \frac{b}{\varepsilon} \left[\left(\frac{R}{Ro} \right)^{\varepsilon} - 1 \right] + 1 \right\}$$

Where K is the strength of a unit cube of coal(kPa)
V is the pillar volume (m^3)
R is the pillar width to height ratio

a = -0,0667
b = 0,5933
Ro = is the critical width to height ratio beyond which the pillar should be regarded as squat.
ε = is the rate of strength increase.

This formula is compatible with the pillar formula of Salamon and Munro when Ro < R.

3.8.2 Laboratory Investigations

Investigations into the general behaviour of squat pillars conducted with sandstone specimens, fitted the squat pillar formula well and showed the following :

Specimens with width to height ratios of 1 to 2 rapidly lose load after the peak strength. As the width to height ratio increases, there is a transition in the mode of failure from a brittle to plastic mode of failure which occurs between the width to height ratio's of about 5 or 6, while specimens with a width to height ratio of 8 display a ductile failure.

The change from a brittle to ductile behaviour at large width to height ratio's is of great significance as far as the stability of bord and pillar workings involving squat pillars is concerned.

3.8.3 Selecting The Values Of Parameters Ro And ε

From field evidence it was found that no pillar with a width to height ratio of greater than 4 has collapsed. The value of the critical width to height ratio was selected as 5. A value of 2,5 was chosen for ε . This is considerably lower than that obtained from the laboratory tests on the sandstone specimens.

Figure 3.10 (after Madden) shows an increase in strength derived from the squat pillar formula as the width to height ratio increases.

Designs using the squat pillar formula are at present being permitted by the government mining engineer on an experimental basis until the relevant parameters have been confirmed by field investigations.

3.8.4. The Effect Of Spalling On Pillar Strength.

The effect of spalling and geological weaknesses on pillars is reduced as the size of the pillar increases due to the smaller percentage of the pillar area which is affected with increase in size.

The strength of the corners and sides of the pillar and the resulting spalling is however independent of the width to height ratio. Pillar stresses along the pillar sides are often greater than the strength of the coal making fracturing unavoidable.

PILLAR STRENGTH CALCULATED BY THE SQUAT PILLAR FORMULA AND THE CURRENT PILLAR STRENGTH EQUATION

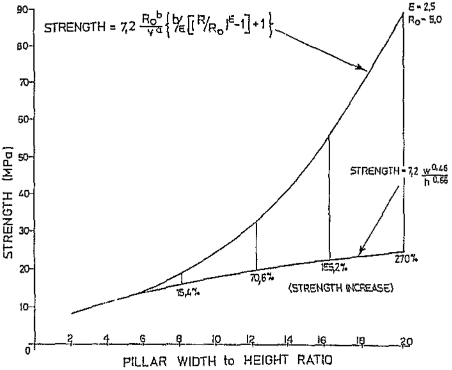


Fig 3.10 (after Madden)

Supporting the fractured surface will considerably enhance the confinement of the central core and therefore the fractured layer must be included in the dimensions of the pillar when considering the width to height ratio.

Side wall support is used underground to prevent accidents which can result from sidewall collapse, not to prevent violent pillar failure.

3.9 CONTINUOUS MINER MANNING LEVELS

3.9.1 American Continuous Miner Sections

Outputs from continuous miner sections are typically in the order of 500t per shift with output per man shift (OMS) values as high as 80t. This makes them not only excellent development systems for retreat mining but also very viable mining systems in their own right.

Manning levels for a U.S. c/m section are typically seven:

1 Miner Operator
1 Miner Assistant
2 Shuttlecar Operators
2 Roofbolters
1 Mechanic
7

One utilities man is often used on one shift to assist in the ancillary operations. The artisans work alone, the only assistance being given by apprentices if there were any in training. Each section has a section foreman who is responsible for ensuring that safety codes are followed, inspections are completed etc. He performs the role of the shift overseer and engineering foreman in S.A.

3.9.2 South African Continuous Miner Sections

Whilst some S.A. operators are achieving production rates in excess of 1000t per shift they would be hard pressed to match the O.M.S values of the American operators. U.S. operators limit their section complements to the minimum in order to reduce labour costs. S.A. practice has been to maximise production levels and accept the higher manning levels because of the relatively cheap cost of labour. This is true for both production and development sections.

The inevitable increase in labour costs is however forcing operators to cut their manning levels. Unskilled workers are being trained to fulfil a wider job category and machine men trained to be multi operators. Further reductions are possible by reducing the chain of command and taking away the team leader. It is unlikely that production would need to be sacrifired in order to reduce labour costs.

A typical complement for a single machine continuous miner section would be as follows :

1	Section Miner
1	Team Leader
2	Continuous Miner Operators
2	Shuttlecar Drivers
2	Roofbolt Operators
1	Electric Drill Operator
2	General Labourers
1	Belt Tailend Attendant
1	L.H.D. Driver
1	Electrician
1	Electrical Aide
1	Fitter
1	Fitter Aide
17	

3.10 MAXIMISING PRODUCTION

3.10.1 Absenteeism

With a reduced workforce the problems of absenteeism become more important and might result in production sections being closed down to man up others at times of high absenteeism. With a large workforce sufficient labour is available to allow production to continue.

Successful U.S. companies have overcome the problem of absenteeism by ensuring that their employees are given a good remuneration package which when linked to productivity incentives increases the responsibility of the individual for ensuring that company goals are attained. In non unionised mines this has been particularly successful with employees realising that they are an important part of the production team. This in turn enables the operation to become more self supervising.

3.10.2 Management of the Operation

A continuous miner is a complex machine which requires a high level of technical expertise in order that it is maintained in optimum condition. A high standard of operator and artisan is required to ensure that the machine gives good availabilities. This is evident from the wide range of production figures which are achieved by different S.A. operators, given that conditions do vary.

In order that the best results be achieved the following criteria have to be met:

a) Personnel must be carefully selected and properly trained and organised in a functional manner.
b) Artisans with good mining skills are recruited and given specialised training applicable to the specific continuous miner and associated machinery.

c) A structured maintenance program with a firm management commitment.

d) Maintenance facilities must ' adequate, systematically arranged and properly tooled.

e) Planning and record keeping are crucial segments of the engineering organisation.

f) Working conditions are conducive to retaining personnel.

g) Personnel are positively motivated to ensure that they give a high level of commitment to their work.

3.11 CONCLUSIONS - CONTINUOUS MINERS

3.11.1 Mining systems

Continuous miners can be considered for a wide variety of mining systems which range from primary development work with multiple or a limited number of headings, to full seam extraction.

Their application is best suited to specialised work such as chain road developments, where the limited number of headings is restrictive on a blasting section, and to pillar extractions, where they offer a greater degree of safety than conventional stooping. Unique mining systems have been developed for the continuous miner, namely rib pillar stooping.

Continuous miners are useful where poor roof conditions prevail, as they cause less damage to the overlying strata than with blasting. Adverse floor conditions will however cause problems, as the heavy machine lacks manouverability.

3.11.2 Technological considerations

The continuous miner requires a high quality of maintenance from skilled artisans, in order that it performs at its optimum rate. Serious consideration has to be given to the training and retention of such personnel.

3.11.3 Labour requirements

The system is less labour intensive than a blasting section, but a smaller tonnage would be expected, given compatible condition.

3.11.4 Application

Where high seams are mined in conjunction with good floor conditions, the potential tonnage from the continuous miner section rises and the engineering costs decrease.

Given these conditions and when employed in one of it's specialised applications, the continuous miner offers a useful mining method.

CHAPTER 4

LONGWALL MINING

CHAPTER 4

LONGWALL MINING

4.1 THE INCREASE I[illegible] POPULARITY OF LONGWALL MINING

4.1.1 THE ORIGIN[illegible] LONGWALLI[illegible]

Mechanised l[illegible]wall faces were developed from European hand got longwalls whe[illegible]e the coal was hewn by hand, loaded on to tubs and pushed to the gate road. Support was by props and bars and the roof was allowed to cave as the face advanced forwards.

Gradually, the system was refined as face conveyor belts, undercutting machines and then the walking chock were developed.

Present day state of the art longwall equipment represents a tremendous leap forward in technology over the past 30 years. This has boosted the production potentials of today's longwall faces quite dramatically.

4.1.2 CURRENT WORLD WIDE TRENDS IN LONGWALL MINING

Around 50% of the world's total underground coal production is presently being mined by the longwall system. Longwall mining has always been the most popular underground mining method in Europe.

Due to the large economic potential of longwall mining, countries which traditionally employed room and pillar mining methods, i.e. USA, South Africa, Australia, New Zealand and India, are switching over to longwalling.

4.1.3 U.S. LONGWALLING

From 1978, U.S. longwall production has jumped from 4% to 17,7% (1985) of underground coal production in a bid to accelerate improvements in productivity and efficiency. Modern longwalling equipment has typically increased production from 910t per shift in 1980 to average 2725 tons.

4.1.4 S.A. LONGWALLING

Although some longwall systems were tried in the 1920's and 30's in Natal without much success, because of the inadequacies of the timber and friction prop support system, the first S.A. longwall was installed at Durban Navigation Colliery in 1965.

Sasol's first longwall commenced production in 1975. This was after earlier experiments with chocks (1967) had proven the rock mechanics to be suitable. It was felt that the increased tonnages which could be expected from the more modern equipment would make the system economical. Since then, a further 7 have been installed at Secunda.

During 1985, twelve longwall faces produced approximately 12 million tons.

At the present time there are 15 longwall faces being operated at the following mines :

Secunda Collieries	7
Sigma Colliery	1
D.N.C.	3
Coalbrook	1
Matla	1
New Denmark	2

4.1.5 THE FUTURE OF SOUTH AFRICAN LONGWALLING

Prediction as to the future of longwall mining in S.A. have tended to be too optimistic, and a more moderate growth rate has transpired.

Mining companies are becoming more conscious of the need to increase their percentage reserve recovery. Future longer term underground mining will tend to be at a greater depth. The number of total extraction mining methods is therefore likely to increase. This does not however, guarantee the growth of longwall mining as alternative methods of total extraction exist. The most important determining factor will be longwall mining's ability to compete with other mining methods on a cost per ton basis.

4.2 PLANNING THE LONGWALL SECTION

4.1.2 CONSTRAINTS TO LONGWALLING

The following factors should be considered when planning for longwall mining :

a) Panels should exceed 1km in unfaulted ground.
b) The time to complete a move must be minimised, requiring effici ransport systems and/or duplicate equipment.
c) A seam height of 0,8 - 4,5 metres is required.
d) Make of water and gas in the seam.
e) Gradient which will influence direction of extraction.
f) Previous and future mining where multiple seams exist.
g) Liability of coal to spontaneous combustion.

4.2.2 Methods of Working

This is influenced by the above factors and will determine the equipment which is purchased.

4.2.3 Panel Design

The number of roads and pillar size between panels affects the stability of the face and gate roadways. This has to be optimised to maximise productivity from the development and the overall percentage extraction.
Modern practice is to maintain a roadway along the inside edge of a longwall goaf so that it can be re-used as the tailgate roadway in the adjacent panel. In this way better subsidence profiles can be achieved.

Durban Navigation Colliery realised an increase in extraction ratios from 62% to 83% by re-designing their panel layouts to do away with barrier pillars. Some extra expense was incurred as another face machine was required to cater for the change in cutting configuration as well as additional support work and labour. This has been reported by Smith (15).

4.2.4 INCREASED FACE LENGTH

Where possible, increases in face length from the standard 200m to 300m will reduce the amount of relatively unproductive development work and improve longwall productivity due to the reduction in section moves. Utilization of reserves will improve, and more face time will be spent on productive cutting.

4.2.5 PREFERENCE FOR RETREAT MINING

Where ground conditions offer the necessary long term roadway stability and where panels can quickly be developed without delaying the face installations, retreat mining is preferred. It offers the following advantages :

a) The panel can be proven before longwalling commences and geological obstacles negotiated prior to production commencing.
b) Face activities are reduced with pre-driven roads.
c) Elimination of stables does away with the main source of delay.
d) The reduced number of gate road activities make for an improvement in safety.
e) The risk of spontaneous combustion is greatly reduced.
f) Face salvage is made simplier.

4.2.6 PRESENT LONGWALL INSTALLATIONS

The rapid improvements which have occurred in longwall technology have made the 2Mt/annum face a reality. The use of the most up to date equipment, though constituting a substantial capital investment, is pursued by the coal producer. These 'heavy duty' faces as they are termed, being more robust and powerful than conventional longwall equipment, are intended to reduce the cost per ton of coal produced by operating at higher production rates.

4.3 LONGWALL EQUIPMENT

An examination of the longwall equipment available when planning a South African medium seam longwall revealed the following :

4.3.1 POWER SUPPORTS

The application of advanced technology to power supports has resulted in the development of 'heavy duty' supports incorporating the following features. (Although this definition will alter as time passes it is currently used to describe those supports with a yield load greater than 250t).

a) More robust and cost effective construction.
b) Improved design with higher yield loads.
c) Improved forepole arrangements.
d) More robust and effective shielding.
e) Application of face sprags.
f) Improved ram arrangements with optional base lifting facilities.
g) Supports capable of taking advantage of modern control systems.

4.3.1.1 Benefits of Chock Type Supports

Chocks or frame type supports offer advantages in thinner seams where :

a) Soft floor conditions (requiring low floor pressures) are encountered.
b) Stability (with vertical legs) problems are minimal.
c) Goaf flushing is not a problem.
d) The weight of the supports has to be minimal to be compatible with transport systems or capital expenditure.

Modern trends have been towards shield supports particularly in higher seams.

They offer direct roof loading plus resistance to roof lateral movement, utilizing pin jointed legs which are free from direct bending forces. Chocks rely on the bending strength of the legs for lateral resistance giving a practical working height limit of 3m.

The 4 bar kinematic linkage on the *shield is known as a* 'lemniscate', which is so designed to give near vertical movement of the canopy. There are various designs of shield support available offering distinct advantages for different conditions.

4.3.1.2 Benefits of Shield Supports

a) Elimination of direct leg bending forces on to the legs. Lateral roof forces are absorbed *mechanically by the lemniscate linkage.*
b) Resistance to roof movement. All roof forces are resisted by the lemniscate linkage and virtually no lateral movement takes place until friction is overcome.
c) The canopy / rear shield design is compatible with fully integrated hydraulic shielding for wide range applications. This is more difficult to achieve with chocks and can be restrictive on *range.*
d) Elimination of leg towers to support the legs giving wider walkways, enhanced access to valve gear and hoses resulting in reduced maintenance costs on the face.
e) Better access to the face for machine operators.
f) Wider height ranges can be achieved by employing inclined legs.
g) The greater versatility of the shield which sustains the wider roof beams, hydraulic canopy sealing and inherent resistance to roof movement make it better suited to full seam extraction. See Figure 4.1.

4 x 825 TONNE SPLAYED LEG CHOCK SHIELD FULLY EXTENDED AND RETRACTED

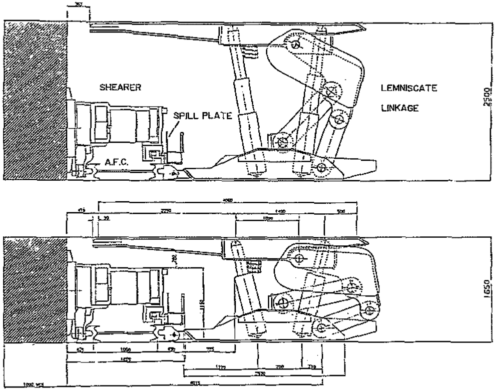
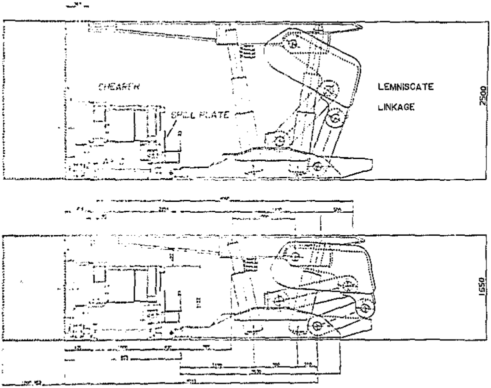


Fig 4.1

4 x 825 TONNE SPLAYED LEG CHOCK SHIELD FULLY EXTENDED AND RETRACTED



Heavy duty supports are manufactured for 1,5m spacing, an increase over the 1,2m spacing necessitated by underground transport constrictions in older European collieries.

Developments such as base lifting rams and the inclined reverse principle ram, have gone a long way to solving the problem of advancing the shield which resulted from the excessive loading of the toe which is prevalent with this type of support.

4.3.1.3 S.A. Support Requirements

Some of the more recent longwall installations have required that heavy duty shield supports be used due to the strong competent strata and relatively high seams. These have high setting loads of up to 32,5 MPa (325 bar), approximately 80% of the yield load. (The increased yield load to setting load ratio is now accepted as producing better roof control). They incorporate rapid relief valves to deal with heavy goafing situations and have provided satisfactory roof control in recent installations.

They operate on the Immediate Forward support principle as do nearly all the longwall faces in the U.S. This gives an unrestricted walkway in front of the support and an increased ventilation area. The support is in a better position to accept a more even load distribution from the overlying strata.

Inclined double telescopic leg supports restrict the walkway dimensions but give good closed heights, making transport easier.

4.3.1.4 <u>Electro Hydraulic Support Operation</u>

This is becoming a standard for new installations. The on-face push button system is very flexible and gives rapid support movement and on-face remote control. The system reliability has proven to be excellent with low system maintenance being required.

4.3.1.5 <u>Operational Advantage of Electro Hydraulic Control</u>

a) Flexibility - Provides full remote control for conventional or immediate forward support working, requiring only one operator for both support and conveyor advance.
b) High speed operation - Support and conveyor advance operations take place while the operator is travelling through the face.
c) Improved roof control - Positive automatic setting. Both adjacent supports must be set before a support can advance.
d) Improved web/face alignment - Sequential support advance eliminates conveyor pull back. Smooth snaking ensures an evenly distributed load on the armoured flexible conveyor.
e) Simplicity of operation.

4.3.1.6 <u>Safety Features of Electro Hydraulic Control</u>

A degree of safety can be built into electro hydraulic control which cannot be achieved on all hydraulic or mixed systems.

a) A minimum number of operators are required in the working area.
b) Audible and visible warning of impending support movement.
c) Fail safe emergency stops on each support.
d) Operators can work from the clean side of the machine.
e) The control system is intrinsically safe.

4.3.2 THE HYDRAULIC PUMP STATION

4.3.2.1 Outbye Pumping Stations

This concept has become popular overseas due to the restricted space at the gate ends and the roadway sizes which hamper the moving of large equipment. Although it has been tried by S.A. operators, an inbye station offers more advantages with local conditions.

4.3.2.2 Advantages of an Outbye Pumping Station

a) Better equipment layout, there is less congestion than at the face end.
b) Improved maintainability.
c) Reduced gate end requirements as their associated electrical equipment is also remote.
d) Enhanced emulsion quality control is a clean accessible environment.

4.3.2.3 Disadvantage of an Outbye Pumping Station

a) Remote stop/start.
b) Increased pressure losses.
c) Burst pipes and leakages.
d) Increased capital cost.

4.3.3 LONGWALL CONVEYORS

The conveyor is chosen to have the required carrying capacity for the planned installation. It must be able to carry the coal-getting machine and accommodate the haulage system. It must be able to flex and advance with a self-cleaning action on the floor horizon and act as an anchor when advancing the supports. It also incorporates the cable duct.

4.3.3.1 The Chain

Chain configuration has tended towards twin centre strand conveyors, particularly on more powerful installations.

The twin outboard conveyor being the original conveyor design, has many attributes, particularly when conveying on steep gradients. The fact that the chain is constrained on both sides subjects it to greater wear. This also means that a new pan section is required for each chain diameter, whereas a centre strand conveyor can use a standard pan side section.

The single centre strand conveyor has the disadvantage that very high chain pre-tension is required to overcome the instability of the flight bars. The twin centre strand conveyor operates on a lower pre-tension. The total chain strength is greater than the single strand and due to the fact that they are more lightly stressed, wear on chain and sprockets is reduced.

4.3.3.2 The Pan Line

With a centre strand chain, the choice of chain size does not pre-determine the pan section and a wide choice is available.

Boltless pan connectors are now commonly used. Present trends have been to operate centre strand conveyors with bottom covered pans. Peak power consumption is reduced and broken bottom chains virtually eliminated. The problems of fitting an inspection cover have been solved through the use of special pan constructions and also thicker deck plates which have made it easier to fit an adequate inspection door.
Heavier duty furniture attachments to the pan side has been made simplier and more secure by the use of slot attachments and fine pitch threaded bolts with anti-vibration nuts.

4.3.3.3 Delivery End Drive

Twin drive conveyors with 300kw motors and spiral bevel gearboxes (allowing the motor to be positioned parallel to the conveyor), are now common for heavy duty installations. The transmission unit should include a hydraulic chain slow running and tensioning system. As an alternative to a fluid coupling a two speed motor can be used. This gives a high torque low current characteristic at start with automatic change over to the high speed winding when the driven conveyor has accelerated. This reduces any problems of voltage drop on start up.

4.3.3.4 Transfer of Coal from the Longwall Conveyor

In order to transfer coal from the longwall conveyor to the stage loader, an overlap is desirable to allow proper cleaning of the armoured flexible conveyor, but any overlap will impede on the transfer of large material. A compromise has to be reached when positioning the longwall sprocket.

Recently, two solutions to this problem have been developed :

The Curved Conveyor

This transforms the armoured flexible conveyor and stage loader into one unit. As it requires a single strand chain system, it limits the power which can be transmitted.

Side Discharge Conveyor

More appropriate to the S.A. heavy duty conveying application is the side discharge conveyor. This allows perfect cleaning of the armoured flexible conveyor. Coal is transferred to the stage loader via a plough blade as the deck plate slopes away over the loader. Any carry over in the central deckplate area goes around the sprocket and falls onto the stage loader from the return strand of the longwall conveyor.

Where height is a serious limiting factor, the two chains can be interlinked so that the carry over coal on the longwall conveyor is deposited on to the return strand of the stage loader. It is then transported around the return sprocket of the stage loader where it joins the main stream of coal being ploughed off.

4.3.4 THE COAL BREAKER

They are necessary to prevent large coal or stone being carried on to the outbye conveyor system, a possibility which is increased through the use of side discharge units. The location of the coal sizer outbye on the stage loader allows adequate bunkerage to be provided by the use of high sided spill plates over a suitable length of stage loader. Its maximum remoteness from the face makes it the safest position. The crusher can either be of single horizontal drum design using picks, or steel segments to crush the coal against a specially strengthed deckplate or of a vertical crusher drum design. Both can have their crushing size easily adjusted and be swung out of the way should a problem occur. While the horizontal crusher can break stronger material, the vertical crusher is said to produce less fines and does not impart any shock loads to the stage loader chain.

4.3.5 THE STAGE LOADER

This forms the intermediary link between the face conveyor and the section belt. Many configurations of stage loader have been tried and a variety of arrangements are appropriate to different conditions and operating routines. Nowadays, preference is for a rigid attachment between the return end of the stage loader and the armoured flexible conveyor drivehead. The stage loader is advanced as the armoured flexible conveyor drivehead is pushed forward.

Up to 15m of movement was accommodated in a beam type stage loader where it straddled the conveyor tailend, creating an overlap distance. The overlap was recovered when necessary by stopping operations and advancing or retreating the conveyor. The modern trend is towards a short bridge which anchors the conveyor belt tailend.

The overl p is exhausted after a couple of shears and the belt tailend is then allowed to retreat with the slack being automatically taken up at the drivehead. The tailend pulley is hydraulically maintained in alignment. The bridge/tailend arrangement can be either skid mounted or cat track assisted.

Large automatic loop take ups can accommodate up to 150m of slack at a time, allowing a long run between production stoppages. Gate end pantechnicons can be secured to the stage loader where space permits, thus simplifying the advance/pullback operation.

4.3.6 POWER LOADERS

4.3.6.1 Coal Ploughs

Although the coal plough is a very efficient coal winning machine, the geological conditions suitable for its efficient operation i.e. relatively soft well cleated coal, do not exist in most of the South African coalfields.

4.3.6.2 Shearers

Many types of shearer have been developed for different cutting conditions, i.e. for seam heights between 800 millimetres and 4,5 metres, and a large choice is available from numerous suppliers. Machines of high technical content are now offered to those able to make use of such improvements.

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Recent developments in shearer concept and design have introduced :

a) Higher powered motors with more powerful haulage systems.
b) Built in systems of machine control and machine health monitoring.
c) An increasing amount of operational automation.

The power requirement is dependent on compressive strength, hardness, density, intrusions, dirt bands and nature of cleavage.

4.3.6.3 Thin Seam Shearers

Thin seams are usually considered to have an upper limit of 1,20 metres. There are a limited number of such seams being worked in South Africa to produce higher grade coals.

A double ended ranging drum shearer (DERDS) has been developed to overcome the difficulties of the restricted coal clearance space under the machine body. This is the buttock shearer which is sited to operate forward of the armoured flexible conveyor in the web, allowing an unrestricted flow of loaded coal when cutting against the conveyor flow. An additional benefit from this machine is that less dust is created as the drum is shrouded against the seam in an area of reduced air turbulence.

4.3.6.4 Medium and Thick Seam Shearers

Single motor shearers in the range of 300kw are *available, and where the toughest cutting* conditions prevail, two motors can offer total machine power of 750 and even 1000kw. With higher installed power, the electric supply has been uprated to 3,3kV giving important advantages in cable size and minimising voltage drop.

With a correct combination of ranging arm, drum diameter and height of underframe, heavy duty machines can be adapted for use in seam sections from approximately 1,5m to over 4,5m. Shearers are designed using a modular construction, allowing any breakdown to be repaired by a component change on the face.

4.3.7 SHEARER DRUMS

It is important that the shearer drums operate at their optimum as any deviation will result in increased power consumption and less coal loaded on the conveyor. With excessive coal left in the track horizon control and advance will be adversely effected.

Drums are successfully designed by computer in the U.K. Computer aided shearer drum design (CAD drums) improve :

a) Product size.
b) Pick life.
c) Make of airborne dust.
d) Power consumption.

The drum is designed to produce the desired tonnages by optimizing the following inter-related factors. Hurt (16)

a) Drum diameter	:	Usually 2/3 of seam height . Output falls as diameter is reduced.
b) Web size	:	Increased in lower seam heights to increase production.
c) Number of starts on drum	:	Requires to be increased with width of drum. This increases clogging of the drum as speed of rotation falls.

d) Drum speed	:	Set to optimize loading capability of drum. Lower drum speeds reduce the make of dust.
e) Haulage speed	:	Increased speed requires more power but will increase production. In lower seams operators would have difficulty in keeping pace with a shearer travelling in excess of 7,5m/min.
f) Drum direction	:	Determines whether coal is to be overthrown or underthrown. Ideally "breakout" should be in the same direction as the coal flow across the drum. Optimum loading direction varies with height and cutting position of drum on a DERDS.
g) Vane angle	:	Set to optimise loading ability.
h) Number of picks	:	Minimised to increase penetration and optimize "breakout" between alternate lines of picks.

Powered cowls can be used to achieve a better clean up of coal in the track.

4.3.7.1 <u>Cutting Picks</u>

While radial picks are favoured on European installations, the hardness of South African coal has resulted in point attack picks (tangentially mounted picks) being more efficient. Experiences at Secunda Collieries showed dramatic increases in performance when such picks were used. Most S.A. longwalls are now operating with drums especially designed to accommodate heavy duty point attack picks.

4.3.7.2 Diamond Tipped

Synthetic diamond picks as described by Collin (17), have proven themselves in various cutting conditions. Their longer life leads to less vibration of the shearer and hence less wear and tear. Unfortunately, their very high cost necessitates a very strict control which is not always easy to achieve in an underground environment.

4.3.7.3. Dust Supression

This important factor can be better controlled at the shearer by raising the water pressure through a booster pump which is sprayed through fine jets adjacent to each pick. More expensive water-through-the-bit cutting systems are also available. Efficient water sprays reduce the possibility of a face ignition considerably. Hollow drums are used to direct air through to the coal face side of the cutting drum. Experimental work is taking place to determine the benefits to be derived from high pressure water jet assisted cutting on shearers.

4.3.8 CHAINLESS HAULAGE SYSTEMS

Chainless haulage systems are now well established. They were developed to allow harder coal to be cut at greater speed and for the operation of two machines on the face. A greater flexibility in machine design is allowed with the result that multiple drive units can be provided.
They offer the following advantages :

a) Greater productivity. Higher tractive forces can be developed and resultant thrusts can be more evenly distributed to both sides of the machine. This counters the tendency of large, long machines to travel with a "crabbing" action.
b) Service reliability giving long term maintenance savings. Tension surges are eliminated during the cutting operation.

c) Safety. The haulage chain tended to whip and lash dangerously.

d) Noise. Chain came into contact with the armoured flexible conveyor flight bars.

e) Simplified design. Chain elimination simplified the design of armoured flexible conveyor driveheads.

There are two main types of chainless haulage in use.

1. The Chain and Rack system of Star track and track reactive as marketed by Mining Supplies, where a chain is driven to engage with the pegs on the side of the armoured flexible conveyor.

2. Wheel and rack used by Anderson Strathclyde in their Roll Rack system, B.J.D. with Multidrive and Eickhoff with Eikotrack. Here the teeth of the driven pinion wheels engages with the rack.

   Mechanical haulages based on clutch and gear selection are being overtaken by electrohydraulic units, giving infinitely variable speeds of up to 13m per minute. These can incorporate automatic load regulating and protection features.

4.3.9 INFORMATION AND CONTROL SYSTEMS

New technology has resulted in many possibilities for improving the collection of information to monitor the health of the machine and to control it. It is important however that those systems do not become so complex that the result is counter productive.

Steering assistance systems which rely on measuring the natural gamma radiation in the strata are constantly being refined and becoming more reliable.

Remote operation of the machine is available to move the operator into the fresh air but no attempt has been made to completely remove the operator from the machine.

4.4 SHORT WALL MINING OPERATIONS

Considerable scope exists for conducting shortwall operations in S.A. and this method is being used successfully in Australia under the name of "Flexiwall".

Although shortwalls have been operated using shuttlecars and continuous miners as an extension of the Wongawilli method of pillar extraction their limited increase in productivity resulted in this method offering little advantage. The application of shortwall mining in S.A. would be with the Flexiwall, namely a shortened longwall operation.

Successful installations require the utilization of proven longwall equipment balanced with some innovative design. This allows consistently high production to be achieved facilitating rapid face moves. In this way inconveniently small coal blocks can be mined. To this end mobility and ease of operation of the main gate equipment is of paramount importance. New equipment such as the roller curve conveyor are being operated at Borken colliery in Germany. One piece vehicles which can encorporate both the delivery drive frame and the stage loader are also popular.

4.5 LABOUR DEPLOYMENT

With more mechanised equipment less persons are required on the face and those that are employed are required to be trained to a higher skills level.

New technology in itself can accomplish very little. It has to go hand in hand with the willingness and adaptability of the workforce, combined with the ingenuity and determination of management.

4.5.1 U.S. LONGWALLS

U.S. longwalls where in excess of 99% of operators employ the retreat method, manning levels are typically between six and eleven, giving daily outputs in excess of 6000t. This could be regarded as an optimum manning level for this type of mining due to the high cost of labour.

Typically it would comprise of:

2 Machine Men
2 Prop Men
1 Stageloader
1 Face General
1 Mechanic
1 Foreman

Often an optional maintenance/production crew are on one shift. They comprise of the same number of mostly mechanics and trainee artisans who can operate the equipment.

4.5.2 S.A. LONGWALLS

S.A. longwalls typically run with between 10-12 facemen giving a complement of:

2 Machine Men
2 Chockmen
1 Stageloader
1 Face General
1 Face Boss
1 Electrician
1 Mechanic
1 Engineering Foreman

Larger complements and especially an increased level of supervision are often necessary because the workforce is unfamiliar with the mining method and new systems are inevitably fraught with many teething problems. In general a longer "learning curve" is experienced with longwalling. Dual purpose mechanicians can reduce the complement but few persons are available who are suitably skilled.

4.6 CONCLUSIONS - LONGWALL MINING

4.6.1 HIGH PRODUCTIVITY

Longwall mining is a concentrated mining system designed to produce high tonnages from one section, which results in a high productivity per man shift. A disadvantage of this centralised production, is that any downtime which leads to a face stoppage will seriously affect production.
In panel extraction ratios are maximised, being in excess of 90%, while good roof control is effected by the power supports, resulting in safer working conditions.

4.6.2 HIGH CAPITAL RISK

A high capital cost is involved in installing a longwall which has a high risk factor attached to it. It is possible to lose a complete face due to adverse geological conditions.

4.6.3 DESIGN CONSTRAINTS LIMIT EQUIPMENT CHOICE

The face equipment can only operate within certain height parameters which must be chosen very carefully to match the mining conditions. As coal production is not continuous because of turn around operations at the face ends, the coal clearance system must be designed to cater for periods of peak load.

4.6.4 NEW MINING METHOD

Longwall mining is relatively new to South Africa, its initial establishment is expensive and time and money has to be spent training personnel to operate the equipment.

4.6.5 EXPECTATIONS

While high extraction ratios are assured, given good mining conditions, the most important benefit is in increased productivity per man shift. This ensures that an increase in labour costs has a lesser impact on cost per ton.

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CHAPTER 5

MINING SYSTEMS COST COMPARISON

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5.1 EXERCISE PARAMETERS

In order that a full comparison can be made of the different underground mining methods reviewed in the previous chapters, it is necessary that they be quantified in terms of cost.

This can best be done by comparing the operation of each under similar conditions. The chosen parameters were that of a 3m seam with a competent sandstone floor and a coal roof. The depth of cover was taken to be 90m, which would allow 18m centres to be mined with conventional 6,0m bords.

For the purpose of the exercise, it was assumed that a producing Colliery with the existing infrastructure was required to increase its output by 150,000t per month, by the installation of new mining equipment. This enabled a comparison of the different mining systems to be made on an equal basis.

5.1.1 PRODUCTION TARGETS FOR THE MINING SYSTEMS

The required production was planned to be produced by the 3 mining systems under consideration in the following manner :

a) Three single header conventional sections, producing 50,000t per month on a double shift operation.

b) Four single header continuous miner sections. These were targeted to produce 37,500 tons per month on a double shift operation.

c) One longwall face. This would produce 150,000t per month working on a treble shift basis. In order to achieve this, a production of 163,640 tons per month over eleven months would be required, allowing one month for face moves.

By virtue of the nature of the operation, the longwall cannot commence production immediately. A face line has to be driven and chain roads developed, if the panel is to be retreated. The installation of the face equipment also takes time.

Longwall mining is therefore dependent on a primary mining system to complete the necessary development work, unlike the other mining methods.

'.2 PRODUCTION POTENTIALS

Scope for increasing production from each mining method does exist. *As far as possible, an average* production was calculated for the given production parameters. Some operations are, however, achieving tonnages in xcess of those suggested, through *combinations of* better conditions and management of their operations.

Higher tonnages are, however, not always sustainable over a long period of time and should not ne sarily be accepted as the norm.

A look at the most successful operations shows that the following production potentials can be achieved for the stated mining parameters, should able conditions prevai'

MINING SYSTEM	GIVEN PRODUCTION TARGET/MONTH	MAXIMUM PRODUCTION POTENTIAL/MONTH	% INCREASE
Conventional	50,000	65,000	30
Continuous miner	37,500	60,000	60
Longwall	*150,000*	*190,000*	26,7

It is evident that the scope for the largest increase in production exists with continuous miner sections. Apart from varying coal conditions, which as stated earlier, play a very important part, the operation and management of the system is very different to that of a conventional section. This must be fully understood if the maximum benefit is to be derived from this mining system.

5.1.3 SHIFT SELECTION

The longwall is to operate on a treble shift basis because of the high capital costs of the machinery and also to promote a more constant rate of advance, facilitating be[illegible] [illegible] conditions.

MINING [illegible] OVERHEADS

To simplify the comparison of each type of mining operations, certain costs were considered to be communal and [illegible] for this reason, excluded.

5.1.4.1 OFFICIALS

For the purpose of the exercise, the cost of officials were excluded as the numbers required to supervise each of the operations was considered to be very similar. Although the longwall face comprises one production section, most operators require that one official is solely responsible for the face on each of the shifts. Additional officials are also required to plan and co-ordinate the face moves.

5.1.4.2 SECTION LABOUR COSTS

Labour costs have been calculated for section personnel only. Mining personnel employed on general work and those who provide a back-up to the mining operation, i.e. belt maintenance crews and cleaners, rockdusters and supplies personnel, have not been included. Likewise, special engineering maintenance crews and those employed in outbye workshops have been excluded.

5.1.4.3 OUTBYE MACHINERY

The cost of operating outbye machinery has been excluded, as similar costs would be experied with all 3 mining systems. The operation of specialised longwall chock movers have been included, as they form an integral part of the longwall system.

5.1.4.4 VENTILATION COST

These were regarded as being similar and therefore excluded. A longwall face requires less air per R.O.M. ton of coal, but is reliant upon a development section opening up pit room, which also requires to be ventilated.

5.1.4.5 POWER

Power consumption for the various mining systems has been treated as being equal.

5.1.4.6 PUMPING

Pumping costs have been considered to be equal. It is recognised that the total extractive method would create far greater water problems as the overlying stratas were broken, and a greater pumping capability would have to be available. These costs are, however, marginal.

5.1.4.7 CONVEYOR BELTING

The cost of conveyor belting was taken to be approximately 40% more expensive for longwalling. Belting required for the longwall section is generally of a higher capacity. It is subjected to more wear, being constantly retreated/advanced as the face moves, but will convey greater tonnages in its lifetime than other section conveyors.

An amount of 3000 linear metres of 1050mm section conveyor was considered to be suitable for serving the continuous miner and conventional sections. The longwall section required 4000 linear metres of 1200mm conveyor, 2000m for the production face and 2000m for the next developed chain road.

5.1.4.8 TRAILING CABLES

The cost of trailing cables were considered to be equal, due partially to the relatively small cost which they represent.

5.1.5 SECTION MACHINERY

The choice of mining equipment for the purpose of the comparison was selected to be the most suitable of the locally available machinery, for which an established back-up service exists.

The Joy 10SC22 shuttlecar was selected in preference to the 488 NMS Torkar. Although its initial purchase price is more expensive, it has proven itself to be cheaper to operate, giving longer intervals between [illegible]es (100,000 loads as opposed to 60,000). It can have an operating cost as low as 30c per ton, compared to 65c per ton for the Torkar. It also has the following design benefits :

a) More rigid and narrower body construction.

b) Higher ground clearance.

c) Better traction with twin motor drive which eliminates differentials.

d) SCR traction system which offers smooth acceleration and assists with braking.

The Joy 14CM9 continuous miner is compared, which can produce up to 9 tons per minute in a medium seam height. This is a solid drum type machine which is currently out-performing the 12CM6 model, incorporating the ripperveyor, in terms of productivity and machine availability.

5.2 CAPITAL INVESTMENT

The capital investment required for modern machinery is substantial. High technology hardware has to be imported from overseas often at unfavourable exchange rates.

The manufacture of low volume machinery is expensive. Usually no single product can be produced to satisfy every customer's needs and each piece of equipment has to be customised to some degree. Large amounts of money are needed to reinvest in updating the technology in order to maintain a competitive edge.

Every investment which has been made in longwall equipment and nearly all that have been made in continuous miners, are for either synfuel projects, Iscor, or Eskom tied powerstations, where the capital burden has not been the sole responsibility of the mining company.

As demand increases it may be possible to set up a local manufacturing plant. Joy have successfully done this and now manufacture a wide range of their products locally. At present the local content of their continuous miners and shuttlecars is 80% and 84% respectively. With a view to reducing their prices they intend manufacturing the remaining imported components in order to achieve 100% local content within the next 12-18 months.

Usually the market for spare parts and sub assemblies is captured by the machine manufacturers who regard it as an important source of income. They tend to exploit their monopoly situation by charging high prices. Although pirate parts become available for certain component types, quality problems can arise and such spares will invalidate manufacturer's guarantees.

5.3 CONVENTIONAL MINING

5.3.1 CURRENT OPERATING COSTS

Conventional mining operations are typically producing coal for as little as R11 per R.O.M. ton, where the coal is sold directly to a powerstation without beneficiation, and R24 where a higher quality coal is produced. R11 per R.O.M. ton is in fact, a lower working cost than that of a compatible opencast mine being operated on the same colliery. Often, higher costs are justified with conventional mining, as the higher prices which can be commanded by export quality coals result in the exploitation of more difficult coal fields being attractive propositions.

While most export coal is mined by conventional means, yielding less fines for the plant, some coal is also produced by the same method for power station consumption.

Operators are successfully containing increases in costs by reducing section complements through :

a) Introducing mobile face drill rigs.

b) Employing multi-operators.

Other savings have been effected by :

a) Improving blasting efficiencies.

b) In-house repairs to sub-assemblies.

While costs vary depending upon seam height and mining conditions, a typical breakdown for an export colliery with average mining conditions would be :

	R/TON
Officials	1,68
Senior skilled	1,21
Skilled and semi-skilled	3,57
Explosives and accessories	0,89
Petroleum products	0,41
Mining consumables	0,76
Engineering consumables	1,12
Plant	0,59
Hostel	0,46
Other	0,73
Working cost suspense	3,02
Sundry debits	4,56
	19,00

This gives a total of R19 per R.O.M. ton, with beneficiation of the product typically bringing this to around R24 per sales ton.

5.3.2 EXPORT COAL PRICES

Due to the current recovery in world coal price, F.O.B. prices at Richards Bay of R88 for low ash coal and R64 for steam coal can now be realised.

Typical railage tariffs now amount to R22 a ton, with warfage fees and stevedoring charges raising selling expenses to R27.50 per ton.

Many prudent operators are accruing profits from the exchange rate and forward cover transactions. While current rates are ensuring a healthy profit for coal exporters, they remain susceptable to fluctuations in the rand/dollar exchange rate and the ever present risk of sanctions.

This latest trend is a dir[illegible]ion of the envisaged scenario of 12 months ag[illegible]ime, many producers were planning to close tho[illegible]table export mines as sales revenue declined. It was expected that the bulk of coal division profits for the larger mining houses would be derived from the tied power collieries which offer a lesser but more secure profit margin.

5.4 COST ANALYSIS - CONVENTIONAL SECTION

The following costs were calculated for a conventional section capable of producing 50,000t per month under the stipulated control conditions.

5.4.1 MONTHLY LABOUR COSTS (double shift operation)

5.4.1.1 MINING

	R	R/TON
40 x skilled & semi-skilled employees :		
Basic wage	28 793,60	
Accommodation and medical	7 198,40	
Bonus @ 30% basic	8 638,08	
Overtime @ 20% basic	5 758,72	
	50 388,80	1,01
2 x Miners	6 339,40	0,13
TOTAL	56 728,20	1,14

5.4.1.2 ENGINEERING

4 x skilled & semi-skilled employees :		
Basic wage	2 628,56	
Accommodation and medical	657,14	
Bonus @ 30% basic	788,56	
Overtime @ 20% basic	525,72	
	4 599,98	0,09
2 x Fitters	7 180,44	
2 x Electricians	7 180,44	
	14 360,88	0,29
TOTAL	18 960,86	0,38
T O T A L	75 689,06	1,52

5.4.2 CAPITAL COST

	R
1 x Rham roofbolting machine	85 000
2 x Joy 10RU coalcutters	777 040
2 x Schroeder face drills (roll over boom)	322 000
2 x Joy 14B1011C loaders	816 340
3 x Joy 10SC22 shuttlecars	1 205 220
1 x Rhino feederbreaker	193 000
1/2 x Eimco 913 LHD	130 000
	3 528 600

The cost of capital for this equipment based on an average production of 50 000t per month is R1,18 at a cost of capital of 20 percent per annum.

5.4.3 REPLACEMENT COST

The replacement is planned on an estimated life of individual items as shown below :

	EXPECTED LIFE (YEARS)	ANNUAL RPA. (R)
Roofbolt machine	10	8 500
Coalcutters	15	51 800
Face drills	10	32 200
Loaders	15	54 400
Shuttlecars	15	80 400
Feederbreaker	10	19 300
LHD	9	14 400
		261 000

This equates to R0,44 per ton.

5.4.4 WORKING COST SUSPENSE

5.4.4.1 MAJOR OVERHAULS

	R	OVERHAULS/ MACH. LIFE	R/TON
Shuttlecar/100 000 loads	205 000	3	0,21
Loader/100 000 loads	237 000	3	0,16
Coalcutter/28 000 cuts	162 000	3	0,11
Roofbolter/60 000 holes	41 000	2	0,02
Drillrig/200 000 holes	80 000	2	0,05
Feederbreaker/210 000 loads	87 000	2	0,03
Eimco 913/3 years	145 000	2	0,02
			0,60

The cost of major underground equipment overhauls is R0,60 per ton.

5.4.4.2 SUB ASSEMBLY OVERHAULS

From machine history data compiled by the engineering planning departments of several Amcoal Collieries, the average cost for the overhauling of underground sub-assemblies, for conventional mining machinery, was found to be R0,39 per ton.

5.4.4.3 CONVEYOR BELTING

The capital and maintenance costs for the necessary 1 050mm conveyor belting was calculated to be R0,25 per ton.

5.4.5 MONTHLY STORES COSTS (per section)

5.4.5.1 MINING

	R	R/TON
Consumables	38 500	0,77
Explosives and accessories	36 500	0,73
Petroleum products	4 500	0,09
	79 500	1,59

5.4.5.2 ENGINEERING

Consumables	51 000	1,11
Petroleum products	8 000	0,16
	59 000	1,27

A breakdown of the cost of consumables per underground production machine comprised of the following :

	R	R/TON
Coalcutter	16,30 per cut	0,27
Feederbreaker	0,80 per load	0,09
Facedrill	0,14 per hole	0,04
Loader	2,60 per load	0,29
Roofbolter	0,33 per bolt	0,01
Shuttlecar	2,86 per load	0,32
		1,02

5.4.6 TOTAL COST FOR CONVENTIONAL SECTION

	R/TON
Mining labour	1,14
Engineering labour	0,38
Capital cost	1,18
Replacement cost	0,44
Major overhauls	0,60
Sub-assemblies	0,39
Conveyor belting	0,25
Mining stores	1,59
Engineering stores	1,27
	7,24
Additional costs communal to all three mining systems	11,00
	18,24

5.5 CONTINUOUS MINERS

5.5.1 CURRENT OPERATING COSTS

Continuous miners are operated by a number of large Eskom tied collieries, either as the exclusive coal winning method or in conjunction with other mining systems.

Continuous miners are also employed at export and Iscor mines where they perform specialist functions of pillar extraction and development work through igneous intrusions.

Operating costs for continuous miners vary from between R16,00 and R25,00 per R.O.M. ton, dependant to a certain extent, upon seam height and mining conditions. While labour costs are less than those of a conventional section, a higher expenditure is realised on machinery.

Typically, the costs are broken down as follows :

	R/TON
Officials	1,97
Senior skilled	1,53
Skilled and semi-skilled	1,95
Explosives and accessories	0,02
Petroleum products	0,57
Mining consumables	1,17
Engineering consumables	1,02
Plant	NIL
Hostel	0,40
Other	0,92
W.C.S./RPA provision	6,15
Sundry debits	5,20
	20,90

5.5.2 FACTORS INFLUENCING PRODUCTIVITY

Where large numbers of continuous miners are employed, it is important that the mining company adopt a scientific approach towards their operation and maintenance. The single coal winning machine has a more critical impact on the productivity of the section.

Future developments to improve the efficiency of the machine are set to introduce a greater amount of instrumentation into the cab. This could prove to be retrogressive to their productivity. At present, collieries are experiencing a shortage of skilled artisans and the problem of attracting and retaining such people needs to be pursued more vigorously, if the *expected benefits are to be derived from more sophisticated mining machinery.*

One solution is to increase wages, which is effectively happening, as a larger number of contractors are being employed. A more beneficial approach would be to improve the remuneration for permanent staff in order that a stable, experienced workforce can be built up. As the degree of engineering sophistication increases, so does the requisite training period before which a person can be of full use to the company. An unstable workforce drains training capabilities and ties up valuable resources which could otherwise be better utilised.

The proper management of the operation is the key to attaining the above goals. High technology can never in itself, achieve the desired results and an equal amount of attention must be focused on the needs of the *employees if the maximum benefits are to be derived.*

5.6 COST ANALYSIS - CONTINUOUS MINER SECTION

The continuous miner section, capable of producing 37,500t per month, was costed as follows under the exercise conditions. The mining system employed is to be bord and pillar development with no stooping.

5.6.1 MONTHLY LABOUR COSTS (double shift operation)

		R	R/TON
5.6.1.1	MINING		
	22 x Skilled and semi-skilled employees :		
	Basic wage	15 593,16	
	Accommodatinn & medical	3 898,30	
	Bonus @ 30% basic	4 677,94	
	Overtime @ 20% basic	3 118,44	
		27 289,04	0,73
	2 x Miners	6 339,40	0,17
	TOTAL	33 627,44	0,90
5.6.1.2	ENGINEERING		
	3 x Skilled and semi-skilled employees :		
	Basic wage	1 971,42	
	Accommodation & medical	492,86	
	Bonus @ 30% basic	591,42	
	Overtime @ 20% basic	394,29	
		3 449,99	0,09
	2 x Fitters	7 180,44	
	2 x Electricians	7 180,44	
		14 360,88	0,38
	TOTAL	17 810,87	0,47
	T O T A L	51 438,31	1,37

5.6.2 CAPITAL COST

	R
1 x Rham roofbol'ing machine	85 000
1 x Joy 14CM9 continuous miner	1 759 000
3 x Joy 10SC22 Shuttlecars	1 205 220
1 x Rhino feederbreaker	193 000
1 x Eimco 913 LHD	260 000
	3 502 220

The cost of capital for this equipment, based on an average production of 37,500t per month is R1,56 at a cost of capital of 20 percent per annum.

5.6.3 REPLACEMENT COST

The replacement is planned on an estimated life of individual items as shown below :

	EXPECTED LIFE (YEARS)	ANNUAL RPA. (R)
Roofbolt machine	10	8 500
Continuous miner	4	439 750
Shuttlecars	15	80 400
Feederbreaker	10	19 300
LHD	9	28 900
		576 850

This equates to R1,28 per ton.

5.6.4 WORKING COST SUSPENSE

5.6.4.1 MAJOR OVERHAULS

	R	OVERHAULS/ MACH. LIFE	R/TON
Shuttlecar/100 000 loads	205 000	3	0,21
Roofbolter/60 000 holes	41 000	2	0,02
C. Miner/600 000 ton	650 000	2	0,72
Feederbreaker/210 000 loads	87 000	2	0,03
Eimco 913/3 years	145 000	2	0,05
			1,03

The cost of underground major equipment overhauls is R1,03 per ton.

5.6.4.2 SUB ASSEMBLY OVERHAULS

The average cost of overhauling underground sub-assemblies was calculated at R0,98 per ton. This figure was determined by analysing the machine history data compiled by the engineering planning department of an Amcoal Colliery. The figure was found to be reasonably close to that determined at a major Gencor and Rand Mines Colliery.

5.6.4.3 CONVEYOR BELTING

The capital and maintenance costs for 1050mm conveyor belting was calculated at R0,25 per ton.

5.6.5 MONTHLY STORES COSTS (per section)

5.6.5.1 MINING	R	R/TON
Consumables	42 000	1,12

5.6.5.2 ENGINEERING	R	R/TON
Consumables	21 000	0,56
Petroleum products	6 375	0,17
	27 375	0,73

The average cost of a continuous miner to a colliery equates to R1,45 per ton. This includes sub-assemblies, annual service by mine personnel (excluding labour), stores and lubricants.

5.6.6 TOTAL COST FOR CONTINUOUS MINER SECTION

	R/TON
Mining labour	0,90
Engineering labour	0,4[illegible]
Capital cost	1,56
Replacement cost	1,28
Major overhauls	1,03
Sub-assemblies	0,98

TOTAL COST FOR CONTINUOUS MINER SECTION (CONTINUED)

	R/TON
Conveyor belting	0,25
Mining stores	1,12
Engineering stores	0,73
	8,32
Additional costs communal to all three mining systems	11,00
	19,32

5.7 LONGWALL MINING

5.7.1 CURRENT OPERATING COSTS

Longwalls, as reviewed in Chapter 4, are being operated by a number of mining companies, where the greater capital expense can be shared with the customer. Due to the large imported content of longwall equipment and spares, the overall economics of longwall mining in South Africa has been seriously affected, equipment being the most costly part of the operation.

This is currently evident as the budgeted provision for working cost suspense is typically found to be inadequate.

The high cost of face supports is one of the factors which has influenced *Secunda in their decision not to* re-equip two of their longwalls. Continuous miner total extraction methods are now considered to be cheaper.

For any new mining method, a learning curve is experienced before people become fully conversant with the system. As with continuous miners, the importance of suitably qualified persons with the necessary technical skills is not be be under-estimated and many companies have been reliant upon recruiting personnel from overseas.

When capital charges are excluded, longwall operators are realising operating costs of 2/3 rd's that of a continuous miner section.

An additional 20% of longwall coal production would have to be costed *as per a continuous miner section*, this being the amount which would be mined by the chain road development. Such developments, however, are more expensive than continuous miner production sections as the restricted space and faster rate of advance slow down the production potential of a chain road section.

Collieries are typically producing at R16,00 per ton from their longwall sections. This is broken down as follows :

	R/TON
Officials	1,50
Senior skilled	0,91
Skilled and semi-skilled	1,38
Explosives and accessories	NIL
Petroleum products	0,37
Mining consumables	0,96
Engineering consumables	0,96
Plant	NIL
Hostel	0,26
Other	0,73
W.C.S./RPA provision	4,43
dry debits	4,46
	15,96

5.8 COST ANALYSIS - LONGWALL SECTION

The longwall section budgeted for the cost comparison exercise at 163,640 tons per month, was costed as follows :

5.8.1 MONTHLY LABOUR COSTS (treble shift operation)

5.8.1.1 MINING	R	R/TON
21 x Skilled and semi-skilled employees :		
basic wage	16 926,00	
Accommodation & medical	4 231,00	
Bonus @ 30% basic	5 078,00	
Overtime @ 10% basic	1 693,00	
	27 928,00	0,19
3 x Face supervisor	12 705,00	
TOTAL	40 633,00	0,27

5.8.1.2 ENGINEERING

	R	R/TON
6 x Skilled employees :		
Basic wage	4 999,74	
Accommodation & medical	1 414,22	
Bonus @ 30% basic	1 499,92	
Overtime @ 10% basic	499,97	
	8 413,85	0,05
3 x Fitters	11 670,66	
3 x Electricians	11 670,66	
	23 341,32	0,16
TOTAL	31 755,17	0,21
T O T A L	72 388,17	0,48

5.8.2 CAPITAL COST

	R
140 x Dowty 825t chock shields :	
Imported contents	15 040 000
Local contents	12 705 000
1 x Eickhoff 750kW shearer :	
Imported contents	5 440 000
Local contents	1 724 000
1 x Dowty armoured face conveyor :	
Imported contents	1 934 000
Local contents	2 088 000
1 x Anderson Strathclyde stage loader :	
Imported contents	1 068 000
Local contents	257 000
Electrics (cost difference from bord and pillar mining)	750 000
Ocean freight	746 000
Back-up equipment including pan launcher, pump station, hydraulic pipes	3 300 000
2 x Wagner chock movers	1 157 000
	46 209 000

The cost of capital for this equipment based on an average production of 150 000t per month is R5,27 at a cost of capital of 20 percent per annum.

5.8.3 REPLACEMENT COST

The replacement is planned on an estimated life of individual items as shown below :

	EXPECTED LIFE (YEARS)	RPA (R)
Powered supports	Replaced at 15/annum	2 972 600
Shearer	10	716 400
Armoured face conveyor	2	2 011 000
Stage loader	5	265 000
Electrics	10	75 000
Back-up equipment	10	330 000
Chock movers	9	128 000
		6 498 000

This equates to R3,61 per ton.

5.8.4 WORKING COST SUSPENSE

5.8.4.1 MAJOR OVERHAULS

	R	R/TON
Shearer R1,2m per 3m tons	720 000	0,40
Cutting drums R80 000 per 0,5m tons	288 000	0,16
Armoured face conveyor (chains) R0,4m per 2m tons	360 000	0,20
Supports 15 @ R30,000 each	450 000	0,25
Stage loader (chains)	120 000	0,07
Support movers overhaul twice @ R240,000	86 300	0,05
[illegible]le handler per face installation	75 000	0,04
	2 099 300	1,17

5.8.4.2 SUB ASSEMBLIES

	R	R/TON
Shearer	470 000	0,26
Armoured face conveyor	1 450 000	0,80
Supports	575 000	0,32
Stage loader	145 000	0,08
Support movers	35 000	0,02
	2 675 000	1,48

5.8.4.3 CONVEYOR BELTING

The capital and maintenance costs for the necessary 1 200mm conveyor belting was calculated to be R0,35 per ton.

5.8.5 MONTHLY STORES COSTS (per section)

5.8.5.1 MINING

	R	R/TON
Consumables	93 000	0,62

5.8.5.2 ENGINEERING

	R	R/TON
Consumables	81 250	0,65
Petroleum products	48 750	0,39
	130 000	1,04

5.8.6 TOTAL COST FOR LONGWALL SECTION

	R/TON
Mining labour	0,27
Engineering labour	0,21
Capital cost	5,27
Replacement cost	3,61
Major overhauls	1,17
Sub-assemblies	1,48
Conveyor belting	0,35
Mining stores	0,62
Engineering stores	1,04
	14,02
Additional cost communal to all three mining systems	11,00
	25,02

5.9 CONCLUSION TO COST COMPARISONS

A cost comparison of the 3 mining systems under consideration is shown in figure 5.1, 2 and 3. The distribution of capital to labour and consumables costs is clearly illustrated.

5.9.1 CONVENTIONAL MINING

While labour costs for conventional mining are the highest of all 3 systems, capital and maintenance costs are lowest.

5.9.2 *CONTINUOUS MINERS*

Capital costs for the continuous miner section were more expensive that for the conventional section.

A reduction in operating costs is derived as a result of the saving in explosives being greater than the cost of coal cutting picks.

Maintenance costs for the continuous miner contribute largely towards the higher material costs.

5.9.3 LONGWALL MINING

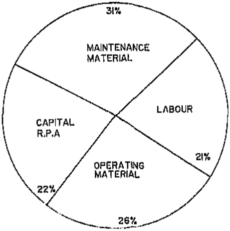
Longwall mining was found to be the most expensive method, although labour and operating material costs were significantly lower than for the other mining methods. *This is due to the high cost of the equipment* and the correspondingly more expensive spares.

5.10 INFLATIONARY TRENDS

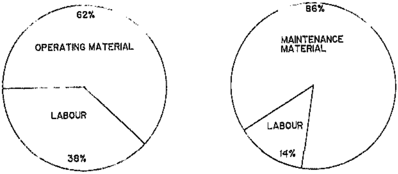
5.10.1 PREVIOUS SITUATION

The development of mining systems to operate with the minimum amount of labour has been a very important consideration in Europe and America.

CONVENTIONAL SECTION



CONVENTIONAL PRODUCTION COST
724 c/TON



MINING CONTRIBUTION (41%)

ENGINEERING CONTRIBUTION (37%)

Fig 5.1

CONTINUOUS MINER SECTION

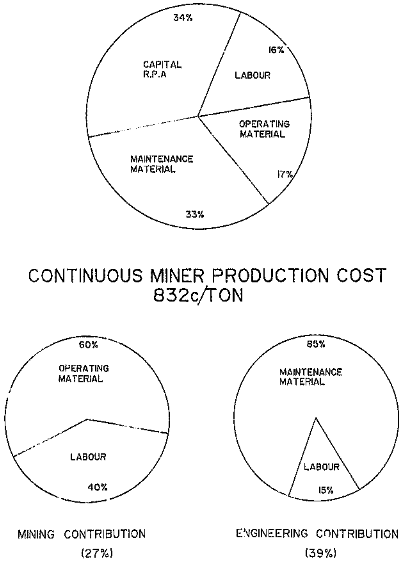


Fig 5.2

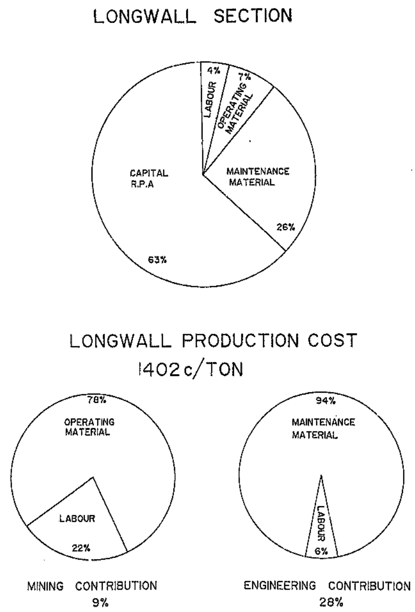

LONGWALL SECTION
4%
LABOUR
7%
OPERATING MATERIAL
MAINTENANCE MATERIAL
26%
CAPITAL R.P.A
63%
LONGWALL PRODUCTION COST
1402 c/TON
78%
OPERATING MATERIAL
LABOUR
22%
94%
MAINTENANCE MATERIAL
LABOUR
6%
MINING CONTRIBUTION
9%
ENGINEERING CONTRIBUTION
28%

Fig 5.3

South African labour, being considerably cheaper, has never required the same savings to be made. At the start of the 1980's, it was perceived that more substantial increases in the cost of labour would be a feature of the economic development of the country. What was not foreseen however, was the sharp decrease in the value of the rand and the resultant increase in the cost of imported machinery. As a result, labour costs were outstripped by the escalating price of machinery.

The inflationary impact on the more labour intensive methods did not therefore push them out of line with the other mining systems, and those that were reliant on expensive imported machinery, rose more sharply.

5.10.2 FUTURE EXPECTATIONS

Future expectations are that the value of the rand on the international market will remain weak, making imports expensive. Assuming that it does not depreciate further, lower rates of inflation in Western Europe will be a limiting factor on price increases. After 1990, it is predicted that the rand will start to appreciate against the major foreign currencies.

Cost expectations over the next 5 years are based on labour inflating at an average of 15%. While many consumables have risen in excess of the inflation rate, these are expected to come more into line and escalate at a lesser rate to that of labour, i.e. 14% after 2 years. Most of these materials are locally sourced.

5.10.3 <u>INFLATIONARY INDICES</u>

Current SEIFSA indices and the consumer price index were consulted to determine the predicted rates of inflation for various categories of equipment and labour. From these, the following 5 year inflationary indices were constructed to represent what is, in the author's opinion, the most likely trend.

	SEPT. '88	SEPT. '89	SEPT. '90	SEPT. '91	SEPT. '92	SEPT. '93
Labour	1,0000	1,1700	1,3572	1,5608	1,7793	2,0106
Operating materials	1,0000	1,1800	1,3688	1,5604	1,7477	1,9574
Maintenance materials	1,0000	1,2000	1,4160	1,6426	1,8725	2,1347
Equipment	1,0000	1,1800	1,3688	1,5604	1,7477	1,9574

5.10.4 <u>CONCLUSION TO FUTURE MINING COSTS</u>

Using the inflationary indices, the operating costs for the different mining systems 5 years hence, are calculated.

Table 5.2 shows the predicted costs of operating the systems implemented in 1988, and table ' the predicted cost of commencing production in ne.

It is evident from this inflationary sce at conventional mining will remain the cheapest alternative for the next 5 years.

TABLE 5.1 <u>CURRENT OPERATING COSTS</u>

	CONVENTIONAL	CONTINUOUS MINER	LONGWALL
Labour	1,52	1,37	0,48
Operating materials	1,84	1,37	0,97
Maintenance materials	2,26	2,74	3,69
Capital/R.P.A.	1,62	2,84	8,88
	7,24	8,32	14,02

TABLE 5.2 COST OF OPERATIONS IN 5 YEARS TIME

	CONVENTIONAL	CONTINUOUS MINER	LONGWALL
Labour	3,06	2,75	0,96
Operating materials	3,60	2,68	1,90
Maintenance materials	4,82	5,85	7,88
Capital/R.P.A.	1,62	2,84	8,88
	13,10	14,12	19,62

TABLE 5.3 COST OF COMMENCING MINING IN 5 YEARS' TIME

	CONVENTIONAL	CONTINUOUS MINER	LONGWALL
Labour	3,06	2,75	0,96
Operating materials	3,60	2,68	1,90
Maintenance materials	4,82	5,85	7,88
Capital/R.P.A.	3,17	5,56	17,38
	14,65	16,84	28,12

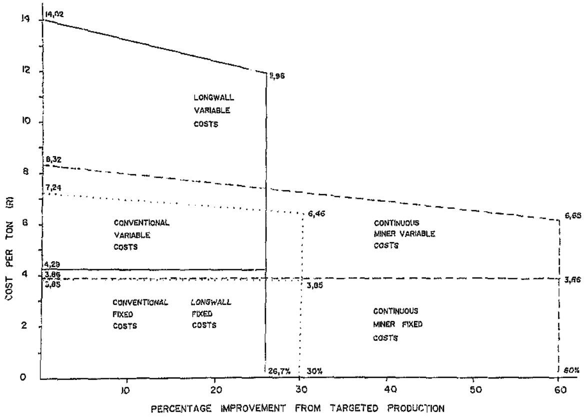
5.11 CONSEQUENCES OF INCREASED PRODUCTION

As reviewed in 5.1.2, the potential exists for increasing the production from the various mining methods, to differing degrees.

Should the productivity of the 3 mining methods increase to their hypothetical maximum, then the cost per ton of the continuous miner section would become very close to those of the conventional section. This is due to the larger potential which exists to increasing the productivity of the newer, less familiar, and more exacting mining method.

Fig. 5.4 shows how the cost per ton decreases as the production is increased. The cost per ton for major overhauls, sub-assemblies and stores, were assumed to remain the same, while the cost of labour, capital, R.P.A. and conveyor belting, was decreased.

DECREASE IN COSTS WITH INCREASE IN PRODUCTION



MINING METHOD	TARGETED PRODUCTION t	COST R/TON	INCREASED PRODUCTION TARGET	% INCREASE	COST R/TON	FIXED COSTS
Conventional	50 000	7,24	65 000	30	6,46	3,85
Continuous miner	37 500	8,32	60 000	60	6,65	3,86
Longwall	150 000	14,02	190 000	26,7	11,96	4,29

With improvement, a continuous miner section can be operated at approximately the same cost as that of a conventional section, which explains the bias that certain operators have for one or other of the same.

5.12 GENERAL CONCLUSIONS

It is concluded that conventional mining still has a valuable role to play as the most economical method of underground coal mining, notwithstanding the fact that it is more labour intensive. Lower capital and maintenance costs more than make up for this.

5.12.1 SUPERVISION

The underground environment requires a particular type of employee with skills and knowledge derived from years of experience. The retention of these personnel is of great importance to the industry when an expanding economy entices artisans into factory and service employment, offering competative salaries and more favourable working conditions.

Personnel shortages are not restricted to the engineering discipline and the training and retention of good miners is important if the shift overseer is to be allowed to operate at his proper level. If not, outbye operations will suffer, resulting inevitably in unnecessary production delays.

It is important that the mining industry meets this challenge in order that it prosper and new mining methods can be successfully implemented.

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Longwall	150 000	14,02	190 000	26,7	11,96	4,29

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It is important that the mining industry meets this challenge in order that it prosper and new mining methods can be successfully implemented.

5.12.2 MANAGEMENT

The success of any mining operation is dependant to a large extent on the quality of the management. The efficiency with which the mining objectives are pursued and the relationship with the workforce and the unions are crucial determinants which have a fundamental bearing on this.

Problems should be skillfully countered by balancing a solution which suits the prevailing conditions. High tech. solutions can bring disappointing results and simpler remedies often give more reliable long term results for a lesser cost. Ideally, the degree of technological innovation should be carefully assessed so that it can be pitched at the skills level of the workforce.

5.12.3 CONVENTIONAL MINING

The shortage of skilled technical personnel is a considerable problem with the operation of advanced mining methods, as proper maintenance and the skillful operation of the equipment are seriously affected.

The more simple conventional machines, which are very often backed up with spare units, reduces the critical impact of service and maintenance.

Increasing the level of engineering expertise would bring about major cost reductions through more efficient preventative maintenance and by increasing availabilities, thereby increasing production. The number of back-up machines could also be reduced.

The labour complement of the conventional section can also be reduced to fall more in line with those of American operators. An acceptable standard must then be reached between costs, production and section standards.

5.12.4 CONTINUOUS MINERS

Continuous miners have the ability to achieve extraction ratios compatable with longwalls for a lower cost. Successful operation of these machines does require a more skilled level of maintenance and operation than conventional machinery.

5.12.5 LONGWALL MINING

Capital expenditure on mining equipment is tax deductable. If large amounts of money are spent on longwall mining equipment, a large turnover would be required if this is not to be the only major capital project which is to be planned.

Should labour costs inflate at a faster rate than material costs, then the more highly mechanised mining systems are going to become increasingly attractive.

The capital and maintenance costs of this sophisticated equipment have already increased to such an extent as to give serious doubt to further installations by even the largest of coal producers working in the deepest mines.

5.12.6 BONUS PAYMENT

Production bonus payments are an important management tool in the operation of any mining system.

South African bonus payments for underground coal miners are notably lower than those of European and American coal operators.

An increase in such an incentive, calculated on weekly or monthly tons produced, would make the operation more self-supervisory.

This is a very important consideration if the section is to be run on a decreased complement where a more diverse workload is required of each employee.

APPENDIX 1

LABOUR RATES

The following rates of remuneration consistent with those agreed upon by the Chamber of Mines, as of October 1988, were used for the purpose of the exe[illegible] :

Skilled and semi-skilled employees :

JOB GROUP	R	
7	40,93	per shift
6	36,23	
5	31,36	
4	28,26	
3	25,84	
2	23,51	

Accommodation, medical and benefits are calculated at an additional 25%.

Section Miner :	Basic	1 675,93
	P.F., medical aid	603,33
	Housing costs	350,00
	Bonus	127,0[illegible]
	Overtime	530,02
		R3 286,28

Artisan :	Basic	1 753,33
	P.F., medical aid	631,20
	Housing costs	350,00
	Bonus	196,00
	Overtime	659,69
		R3 590,22

REFERENCES

1. De Jager, F.S J. -
Coal reserves of the Republic of South Africa - an evaluation at the end of 1982. Pretoria, *Geological Survey*, Bull. 74. 1980. pp. 289 - 330.

2. Falcon, L.M. and Falcon, R.M.S. -
The petrographic composition of Southern African coal in relation to friability, hardness and abrasive indices. J.S. Afr. Inst. Min. Metallurgy.
Vol. 87, No. 10. Oct. 1987. pp. 323 - 326.

3. Harrold, R. ass. ed, -
Coal Age Second Operating Handbook of Underground Mining. New York : *McGraw Hill, 1980.*
Vol. 4, pp. 6 - 29.

4. Smith, A. -
The mechanisation of pillar extraction at the Durban Navigation Collieries (Pty) Ltd. J.S. Afr. Inst. Min. Metallurgy.
Vol. 85, No. 2. May 1985. pp. 151 - 155.

5. Major, P. -
Productivity and operating costs for L.H.D. machines. S.A. Mining World.
Vol. 7, No. 4. May 1988, pp. 65 - 72.

6. Trueman, R. -
An evaluation of the equipment used in South Africa for the bord-and-pillar mining of thin coal seams. J.S. Afr. Inst. Min. Metallurgy.
Vol. 84, No. 11. Nov. 1984. pp. 357 - 361.

7. Hardman, D.R. and Oberholzer, J.W. -
The performance of continuous miners in South African collieries. J.S. Afr. Inst. Min. Metallurgy.
Vol. 87, No. 1. Jan. 1987. pp. 7 - 13.

8. *Roxborough, F.F. and Pedroncelli, E.J.* -
A practical evaluation of some coal-cutting theories using a continuous miner. Journal of the Institution of Mining Engineers.
Vol. 142, No. 252. Sept. 1982. pp. 145 - 156.

REFERENCES

1. De Jager, F.S.J. -
Coal reserves of the Republic of South Africa - an evaluation at the end of 1982. Pretoria, Geological Survey, Bull. 74. 1980. pp. 289 - 330.

2. Falcon, L.M. and Falcon, R.M.S. -
The petrographic composition of Southern African coal in relation to friability, hardness and abrasive indices. J.S. Afr. Inst. Min. Metallurgy.
Vol. 87, No. 10. Oct. 1987. pp. 323 - 326.

3. Harrold, R. ass. ed, -
Coal Age Second Operating Handbook of Underground Mining. New York : McGraw Hill, 1980.
Vol. 4, pp. 6 - 29.

4. Smith, A. -
The mechanisation of pillar extraction at the Durban Navigation Collieries (Pty) Ltd. J.S. Afr. Inst. Min. Metallurgy.
Vol. 85, No. 2. May 1985. pp. 151 - 155.

5. Major, P. -
Productivity and operating costs for L.H.D. machines. S.A. Mining World.
Vol. 7, No. 4. May 1988, pp. 65 - 72.

6. Trueman, R. -
An evaluation of the equipment used in South Africa for the bord-and-pillar mining of thin coal seams. J.S. Afr. Inst. Min. Metallurgy.
Vol. 84, No. 11. Nov. 1984. pp. 357 - 361.

7. Hardman, D.R. and Oberholzer, J.W. -
The performance of continuous miners in South African collieries. J.S. Afr. Inst. Min. Metallurgy.
Vol. 87, No. 1. Jan. 1987. pp. 7 - 13.

8. Roxborough, F.F. and Pedroncelli, E.J. -
A practical evaluation of some coal-cutting theories using a continuous miner. Journal of the Institution of Mining Engineers.
Vol. 142, No. 252. Sept. 1982. pp. 145 - 156.

9. Boardman, P.A. and Pedroncelli, E.J. -
Investigations into coal cutting using a continuous miner. Johannesburg, Chamber of *Mines of South Africa.*
Research Report No. 8/80, 1980.

10. Rataj, M.S. and Thorpe, L. -
Greater production from continuous miners. Johannesburg, Chamber of Mines of South Africa.
Research Report No. 46/87, 1987.

11. Wheeler, S.J. -
An application of computer simulation : production *target-setting* in mechanised bord-and-pillar mining. Johannesburg, Chamber of Mines of South Africa.
Research Report No. 28/72, 1972.

12. Posniak, L.E. -
The face simulator, 'FACESIM', a brief user manual. Johannesburg, Chamber of Mines of South Africa.
Research Report No. 69/78, 1978.

13. Fauconnier, C.J. and Kersten, R.W.O. eds. -
Increased underground extraction of coal. Johannesburg : S. A. Inst. Min. Metallurgy.
Monograph Series No. 4, 1982, pp. 227 - 276.

14. Madden, B.J. -
An introduction to the squat pillar design formula for collieries. Johannesburg, Chamber of Mines of South Africa.
Research Report No. 2/87, 1987.

15. Smith, A. and Collins, R.E. -
The extraction of barrier pillars between adjacent longwall panels at the Durban Navigation Collieries (Pty) Ltd. J.S. Afr Inst. Min. Metallurgy.
Vol. 85, No. 4. Apr. 1985. pp. 125 - 130.

16. Hurt, K.G., Morris, C.J. and Mullins, R. -
Developments in coal cutting techniques. Journal of the Institution of Mining Engineers.
Vol. 145, No. 296. May 1986. pp. 467 - 477.

17. Collin, W.D., Huddy and Kornecki, J.A. -
Diamond picks for shearers.
International Mining. June 1986. pp. 35 - 43.