The application of continuous mining machines at Coalbrook Collieries

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SYNOPSIS

The nature of the coal and of the roof in No. 3 seam at Coalbrook Collieries is such as to preclude the use, during bord and pillar mining, of conventional mining equipment that employs cutting and blasting in its production cycle.

Continuous mining machines of the borer type, operating within a mining height range of 1,9-2,3 m, have been successfully employed in No. 3 seam since 1957. The experience gained with this type of equipment, the operational methods adopted, and the results achieved are described. The ventilation method used to eliminate the dust and methane hazards created by this type of equipment is stressed.

The limitation on the minimum mining height that can be obtained with the borers in use has lead to the recent introduction of a Rotary Drum type of continuous mining machine. This equipment is capable of operating in areas where the seam width decreases to 1,5 m. The production potential of the machine has been proved. The roof conditions created by the cutting action of the Rotary Drum type of miner are not considered satisfactory and a modified drum head profile is to be tried.

INTRODUCTION

The Coalbrook Collieries of The Clydesdale (Transvaal) Collieries, Limited, supply the total coal requirements of the Electricity Supply Commission's Highveld and Taaibos Power Stations from No. 2 and No. 3 Pits. The Colliery is situated in the south-east of the Vaal basin coal field. Three seams of economic importance occur within this part of the coal field. They are, in descending order, No. 3, 2 and 1 seams. The distribution of the present in situ coal reserves which have been allocated to the power stations is summarised in Table I.

Prior to 1957, an area some 6,0 ha in extent had been mined in No. 3 seam at Coalbrook North Colliery by bord and pillar. The seam was machine cut at roof level, blasted and hand-loaded. Difficulty was experienced in supporting the roof of the seam. The use of close systematic timber support, often placed skin to skin, did not prevent the occurrence of heavy falls, which completely closed the roadways in many places. More recent attempts to mine No. 3 seam with conventional mechanised equipment have confirmed the unsuitability of this method.

No. 3 seam contains an important reserve of coal and it was most desirable to find a safe and economic method for its exploitation. During 1957 a continuous mining machine of the borer type was introduced into No. 3 seam at Coalbrook North Colliery. This machine eliminates the need for all blasting and cuts a roadway having an arched profile. The initial operations proved that this type of mining unit was capable of providing a safe, practical and economic method for the mining of No. 3 seam[1].

TABLE I

DISTRIBUTION OF IN SITU COAL RESERVES

Seam No.	Mining height		Depth of seam below surface m	Stratigraphic location of seam	In situ coal reserve %
	Height range m	Average m			
3	1,50-2,00 +2,00	1,68 2,00			13,8 6,9
	+1,50	1,79	135-180	20-61 m below base of Dolerite	20,7
2	1,50-2,00 +2,00	1,80 2,73			10,4 36,8
	+1,50	2,46	167-235	20-30 m below No. 3 seam	47,2
1	1,50-2,00 +2,00	1,86 2,39			15,9 16,2
	+1,50	2,10	170-240	0-8 m below No. 2 seam	32,1
					100,0
All seams	1,50-2,00 +2,000	1,78 2,51			40,1 59,9
	+1,50	2,15			100,0

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It is necessary to refer to the geological structure of the Coalbrook coal field for an explanation of the difficulties encountered during mining. The coal seams were deposited within a pre-Karroo, north-south elongated basin-shaped depression which dips and widens to the south. The uneven topography of the pre-Karroo floor and the associated drainage channels greatly influenced the width, grade and distribution of the coal seams. The topography was furthermore responsible for the creation of stresses which resulted from the differential compaction of the sediments onto an uneven floor. Numerous slips and minor faults are a feature of the coal seams. In addition, the clay mineral montmorillonite is present within the coal seams. Severe spalling and scaling of the pillar sides takes place. Directionally well defined zones of weakness in the roof of the seams are a common feature and are the starting point of major falls of roof unless immediately and adequately supported.

A dolerite sill, varying from a few metres to more than 125 m in thickness, is present throughout the Coalbrook coal field, and forms an undulating, intrusive mass above the coal seams. In the central area of the field the dolerite plunges beneath the coal seams, elevating an oval-shaped area of coal bearing strata 2 500 m × 1 000 m in extent, by some 50 m above its original position.

The strata between No. 3 seam and the overlying dolerite sill consists of shales and sandstones. The immediate roof of No. 3 seam is composed of very weak friable brown shales. The thickness of this strata is very irregular due to the undulating nature of the dolerite sill. When the base of the sill is within 30 m or less of No. 3 seam, the effect of the dolerite intrusion and the associated deformation stresses become very noticeable. There is a marked deterioration of the roof, numerous faults and fractures are evident in the coal, and the volatile content of the coal decreases. The delineation of devolatilised zones from borehole data is essential for the demarcation of possible mining areas in No. 3 seam.

Continuous miners of the borer type have been found well suited for the safe and efficient production of coal in No. 3 seam under the conditions outlined. This type of machine has also operated successfully in No. 2 seam where roof conditions prevented the safe operation of conventional mechanised equipment.

This paper discusses the experience which has been gained from the application of continuous mining machines since their initial introduction at Coalbrook North Colliery. The machines are described and the more important mechanical and operational problems which were encountered are highlighted. Some of the operating results achieved are set out. A Rotary Drum type of continuous miner capable of mining at a lower mining height than the borers in use at present is described. Reference is made to the limited experience gained from the operation of this type of equipment.

EXPERIENCE WITH BORER TYPE CONTINUOUS MINERS

Equipment Design

Continuous miners of the borer type have been in operation at Coalbrook Collieries since 1957. The first machine was placed on trial in No. 3 seam at Coalbrook North Colliery and operated with a certain degree of success. It became apparent that the equipment had insufficient power to provide the full production potential that this type of machine was known to have overseas.

The penetration rate was of the order of 6,8 mm/s, yielding 11,2 t of coal per m of advance when operating at a mining height of 2,0 m.

A reassessment of the type of machine was made following the decision to purchase further miners of the borer type. A heavier and more powerful borer had been introduced into the American coal fields and potash mines, and it was believed that such a machine would suit local conditions better than the type of borer in operation. The factors which influenced the choice of the improved type of borer were:

(1) The power of the motor driving the rotors had been increased from 112 kw to 186 kw.

(2) The gearbox had been redesigned to give a more rugged construction and provide better operating features. The main rotor shafts operated in taper roller bearings as compared with bronze bushes on the earlier type borer. With bronze bushes the oil consumption increased as soon as any appreciable wear had taken place. It then became necessary to stop the borer during production periods in order to refill the gearbox with oil. The gearing was of a heavier design, promising an increased gear life.

(3) The electric motor driving the hydraulic pumps, which was situated under the conveyor boom on the first type of machine, burnt out regularly. The reasons for this were inadequate power and a lack of ventilation around the motor.

    In an attempt to overcome this problem on the first machine, a water-cooled motor of increased power was designed and installed.

    The location of the hydraulic pumps where duff coal was continually spilling off the conveyor was also most undesirable. The electric motor and hydraulic pumps on the later type of borer were situated in a better position behind the head drive motor.

(4) The cutting height of the later type of machine could be varied more expeditiously. The machine could also operate at a minimum mining height of 1,9 m, as compared with 2,0 m in the earlier borer.

After due consideration, two borer type continuous miners of the later design were introduced into the Coalbrook mines during 1960. It became evident at an early stage that even the improved type of borers were under-powered for the coal at Coalbrook. The equipment gave a greater production due to the increased horsepower, but this factor introduced complications which had not been experienced on the first borer. The electric motor driving the rotors was subject to frequent burn-outs. The motor was not water-cooled and the type of switchgear used did not limit the power that was being drawn by the motor. Following on the installation of a waterjacketed motor and of redesigned switchgear, motor burn-outs were eliminated.

The second major problem which developed was the failure of gears in the main gearbox driving the rotors.

Frequent failures were experienced due to the higher power that was being transmitted through the gear trains by a single motor. The gear failures proved costly in loss of production and repairs. It was felt that gear failures could be eliminated or reduced by the provision of a dual motor drive in which one motor drives each rotor. The manufacturers of the equipment would not agree to the fitting of two electric motors to the gearbox. A mine operator in the United States decided on his own initiative to carry out the conversion of the equipment in his mine. Within a short time every borer type of miner was equipped with dual motor drive to the rotors. Gear loadings were reduced by this modification, and resulted in a considerable reduction in downtime and in maintenance costs. There have been no major gearbox failures at Coalbrook since this modification was carried out.

Productivity improved with the dual motor drive. The penetration rate increased to 13,2 mm/s, and the higher production rate necessitated the fitting of an additional hydraulic motor on the conveyor drive.

The original borers were fitted with gauze filters in the hydraulic oil circuit. These filters were replaced by renewable cartridge filters trapping 10 micron material. Hydraulics were at one time a major cost item in the operation of this equipment. Considering that the conveyor and tramming functions are carried out by hydraulic motors operating at pressures of up to 235 bar, and passing 1 515 l/s, the great importance of clean hydraulic circuits can be appreciated.

Underground Electrical Layout

The electrical distribution in a continuous miner section is shown in Fig. 1. Switchgear and transformer are flameproof. The length of the trailing cable from the

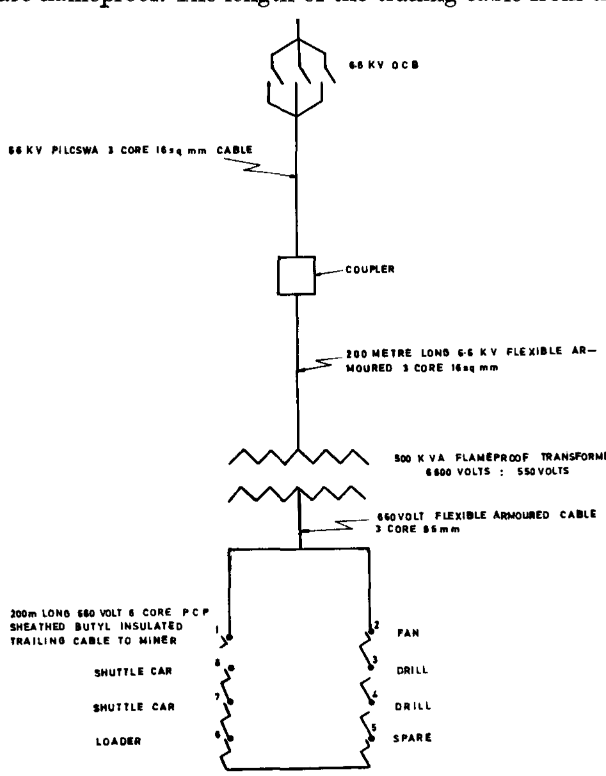

Fig 1 Underground electrical layout for continuous miner section

flameproof circuit-breaker is ±200 m. The voltage drop becomes an important factor when it is borne in mind that the installed power on the machine is 420 kw and the transmission voltage is 550 v.

Mining Dimensions and Layout

Experience has shown that mining layouts using diagonals driven off at 30° provide the best opportunity for high production with continuous miners. Typical panel layouts with varying numbers of roadways are shown in Fig. 2.

Panels having a maximum of seven roadways are favoured, for with this number of roadways the rate of advance is reasonable and shuttlecar tramming distances can be limited to ±150 m from the tail-end of the belt. Given favourable roof conditions, roadways parallel to the belt road are driven ±40 m.

Continuous miners must be kept in one place for as long as practicable if high productivity is to be achieved.

Roof Support

All continuous miner roadways are systematically supported with roof bolts, using mechanical or resin anchors. Two, 2 m long bolts are installed per row, with rows of bolts 1,5 m apart. Hand-held electric drilling machines are used to drill the holes in the soft roof shales. Roof bolts are tensioned with manually-operated roof bolt tensioners.

Experience in No. 3 seam has shown that the borer can be driven for up to ±40 m in a single roadway without installing support. Furthermore, if the roof is bad, it falls on the machine immediately it is exposed. Under such conditions the roadway is only advanced the length of the machine. The machine is then either withdrawn to another roadway or stopped during the roof bolting operation.

In certain areas where the dolerite sill has devolatilised the No. 3 seam, very bad roof and sidewall conditions are encountered. The coal seam itself is full of slips. Where the area can be mined, severe spalling and scaling of the sidewalls takes place. In these areas it is necessary to bolt the sidewalls. A number of accidents have taken place where men were jammed between the sidewall and the machines.

Once a roof fall has started, roof bolts are of no use, as the roof fritters away around the roof bolts and a large fall will eventually result. Timber breaker lines or brick walls are the only practical way in which the extension of a fall can be arrested.

Ventilation

At least 20 cu m/s of air is circulated through a continuous miner section. The intake air is split on the last through roadway. Plastic brattices are used in place of brick stoppings in panel roadways. The fact that these brattices can be erected very quickly ensures that the intake air is concentrated at the face.

Initially a 400 mm diameter forcing fan using 254 mm diameter ventilation tubing was used to ventilate the roadway in which the borer was operating. The quantity of air at the face was 0,75 cu m/s.

After the dual motor drives had been fitted to the

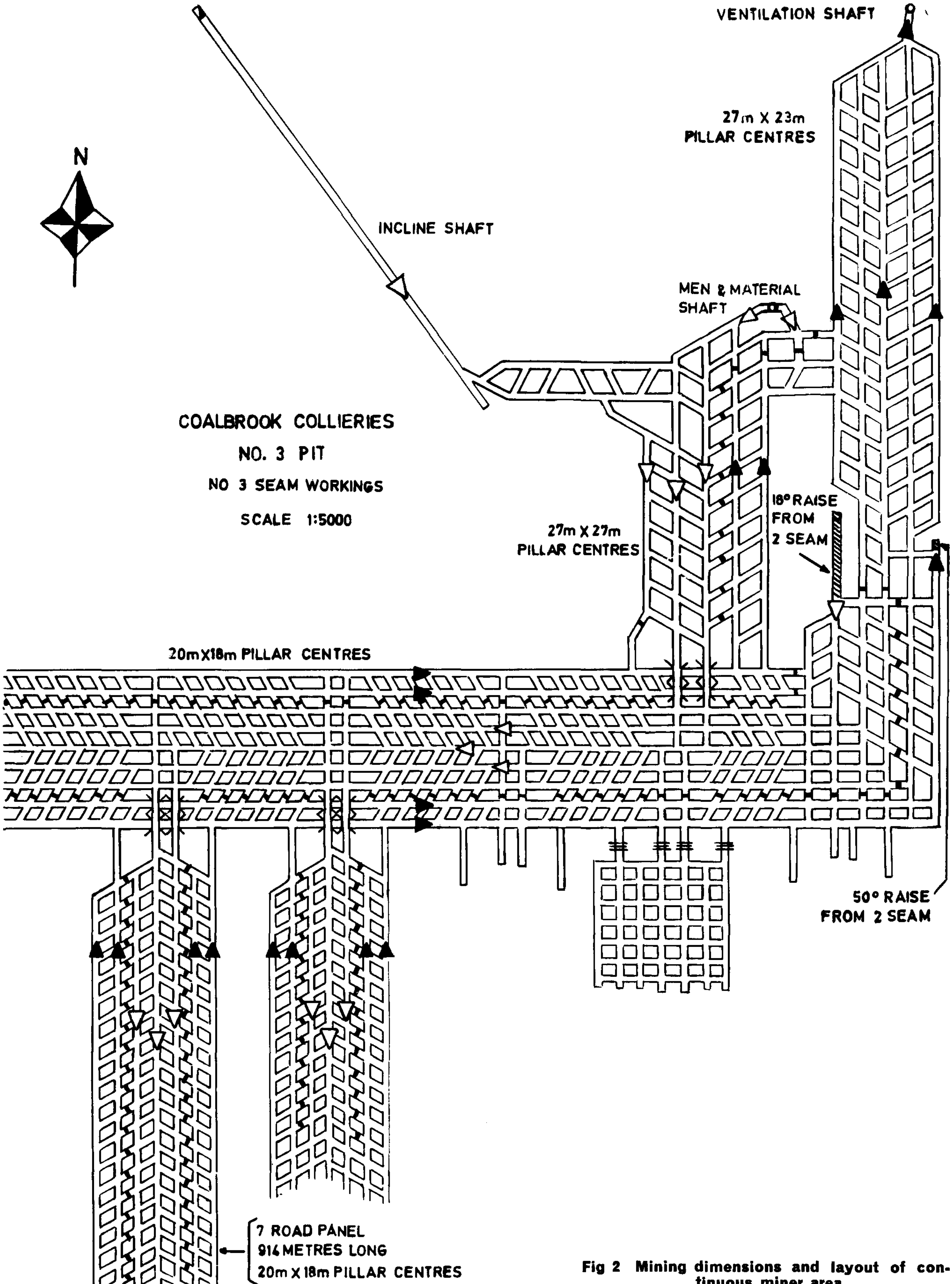

Fig 2 Mining dimensions and layout of continuous miner area

borers, the penetration rates increased considerably. The emission of methane in the borer roadway made it necessary for larger volumes of air to be delivered to the face to dilute the gas. The size of the fan was increased to a 560 mm diameter "in line" fan. The diameter of the ventilation tubing was increased to 400 mm. The average quantity of air delivered to the face with this arrangement is 3 cu m/s.

In certain areas of No. 3 seam, the methane emission was so high that the borer could not be driven into the solid at the desired rate. Production had to be limited in order to keep the roadway clear of methane. As a further means to control the high rate of methane emission encountered, two 560 mm diameter fans were connected together in series to increase the quantity of air at the face to approximately 5 cu m/s. The velocity of the air at the end of the ventilation column became so high that dust was raised and uncomfortable conditions were created for the borer operators.

The use of an exhausting system of ventilation was then considered. This system would eliminate the dust hazard and the high velocity stream of air in the vicinity of the operators. Centrifugal fans with external motor drive are however cumbersome and very heavy. The Mines Department would not permit the flow of exhaust air over an electric motor. The electric motors were replaced by hydraulic motors, driven from an independent power pack. The fans and power pack are mounted on an old loader chassis, which can be trammed from place to place. 400 mm "Flexadux" tubing in 6 m lengths is used to exhaust the air from the borer roadway.

A fan was recently introduced which has the electric motor and drive completely isolated from the air stream. Incorporated in this type of fan is a "Water Spinner" which is placed in the nose faring of the fan and delivers a spray of water from a peripheral slot in the faring of the fan. Any dust that is drawn back through the ventilation column is allayed by this method.

Labour

The labour complement to operate a borer section is as follows:

1 Miner
2 Borer Attendants or Cable Handlers
1 Ventilation Assistant
2 Shuttlecar Drivers
2 Shuttlecar Cable Handlers
5 Roof Bolters
3 Sweepers
1 Belt Attendant
—
17 Total section labour complement

A fitter is allocated to each section, while one electrician covers two sections. They each have one non-White assistant. A machine is stopped on one shift per week for routine maintenance. Extra engineering personnel is brought in on this shift to assist in the maintenance of the borer and the shuttlecars.

Production

The call from a continuous miner section is 675 t/shift, including Saturdays. When roof conditions are normal, this figure is attained and often surpassed. The highest production to date from a borer over the [illegible] month was 39 322 t for [illegible]5 shifts [illegible] average of 874 t/shift. The highest production [illegible] in one shift was 1 156 t, representing an advance of 103 m.

Since the introduction of borers at Coalbrook, 9 000 000 t have been mined with three machines.

Costs

A comparative breakdown of underground section costs for a conventional mechanised unit and a borer unit are shown in Table II.

TABLE II

MAKE-UP OF UNDERGROUND SECTION COSTS FOR A CONVENTIONAL MECHANISED UNIT AND A BORER UNIT

Cost item	Cost as a percentage of total cost	
	Mechanised unit	Borer unit
Mining: White Wages	11,6	12,6
Non-White Wages	12,9	10,3
Stores	33,7	28,4
Engineering:		
White Wages	12,4	10,7
Non-White Wages	1,9	1,9
Stores	27,5	36,1
Total section cost	100,0	100,0

No provision has been made for the amortisation of any equipment. Mining stores costs are high, for the reason that roof bolting alone costs 15 cents/t. Pick costs on the borers average 2,5 cents/t.

It must be accepted that, when costs of major overhauls are included, the cost of production from continuous miners is higher than the cost from less sophisticated equipment. When costs are considered and compared it must be borne in mind that No. 3 seam can only be mined at Coalbrook by continuous mining methods at present.

EXPERIENCE WITH CONVENTIONAL MECHANISED EQUIPMENT IN NO. 3 SEAM

An attempt was recently made to mine No. 3 seam at No. 3 Pit with conventional mechanised equipment. The panel was worked on square pillars and can be seen on the plan (Fig. 2). The bords were driven 4,4 m wide on 18,3 m centres. The panel was advanced for about 100 m and conditions appeared normal. Systematic roof bolting did not however prevent the complete roof collapse in a cross-road from barrier pillar to barrier pillar during one weekend. This experience again confirmed the opinion that No. 3 seam can only be mined by continuous miners when the bord and pillar method is employed.

THE ROTARY DRUM TYPE CONTINUOUS MINER

Introduction of Rotary Drum Miner

The in situ reserves of coal that can be mined with borers is limited to the northern area of the No. 3 seam. In order to mine the southern area of No. 3 seam, a suitable mining machine had to be found that was capable of mining coal between 1,5-2,0 m thick. The oscillating head type of machine is popular in the American coal fields. This type of machine was considered, but was not favoured on account of the "dead" nature of No. 3 seam coal. No. 3 seam coal is devoid of any cleats or cleavage planes and every bit of coal has to be cut from the face. The coal however is easily cut.

The Rotary Drum type of continuous miner was introduced into the American mines about four years ago. Since its introduction, it has rapidly gained favour with mine operators. After a careful study of this type of continuous miner, the decision was taken to test thoroughly its performance and suitability at Coalbrook Collieries.

Description and Operation of Rotary Drum Miner

The Rotary Drum miner is fundamentally a loading machine with a horizontal helical cutting element mounted on a boom that can be elevated or depressed in a fixed vertical arc about the loading head. The cutting element comprises two helical scrolls located horizontally on either side of a Ripperveyor. Plumb Bob type bits, welded onto the scrolls and the Ripperveyor cut the coal. The helical scrolls move coal towards the centre of the loading head. The ends of the rotary drum head retract when the machine is trammed from one working place to another. The cutting width of the rotary drum head is 3,8 m. The rotary drum head is driven by two 90 kw-550 v water-cooled electric motors. A similar motor drives three hydraulic pumps. Two of these pumps supply hydraulic oil to independent tramming motors. The third pump is used to provide oil for the jack circuits. A 37,5 kw motor powers the gathering head and conveyor chain. The modus operandi with the drum rotating is:

The whole machine sumps into the solid coal face at roof level, for a depth of $\pm 0{,}6$ m. The boom then shears down to the floor in a flat vertical arc. The whole machine moves backwards for the approximate sump depth. The coal so mined is conveyed through the centre of the machine by means of the loading element, and dumped onto the floor behind the machine. A loader of equivalent capacity loads the coal into shuttlecars from the pile of dumped coal. The operation of sump, shear and retreat takes less than a minute. This operation yields about 6,0 tons at a mining height of 2,0 m.

Experience to date with the Rotary Drum Miner

The machine has been in operation for a period of about 12 months. Initial doubts about power requirements were very quickly allayed. The machine is capable of cutting coal at a very high rate, and a production of 974 t/shift has been obtained in a seam of 2,0 m.

The Rotary Drum type miner has a different cutting action to the borer type of continuous miner. The profile cut by this machine is a rectangle 3,9 m wide and with a height of between 1,5 m and 3,0 m, depending on the seam width. Under normal conditions the machine will advance a roadway 30 m before it is withdrawn and the face supported.

The experience to date is that the exposed roof will remain sound for a period of three to four weeks. Thereafter localised falls occur at intersections, and within a very short time the roof falls become so serious that either roadways have to be heavily timbered or the equipment has to be withdrawn from the area.

The shape of the rotary drum head is at present being changed to a tapered head. The machine will then cut an arched roadway, and it is hoped that this shape of roadway will improve roof behaviour.

Ventilation and Dust Suppression

The exhausting system of ventilation is used to ventilate the working place in which the machine is mining. The system used is as described for the borer type of continuous miner. Provided the exhaust ventilation tube inlet is kept well up to the face, dust conditions are comparable with any other type of coal cutting operation.

The electric motors on the machine are water-cooled. The water, after having passed through the motors, is directed to sprays used for dust suppression. Sprays are located on the boom of the miner and project high pressure water onto the face. It is necessary to have a high standard of discipline and maintenance on the water spray circuit if dust-free conditions are to be maintained. Water is supplied to the machine through 25,4 mm diameter hydraulic hoses at a pressure of 20 bar.

CONCLUSIONS

A prerequisite for the introduction of the type of equipment described is a seam of coal, free from hard stone bands and intrusions. The coal must be easy to cut and the seam must be reasonably flat. Productivity is dependent on the nature of the roof. The operation becomes highly efficient when it is unnecessary to support the roof immediately it is exposed.

The rotary drum type of continuous miner is a more versatile and flexible machine than the borer type. Where conditions favour continuous miners, the rotary drum type of equipment is preferred.

Continuous mining must be regarded as having a special application in Southern Africa at present. In the case of No. 3 seam in the Coalbrook area, the type of equipment described has made it possible to extract approximately 30 per cent of the in situ coal reserve on an areal extraction basis. There is every confidence that a method of mining has been proved which has made it possible to mine No. 3 seam, and other seams, at an economic cost.

The development necessary for longwall retreat mining is best carried out by continuous mining machines. The concentration of the production operation from continuous miners makes this equipment eminently suitable for pillar extraction. The low selling price of coal in the Transvaal and Orange Free State has so far discouraged the mining engineer from employing these methods.

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