Low-Seam Auger Mining at Hlobane Colliery

R E COLLINS
The Vryheid (Natal) Railway, Coal and Iron Co. Ltd
Hlobane Colliery

SYNOPSIS

Hlobane Colliery operates a low-seam auger to extract reserves from outcropping coal seams which would not otherwise be mineable by underground methods.

The auger machine is designed to drill circular holes with a diameter of 500 mm to 700 mm, and with a length of hole of up to 70 m. The total seam recovery is 40 percent.

A production rate of 1 000 run-of-mine tons per month is achieved, operating the auger on a single shift. The cost per ton compares very favourably with underground mining methods.

INTRODUCTION

Hlobane Colliery is situated some 28 km east of Vryheid in the Vryheid Magisterial District of Natal, Republic of South Africa. The Colliery is one of four underground mines owned by Iscor Limited which supply metallurgical coal to Iscor's steelworks. Production averages 165 000 tons of run-of-mine (ROM) coal per month by continuous miner using the rib pillar extraction method, from drill and blast sections with both bord-and-pillar development and pillar extraction, and from a small opencast operation (contour mining) where coal in the highwall is extracted by augering. The majority of the production comes from underground, with only 3 600 ROM tons per month reporting from the opencast and auger operations.

Owing to the shortage of good-quality coking coal reserves in South Africa, it is a policy of Iscor to maximise the extraction of the reserves at Hlobane. The reserves between the underground workings and the coal seam outcrop were identified as an area which could be mined to improve the overall percentage extraction of the coal seams. Previous practice had been for the underground sections, when approaching the outcrop, to stop as soon as roof conditions began to deteriorate. Coal seams at the outcrop were mined only in certain areas by opencast methods, where a favourable stripping ratio existed. This resulted in a strip of coal being left between the underground workings and the surface. It was not initially planned to mine these reserves.

In 1984, an auger was imported from the United States of America for use at Natal Ammonium, a neighbouring colliery. Geological conditions at Natal Ammonium are similar to those at Hlobane, except that the coal seam being mined at Natal Ammonium is thicker. The feasibility of using an auger at Hlobane was confirmed by Hlobane personnel visiting Natal Ammonium. Enquiries regarding a suitable machine to suit the low-seam conditions at
Hlobane, however, proved negative. Hlobane management therefore decided to fabricate an auger machine on the Colliery, suitable for the low-seam conditions at the mine. It was also decided that the machine be designed for both surface and underground mining.

Design and fabrication of the auger commenced in early 1987 and was completed in October 1987. The machine was tested on surface and underground from October 1987 until June 1988, during which time certain modifications were made. Following the trials, a decision was made not to use auger mining as an underground mining system due to the low percentage recovery of coal remaining in developed pillars. It was therefore decided to use the auger only on surface, as in conventional augering operations. Other more promising mining methods such as the ram-plough were also being evaluated.

On 10 June 1988, the auger commenced production on a permanent basis from the highwall of a small contour mining operation. The seam being extracted has an average thickness of 600 mm and the cutting head is 500 mm in diameter. Production rates have been fair with a maximum of 232 m (66 ROM tons) drilled in a single shift. The auger is presently worked on a permanent day shift, but double shift operations will commence in September 1988 once suitable floodlighting arrangements have been made.
GEOLOGY

The coal measures at Hlobane belong to the Vryheid Formation (Middle Ecca) of the Ecca Group. The sediments consist of predominant coarse-grained sandstones with some shale horizons, as shown in Figure 1. Two major dolerite sills, the Zuinguin and Matshongololo, cap the Hlobane Mountain and create the characteristic plateaux in the area. The underlying coal seams outcrop around the sides of the mountain and access to the underground workings is generally by horizontal adits. The heating effect of the dolerite sills at the time of intrusion gave the coal seams their coking properties. The quality of the coking coal is poorer in the upper coal seams, which are closer to the dolerite sills.

The coal measures consist of several seams, of which only four (the Alfred, Gus, Upper Dundas and Dundas) are of economic importance. A general section of the coal seams is shown in Figure 2.

The Alfred Seam, averaging 1.60 m thick, is now virtually mined out, with only a small reserve remaining as pillars. The underlying Gus Seam, 17 m below the Alfred, has an average thickness of 980 mm. The Dundas Seam, lying 15 m below the Gus, has an average thickness of 1.5 m but contains a sandstone and shale intra-seam parting averaging 600 mm thick. The bottom coal below the parting is generally 600 to 700 mm thick, whereas the top coal above the parting has a thickness of only 200 to 300 mm. The Upper Dundas is mined locally, where the seam becomes thicker.

At present the entire production is from the Gus and Dundas seams, with 40 percent reporting from the Gus and the remainder from the Dundas. Due to a difference in the coal qualities, the two seams are not blended together but are beneficiated and despatched to the steelworks as separate products.

The seams are generally flat-lying, but are divided into a number of blocks defined by dyke-fault structures with throws of up to 27 m. Dolerite dykes, with associated minor displacements, occur frequently in the workings. The dykes are orientated generally in a northwest-southeast or northeast-southwest direction. However, as the Alfred Seam has been mined out, the dyke and fault structures can be plotted with reasonable accuracy on the plans of the underlying coal seams.

In the underground trials, the auger was used to extract the bottom coal of the Dundas Seam in pillars developed at the full seam height. In the surface operations, the auger has been used on the Gus Seam and also on the bottom coal of the Dundas.
BASIC DESIGN PARAMETERS OF THE AUGER

The auger was designed for both surface and underground operations. The dimensions of the developed roadways in the underground bord-and-pillar workings placed severe restrictions on the overall size of the machine. It was determined that the auger had to be designed to operate in a roadway with a width of 5,5 m and a height of 1,2 m.

The basic design parameters that the auger was required to meet are detailed as follows:

Physical size
- Maximum overall height: 1,2 m
- Maximum length of machine base plate: 5,0 m
- Maximum width of machine base plate: 4,0 m
- Length of individual auger sections: 2,0 m
- Diameter of cutting head (3 sizes to optimise extraction of coal seams): 500 mm, 600 mm and 700 mm
- Maximum length of auger hole: 70 m

The maximum length of a scroll section could not exceed 2 m, owing to the confined space in the underground workings. It was envisaged that the short scroll sections would increase deviation of the cutting head, and have an adverse effect on directional control. A suitable coupling was required to minimise the deviation between scroll sections.

As Hlobane Colliery is classified as a fiery mine, all equipment had to comply with the relevant South African Bureau of Standards and Government Mining Engineer specifications for flame-proof equipment.

TECHNICAL SPECIFICATIONS OF AUGER

Following the underground and surface trials carried out between October 1987 and June 1988, certain modifications were made to the original machine. The machine was altered in accordance with the specifications given below. The components of the auger are indicated in Figure 3.

**Dimensions of machine**
- Length of machine base plate: 4,0 m
- Width of machine base plate: 2,0 m

**Auger**
- Length of individual auger sections: 2,0 m
- Diameter of cutting head (3 sizes to optimise extraction of coal seams): 500 mm, 600 mm and 700 mm
- Pitch of auger spiral: 500 mm
- Designed length of auger hole: 70 m
- Rotational speed: 87 rpm

**Auger couplings**
- Type: Tapered coupling with an angle of 10°
- Material used: EN 19 condition T
**Main electric motor**

- Power: 110 kW
- Speed: 1 440 rpm
- Flameproofing: Flameproof
- Voltage: 380 V, 3 phase, 50 cycles
- Type: TEFC

**Main hydraulic pump**

- Type: Hall 750
- Delivery: 336 l per minute (two in parallel mounted on common shaft)
- Working pressure: 17 MPa
- Speed: 1 440 rpm

**Hydraulic motor**

- Type: Staffa B270
- Power at maximum continuous speed: 127 kW
- Displacement: 4,31 l per revolution
- Torque output: 14 kNm at 20 MPa
- Speed: Variable up to 125 rpm
- Rotation: Bi-directional

**Secondary electric motor**

- Power: 37,5 kW
- Speed: 1 440 rpm
- Flameproofing: Flameproof
- Voltage: 380 V, 3 phase, 50 cycles
- Type: TEFC

**Secondary hydraulic pump**

- Type: Hall 750
- Delivery: 250 l per minute
- Working pressure: 13,7 MPa
- Speed: 1 440 rpm

**Coal transport system**

- First stage: Auger
- Second stage: Armoured flight conveyor
- Third stage: Belt conveyor

**Hydraulic motor on armoured flight conveyor**

- Type: Motoridutorri, Series MR301
- Power at maximum continuous speed: 15 kW
- Displacement: 0,588 l per revolution
- Torque output: 114 Nm at 15,5 MPa
- Speed: Variable up to 105 rpm
- Rotation: Bi-directional
DESIGN OF CUTTING HEAD

The criteria adopted in the design of a cutting head were to obtain:
- Maximum penetration speed
- Minimum power requirements
- Minimum head deviation

In order to satisfy the above requirements it was decided to design a cutting head with a concave pick configuration. Much emphasis was placed on the calculations of lacing, spacing, cutting speeds, rake angles etc, but field tests showed that the specific energy required to obtain a reasonable penetration speed was much beyond the capacity of the machine.

The head was redesigned and a convex type was built. It was found that by increasing the rake angle to a minimum of 30° the specific energy and cutting forces were reduced considerably.

In order to further reduce the specific energy consumed it was necessary to achieve optimum interaction between picks. The depth to spacing ratio for minimum energy consumption was determined as shown in Figure 4.

Some design refinements were made after a series of trial tests were run. The final head design is shown in Figure 5.

In order to minimise deviation problems, the auger couplings had to be designed to achieve the required rigidity with minimum coupling and decoupling time.

AUGER COUPLING

The design of the auger coupling is shown in Figure 6. Since the auger sections were limited to a maximum length of 2 m, rigidity and quick coupling characteristics are of prime importance. Conical, tapered, male and female halves are used. The coupling and coupling pin are made from EN 19 material. The taper on the coupling is 10°, as this angle was found most suitable to prevent self-locking and maintain rigidity.

SLIDING DRIVE UNIT

A general view of the sliding drive unit is shown in Figure 7.

Owing to the large end thrusts, careful consideration had to be given to the design of the jack shaft. A heavy duty plummer block arrangement, as shown in Figure 8, was designed and manufactured for this application.

UNDERGROUND TRIALS

Underground trials were conducted in the Dundas Seam workings of Mountain Adit. The workings had been developed on a bord-and-pillar layout several years prior to the commencement of the trials. The adit was worked originally using handgot methods, and tubs were transported by an endless rope haulage. As the haulage was in good condition it was decided to make use of the existing infrastructure rather than to install an extensive conveyor belt system.
Roadways were developed 5.0 m wide by 1.67 m high, the full height of the Dundas Seam. A typical section of the Dundas in the area of the trials at Mountain Adit is shown in Figure 9.

It had always been planned to mine the developed pillars to improve the overall extraction of the reserves. Pillar extraction (or 'stooping') has been practised at Hlobane Colliery for many years, allowing recovery of up to 85 percent of the coal within a panel. However, as the Dundas contains a stone parting, a low mining yield is achieved when developing and extracting pillars at the full seam height. Past efforts to improve the mining yield by mining bottom coal and only a portion of the stone parting have met with little success, owing to excessive costs associated with stone mining and mechanical support requirements.

The overall ROM yield at Hlobane Colliery is 36 percent and an improvement in the yield was seen as critical to improve the cost per sales ton. The auger was therefore designed to extract the bottom coal in developed Dundas pillars to improve the yield of the ROM coal reporting to the beneficiation plant.

At Mountain Adit the bottom coal has a thickness of 700 mm, and it was found that a cutting head with a diameter of 600 mm would maximise extraction without fouling the stone parting or floor. The pillars mined had a length of 25 m and a width of 16 m. As the depth of cover was only 45 m, the conditions for pillar extraction were considered to be good.

The bottom coal was augered out in the manner shown in Figure 3. Ribs of 200 mm were left between holes, with 50 mm of coal left above and below the hole. The machine is moved along the face in the underground workings by means of hydraulic cylinders and hydraulic anchor jacks which are set against the roof. Augered coal is loaded into tubs and transported out of the section on an endless rope haulage, which was already in existence at Mountain Adit prior to the trials. It was planned that should the trials prove successful, the coal would be transported using a continuous conveyor system.

Figure 10 shows the auger in operation in the underground section. In this photograph, the hydraulic motor is in a different position to that on the machine now in use.

No serious operating problems were experienced, although some holes were drilled short owing to rolls in the coal seam, which resulted in the head cutting into the floor or stone parting.

The results of the trials can be summarised as follows:

1. The auger achieved the objective of improving the mining yield. A yield of 70 percent was achieved from the section, compared with 27 percent had the full seam been mined by conventional methods.

2. The cost per sales ton was good, comparing very favourably with the other methods in use at Hlobane Colliery, as given below, ranked in order from the lowest in-section cost to the highest:
Auger.
Fairchild Wilcox continuous miner.
(3) Pillar extraction using handloading methods.
(4) Double-stall scraper-winches mining.
(5) Bord-and-pillar mining using gathering arm loaders discharging into battery powered tractor-trailers.
(6) Bord-and-pillar mining using ultra-low battery powered scoops.

3. Production during the trials was poor, with only 300 tons produced on a single shift in one month. It must be stressed, however, that several teething problems were experienced which had a serious effect on production. These teething problems have been rectified on the machine now in operation.

4. The total coal recovery from a developed pillar is 40 percent. This compares with 70 percent if conventional pillar extraction methods are used.

On completion of the underground trials, a decision was made not to use the auger as an underground mining system based mainly on the low percentage recovery, and investigations into other more promising mining methods such as the ram-plough mining system.

SURFACE OPERATION

On 10 June 1988, the auger commenced production on a permanent basis from the highwall of a small contour mining operation. To date, the auger has been used on both the Gus and Dundas seams.

In the contour mining operation the overburden is removed by ripping and dozing the broken material down the slope of the mountain. In this operation a volumetric stripping ratio of 7:1 is achieved, resulting in a competent highwall, 7 to 10 m high. The highwall is sloped back at an angle of 15°, and dressed down to remove loose rubble during the dozing operation. Final barrelling down of the highwall is carried out by hand where dangerous conditions exist.

After removing and discarding badly weathered coal from the immediate outcrop area, the coal remaining up to the highwall is loaded by front-end-loader into trucks for transportation to the beneficiation plant.

The coal seams in the area of the contour mining operation dip gently toward the centre of the mountain, but no problems are experienced provided the base plate of the machine is resting on the true floor of the coal seam. For this reason, the area below the highwall must be cleared of loose material to keep pace with the progression of the auger. The auger is fitted with levelling jacks to position the cutting head, as accurate levelling of the machine reduces the amount of coal which must be left above and below the auger hole.

The Gus Seam in the area being mined is 700 mm thick and a 600 mm cutting head is used for augering. In the underlying Dundas Seam, the bottom coal is 600 mm thick and is successfully mined using a 500 mm diameter cutting head.
Holes of up to 70 m in length are drilled, but many holes are considerably shorter owing to the presence of dolerite dykes which cut through the highwall at various angles. An area of burnt coal is found adjacent to the dykes and the auger is stopped as soon as burnt coal is observed coming from the auger holes.

The cutting head sumping rate is good, with a time of 60 seconds per individual auger section, each with a length of 2.0 m. However, it takes 20 minutes to extract an auger string with a length of 50 m, which has a serious effect on the overall production rate of the machine. Efforts are now being concentrated on the reduction of time spent on non-productive operations, such as withdrawing the auger string and moving the machine to the next hole.

The machine is trammed using an underground battery powered scoop, which is also used for general clean-up duties along the highwall. The coal carried out of the holes by the auger flights is conveyed by an armoured flight conveyor onto a stacking conveyor, which deposits the coal in conical heaps ready for loading and transporting to the plant. The auger is operated with a crew of three, plus a scoop driver. Figure 11 shows the machine drilling the Dundas highwall.

The sizing of the coal produced by the auger is good, with a high percentage of $-38 \text{ mm} + 0.5 \text{ mm}$, which is ideally suited to beneficiation using dense medium cyclones. Very little crushing is required due to the virtual absence of $+38 \text{ mm}$ material.

After the highwall has been augered, the area will be backfilled to restore the original contours. Full rehabilitation to an approved plan will follow.

The cost per sales ton produced by the auger compares very favourably with that of other mining methods employed at Hlobane. Production rates have, however, been lower than initially planned. The maximum production rate achieved since 10 June 1988 has been 232 m (66 ROM tons) drilled in a single shift. The auger has a production rate of 1 000 ROM tons per month operating on a single shift, when drilling 500 mm diameter holes. A higher production can be expected for the 600 and 700 mm cutting heads.

The production figures achieved during August 1988 are given in Table 1. The auger production rate, given in metres advance using a 500 mm diameter cutting head, is shown graphically in Figure 12. Availability and utilisation of the machine are given in Figure 13. It can be seen from the graphs that an upward trend in production and utilisation is evident. This upward trend is due to minor teething problems being solved, and also due to the experience gained by operating and maintenance personnel.

An additional advantage of the auger is that reserves which would otherwise not be mineable by underground methods are being extracted. The underground workings are only advanced to within 30 to 100 m of the outcrop, as weathering causes the roof conditions to deteriorate. Augering the coal from this weathered zone is the only practicable method of recovering these reserves (opencast methods are not economic due to the high stripping ratio). Thus, although the auger has a total seam recovery of only 40 per-cent, the mine is benefitting by extracting this percentage of the reserves, which would otherwise have been written off.
CAPITAL COST OF AUGER

The machine described in this paper was designed and built entirely by personnel at Hlobane Colliery. This was necessary owing to the unique design parameters required for the auger.

The machine has a total capital cost of R253 700, which can be broken down as follows:

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LABOUR COSTS

The total labour cost to construct the auger was R35 950. This figure does not include work carried out by supervisory and management group employees.

CONCLUSION

An auger machine designed to drill circular holes with a diameter of 500 to 700 mm, and with a length of up to 70 m, has been brought successfully into production at Hlobane Colliery.

The auger was constructed at a total cost of R289 650, and was designed and built at Hlobane Colliery by Hlobane personnel.

Although the auger was designed for both surface and underground mining, the results of the underground trials were not sufficiently encouraging to warrant further development. After the underground trials it was decided that the auger would be restricted to surface operations.

The cost per sales ton achieved by the surface operation compares very favourably with other mining methods employed at Hlobane. The production rate is, however, lower than planned and efforts are being made to improve on the results achieved to date. As the auger has a crew of four, the labour productivity is high.

The surface mining operation has the added advantage of improving the overall recovery of the reserves, thus extending the life of the mine.
ACKNOWLEDGEMENT

Mr B.C. Alberts, Senior General Manager, Mining, Iscor Limited, for permission to publish this paper.

LIST OF COMPONENTS INDICATED IN FIGURE 3

1. Hydraulic cylinder to extend and retract anchor jack
2. Swing jack
3. Hydraulic motor
4. Sliding drive unit
5. Slide rails
6. Multi-stage hydraulic cylinder
7. Levelling jack
8. 37,5 kW motor for secondary equipment
9. Tank for hydraulic oil
10. Power pack
11. 110 kW electric motor
12. Hydraulic pump
13. Position of operator
14. Hydraulic valve bank
15. Auger coupling
16. Base plate
17. Auger scroll
18. Lifting device
19. Armoured flight conveyor
20. Tertiary conveyor
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**Figure 1**

General stratigraphic section at Hlobane mine.

- **Zuinguin Dolerite**
- **Sandstone**
- **Matshongolo Dolerite**
- **Sandstone with Shales**
- **Coal seams with sandstone partings**
  - Eland
  - Bonas
  - Fritz
  - Alfred
  - Gus
  - Dundas
  - Coking
  - Sandstone
Fine grained Sandstone grading upwards to a coarse grained Sandstone

**FLAND SEAM**
- 0.24m COAL
- 7.00m Sandstone

**BONAS SEAM**
- 0.44m COAL
- 5.00m Sandstone
- 0.55m COAL
- 7.00m Sandstone

**FRITZ SEAM**
- 1.60m COAL
- 17.00m Sandstone and Shale

**GUS SEAM**
- 0.98m COAL
- 9.00m Sandstone
- 0.40m COAL
- 5.60m Sandstone
- 1.50m COAL with Sandstone parting
- 20.00m Sandstone Bioturbated

**UPPER DUNDAS SEAM**

**DUNDAS SEAM**
- 0.25m COAL
- Fine grained Sandstone

**COKING SEAM**

*FIGURE 2*
General section of coal seams
NOTES:
1) CABLES AND HOSES HAVE BEEN OMITTED FOR CLARITY
2) REFER TO LIST TO IDENTIFY COMPONENTS
3) THE METHOD OF EXTRACTING BOTTOM COAL FROM DEVELOPED PILLARS IN THE DUNDALES SEAM IS SHOWN IN THIS FIGURE

FIGURE 3
Components of the auger machine
FIGURE 4
Diagram showing depth to spacing ratio of cutting picks

\[ S = 2d \tan \phi \]
FIGURE 5
Cutting head showing pick configuration

FIGURE 6
Note:
Guards have been omitted for clarity

FIGURE 7
General view of sliding drive unit
FIGURE 9
Typical section of the Dundas Seam in the area of the trials at Mountain Adit
FIGURE 10
The auger in operation in the underground workings of Mountain Adit
FIGURE 12
Auger production rate during August 1988