COALTECH 2020

TECHNICAL REVIEW OF THIN SEAM CLEARANCE SYSTEMS FOR ROM COAL

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EXECUTIVE SUMMARY

The South African coal industry is faced with certain challenges that may be solved by addressing issues surrounding the mining of thin seams. South Africa produces about 220 million tons of ROM coal per annum, part of which is exported and the remainder used locally. In the near future, it will be important to mine thin seams to sustain energy demands and maintain exports as higher seams become depleted.

In addressing this issue, COALTECH focused on identifying the elements that make thin-seam mining economical, such as the mining system, which comprises the coal winning machine and the clearance systems.

A technical review of these clearance systems was carried out with the aim of expanding the option base for thin-seam transport. These systems were divided into three categories: i.e. face, in-section and out-bye clearance systems. All the clearance equipment was analysed between batch and continuous hauling.

This research investigated both past and present systems used globally. The other aspect of the methodology was based on identifying alternative potential clearance technologies for thin seams.

The major outcomes of this study were as follows:

- Adequate thin coal-seam winning machinery is available in the global market to fulfil the required production expectations for the South African coal industry.
- Batch haulage equipment for thin coal seams could be used more effectively to match the tonnage capacities of the winning machines if certain batching technical aspects are understood.
- The ideal system for conveying coal from the face to the surface would be one with minimal intermediate material change points, as these disrupt the material flow. This transportation technique could be more efficient if the mining technique produces the ideal particle size distribution. These may be fluid-based transportation means, i.e. pneumatic conveying, hydrohoisting etc., for instance.
- A number of technologies were identified from extra low profile (XLP) mining equipment and equipment used in other industries, which could be an alternate means for thin-seam transport applications.

These outcomes could form a basis for future COALTECH proposals to address thin-seam production concerns in the South African coal industry.

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GLOSSARY OF TERMS

Thin seam	Coal seams less than 1.4 m.
Mining method	This is the mining layout chosen for a certain mineral extraction process, e.g. room and pillar, open pit mining.
Mining system	This refers to the combination of the mining machine/technique and its immediate transportation line, e.g. continuous miner and shuttle cars, shearer and armoured face conveyor.
Mechanised mining	This mining technique refers to the rock breaking mechanism by machinery, such as continuous miners, shearers, plows etc.
Conventional mining	Drill and blast technique.

1 INTRODUCTION

The Minerals Bureau estimates South African coal reserves to be about 33.8 billion tons and that they may last up to 2050 (Prevost, 2004). It is important for the South African coal industry therefore to maintain maximum recovery of these reserves in order to maintain global competition and meet the country's energy demands. The overriding factor in this regard is economics. With limited coal reserves and resources available, the following realities need to be addressed:

High cost in mining thin seams - The total cost for extracting thin seams in South Africa has proven uneconomical and, in some cases, has led to the discontinuation of mining operations. Hlobane Colliery, for instance, has been closed for these reasons.

Depletion of medium and high seams - The exhaustion of these seams directly impacts on the country's energy supply and the need to acquire the neglected thin seams. Witbank Coalfield is nearing depletion already.

Destroying of thin seams - Undermining of lower seams has been done on economic grounds and has led to the thin seams above the roof strata being destroyed, hence reducing available natural coal resources.

All these factors indicate the necessity of identifying best practices in mining thin coal seams, which would improve coal reserve utilisation. Some of the country's high-quality coal is found embedded in these thin seams. The economic status of a mine dictates the mining method to be used, which has a direct impact on the equipment to be deployed. Problematic aspects of the S A coal mining industry include capital/operating expenses pertaining to the equipment together with mining practices.

It has been observed that one of the problems in thin-seam mining is that the winning machine has higher tonnage capacities than to the clearance machines. This discrepancy creates a bottleneck that restricts the efficient flow of coal in the whole production line.

Another aspect of the problem may be associated with equipment utilisation. For instance, most loading machines are rated at 18 to 30 tons per minute, but in practice they seldom achieve average loading rates in excess of three to seven tons per minute. It is therefore important to understand the technicalities governing thin-seam equipment and finding useful solutions to the problem.

This study presents a review of thin-seam clearance technology subsystems currently used in South Africa and around the globe, and further identifies improvements that could be made to these. It also reviews alternative means of transporting coal from the face to the surface. This study is performed with the assumption that the coal has already been mined by mechanised mining or conventional means. The coal size will therefore vary according to mining technique employed, and the coal may need to be sized if a secondary transportation line is to be accommodated.

The data for this work was collected from:

- Equipment manufacturers, in the form of brochures, website pages and verbal interaction;
- Published articles, both national and international; and
- Mine visits.

This technical evaluation includes past technologies that were revisited to determine trends in the evolution of thin-seam equipment.

2 FACTORS AFFECTING THE CHOICE OF THIN-SEAM CLEARANCE EQUIPMENT

The analysis of thin-seam coal clearance equipment cannot be isolated from the factors set out below.

- *Mining method* – Specific mining systems are well suited to certain mining methods. For instance, continuous mining with shuttle cars is suited to the room-and-pillar method.
- *Overall transport route* – A flow restriction at any point in the transport route from the coalface to the surface affects the whole production line.
- *Integration of mining system* **-** The total mining system is customised to fit its layout. It is therefore difficult to interchange subsystems within different mining systems for other mining methods, e.g. the shearer is designed to fit onto the armoured face conveyor.

2.1 Mining method

The mining method largely influences the type of equipment to be used in a particular mining layout. It is the work of the mining engineers to evaluate which method is economically viable for a certain mineral extraction process. The method that yields the highest return on the capital invested over the life of the mine will be chosen. Other factors affecting the choice of a mining method are:

- Depth of coal;
- Quality and strength of coal ;
- Orientation of coal seam (dip);
- Seam thickness;
- Environmental impact;
- Presence of intrusions;
- Nature of overlying strata and partings between seams; and
- Type and strength of roof and floor rocks.

After the exploration process, these factors are evaluated by mining engineers to decide on either an underground or opencast mining process. The underground choice of mining is favoured if the depth of the coal seam is greater than 40 m or if the removal of the overburden becomes costly. At present, there are no longwall operations in South African coalfields in seams less than 1.4 m as a result of their horizontal inconsistency. The USA mines certain seams between 1.4 and 1.6 m with the longwall mining method and achieves production rates of over 500 000 tons per month. The most commonly used mining method in South Africa is the room-and-pillar method.

A useful mining method used to recover additional coal once the economic limits of overburden removal have been reached in an opencast coal mine is highwall mining. This mining method provides an opportunity to examine an adaptation to thin-seam mining. In this research, highwall systems are considered as potential applications for thin-seam transport.

2.2 Overall transport route

The coal transportation route from the working face to the surface will be determined by the position of the coal seam relative to the surface. The mining equipment used should have production rates matching the conveying capacities of its transportation counterparts in order that any flow bottlenecks can be eliminated. For example, if a shuttle car is used to load from the continuous miner to the secondary transportation line, both these systems should have similar capacities to make the whole transportation process efficient.

Depending on the mining method selected, the method of gaining access to the seam could be either through adits or inclined or vertical shafts. Again, the choice will be based on economics.

Adits are used when the coal outcrops on the side of a hill or in the last cut of an opencast operation (highwall mining). Usually more than one adit is required for a mine operation. One would be used for ventilation purposes and the other for the transportation of personnel, coal and material.

Owing to their simplicity of operation and high capacity, inclined shafts would be used to maximum depths of about 300 m, while vertical shafts would be used below these depths. Incline shafts are usually sunk at dips of around 16^0. They have lower capital costs than vertical shafts, which require expensive hoists and shaft equipment. In addition, vertical shafts need frequent examination and maintenance for them to adhere to safety regulations. The use of vertical shafts is normally attributed to their shorter distance than inclined shafts and in coal strata they usually require very little support. In common practice, inclined shafts would be equipped with a conveyor for coal transportation and a winch for driving the material conveyor. Vertical shafts have automatic lift-type hoists for both men and material. Ventilation is provided through a shaft equipped with a fan on the surface that is used to extract the air from the mine. The vertical shaft system is practised mainly in Europe’s deeper mines. South Africa uses mainly inclined shafts for transporting coal to the surface. Vertical shafts are used only for personnel and material transport, and for providing ventilation.

From the coalface to the bottom of the shaft, the coal may be transported by a conveyor system. Belt conveying is most favoured in South Africa because of its ease of maintenance and its high capacity. Most other coal-producing countries opt for this method too, although some use locomotive, hydraulic and pneumatic transport.

2.3 Integration of mining equipment

Machines used for a particular mining method are normally custom-fitted. For instance, the armoured face conveyor is designed to fit onto a shearer, a plough system and the powered supports (Figure 2-1). If there is any change made to the armoured face conveyor (AFC), the corresponding system partners have to be taken modified as well. It is therefore important to consider how potential clearance machines fit the entire mining system and the relevant mining method. After all potential systems for thin seam clearing have been reviewed in this report; a mining method and mining system are recommended (Chapter 9).

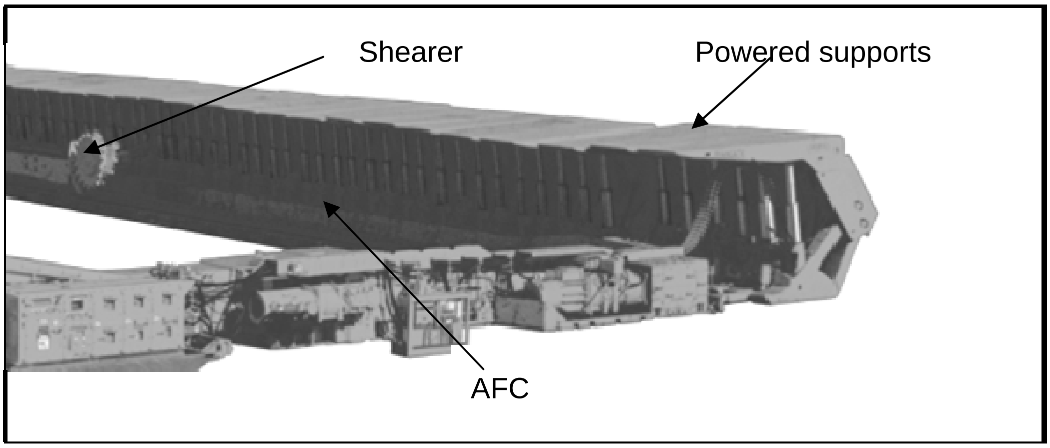

Figure 2-1: An integrated longwall mining system (courtesy of JOY Mining Machinery)

3 COAL WINNING CONSIDERATION

It is essential to set a benchmark for the coal clearance machines in order that their target achievement can be determined. The widely used methods worldwide for coal winning purposes are mechanisation and the drill-and-blast technique. The mechanised technologies include the continuous miner, plow systems, shearers, augers and road headers. The clearance systems should at least meet the production capacities of these mining technologies. Figure 3-1 shows production capacities of some thin seam-winning machines. The automated plow and the continuous miner show rated production capacities while the shearer shows an estimated production capacity.

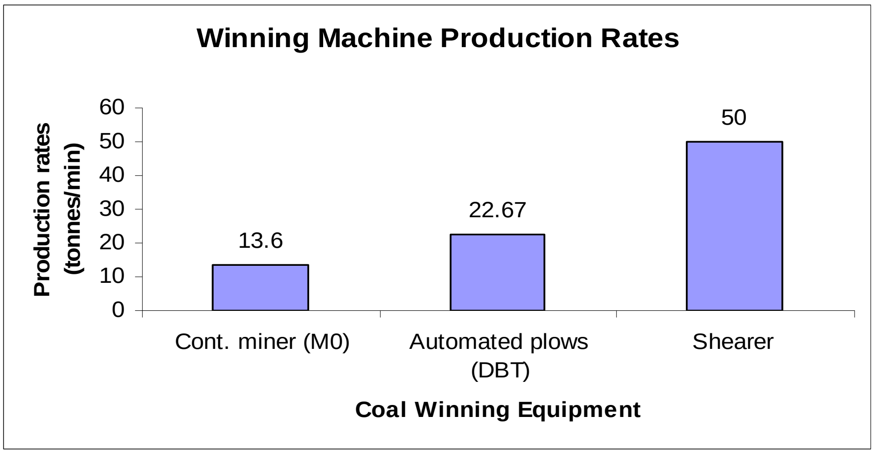

Figure 3-1: Winning machine production rates

The transport systems must be designed to cope with the winning equipment tonnages. It is important to note, though, that batch haulage transport machines have tonnage capacities that depend on various parameters.

The commonly used winning machine in South Africa is the continuous miner. The automated plows (Figure 3-2) and the shearer have integrated armoured face conveyors, which have similar conveying and production rates to each other. The main concern pertaining to this system is the conveying capacities of equipment downstream.

Figure 3-2: The automated plow system (courtesy of DBT)

It is estimated that the roadheader has a similar tonnage rating to the continuous miner since they have similar operating principles.

4 REVIEW OF EARLY THIN SEAM MINING SYSTEMS

It is important to understand that developments in coal clearance techniques are linked to the related mining systems. This section of the report presents a brief outline of past systems that have influenced developments in current thin seam clearance technologies.

4.1 Handgot method

This method was employed in Hlobane Colliery in South Africa in two mining sections. Each of these sections utilised manual loading with 0.75 ton capacity tubs and two rail-mounted coal-cutters. The minimum working height was 1 m and a total monthly production of 15 000 tons was achieved. Timber supports were used. The problem with this method was its labour intensiveness.

4.2 Mole miners

This is a machine that can cut a “blind” narrow-face entry while being remotely operated. The system was composed of a haulage system, ventilation, monitoring and an actuating system for advancing the miner onto the face. These machines used a haulage system for coal removal purposes. This equipment has been employed in the USA, UK and USSR with results that are unsatisfactory compared with those achieved with automated mechanised mining equipment. An example of a mole miner is the Collins Miner (Figure 4-1).

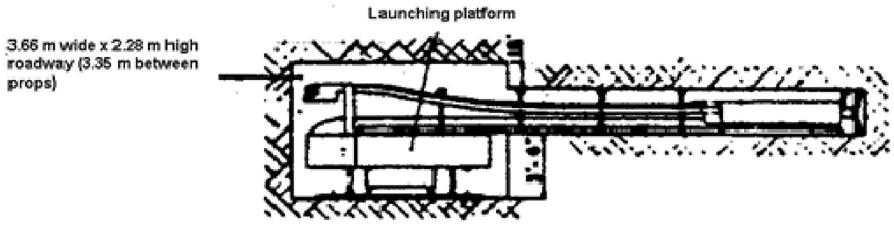

Figure 4-1: The Collins Miner (courtesy of Holman et al., 1999)

The Collins miner was developed in the UK, specifically for mining thin seams. It was developed to cut a 91.44 m long entry, of 1.9 m in width, from development sections measuring 3.66 m wide by 2.28 m high. This mining system was applied for room-and-pillar mining. Its cutting head comprised of three overlapping augers driven by a water-cooled gearbox, which was driven by a single 89.5 kW motor. The coal was transported from the working face via a small flight conveyor to a belt conveyor behind the machine. The complete machine was mounted on skid plates that were connected to the main frame by hinges in the front and by jacks in the rear and the side. The primary function of these jacks was to control the cutting head and offer horizontal steering control. The auger mining system was possibly developed from this technology.

4.3 Full face miners

These machines were designed to cover the entire mining face and advance or retreat simultaneously. Personnel was essential for maintenance because of the sheer bulk and complexity of the equipment. Examples of such systems include the Miniwall, the In-Seam miner, and the Yarmak miner. The Miniwall and the Yarmak systems removed the coal by means of a face conveyor, which dumped it onto a section conveyor line. The In-Seam miner was equipped with a cutter/bucket combination along a belt drive. The buckets collected the cut coal and transported it onto a discharge conveyor.

4.4 Scraper boxes

Scraper boxes were initially used as haulage units on hand-worked longwalls in thin seams. This technology then developed to several scrapers connected by one rope along the whole coalface. The scrapers would break shallow depths of coal as they moved along the face, and were moved along the face to allow the next scraper to pick up where the previous one had dumped the coal. The contents of the scraper onto were then discharged on the scraper conveyor and moved along to the gate conveyor.

Hlobane Colliery in South Africa used this system in five of its sections. The system comprised of 22 kW winches with a one-ton coal scraper, two Fairchild roof-bolters and three belly crawler coalcutters, which represented a development from the scraper box system. The scraper was used solely for face-cleaning purposes. A monthly production of 4 100 tons was achieved per section. Refer to Figure 4-2 for the scraper box layout.

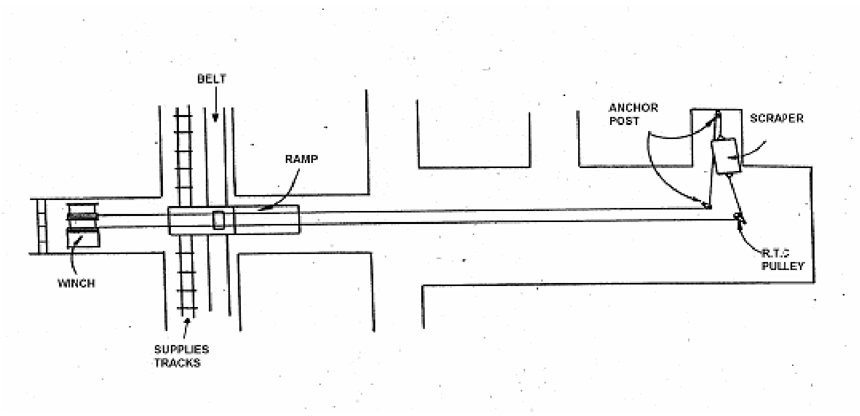

Figure 4-2: Scraper- box layout at Hlobane (courtesy of Wits University)

The Haarman scraper box utilised a heavy skid to enhance the thrust forces against the face. This technology was then developed into the so-called 'chain tension scraper box', which used chain tension to keep the scraper box against the face. A disadvantage of the system was that personnel were needed to install supports. The chain tension scraper box arrangement proved to be problematic, as the chain provided limited thrust forces which slowed down production.

4.5 Ram ploughs

This method was first used in Spain and adapted by Hlobane Colliery in South Africa. The ram plough was attached to a continuous chain, which moved up and down the face ploughed into the coal. The ploughing was done in both directions while the coal was transported in a single direction. The ploughing process was done through the use of hinged scraper flaps inside the plough assembly. Figure 4-3 shows the ram plough configuration.

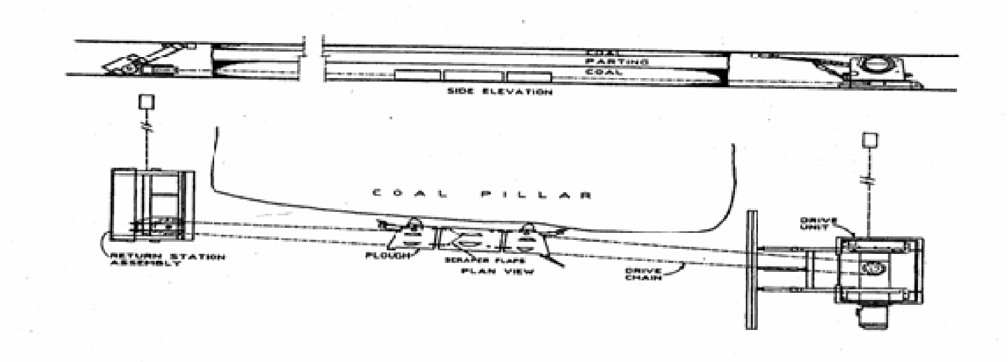

Figure 4-3: Ram plough configuration (courtesy of Kilbridge, 1989)

5 FACE CLEARANCE SYSTEMS

5.1 Pneumatic conveying

This method used negative air pressure to suck broken coal from the gate road to the section conveyor. This system originated in the US and was used with the ram-plough mining system in Hlobane Colliery (Figure 5-1) at the Dundas seam. A PVC pipeline was connected to a primary coal separator, which then split into two 250 mm diameter pipes with two dust cyclones each both leading to a filter box. The cyclones served as the dust-separating mechanism.

The roots blower was then connected to this filter box. Before the introduction of the roots blower, a centrifugal fan was used in its place. The centrifugal fan had lower operating pressure and experienced impeller wear problems. The coal was mined through pillar extraction with the use of ram ploughs. The cutting rate was about 15 tons/h and face cleaning was carried out by the plough scraper. (See Appendix A for system specifications for both the centrifugal fan and the roots blower system.)

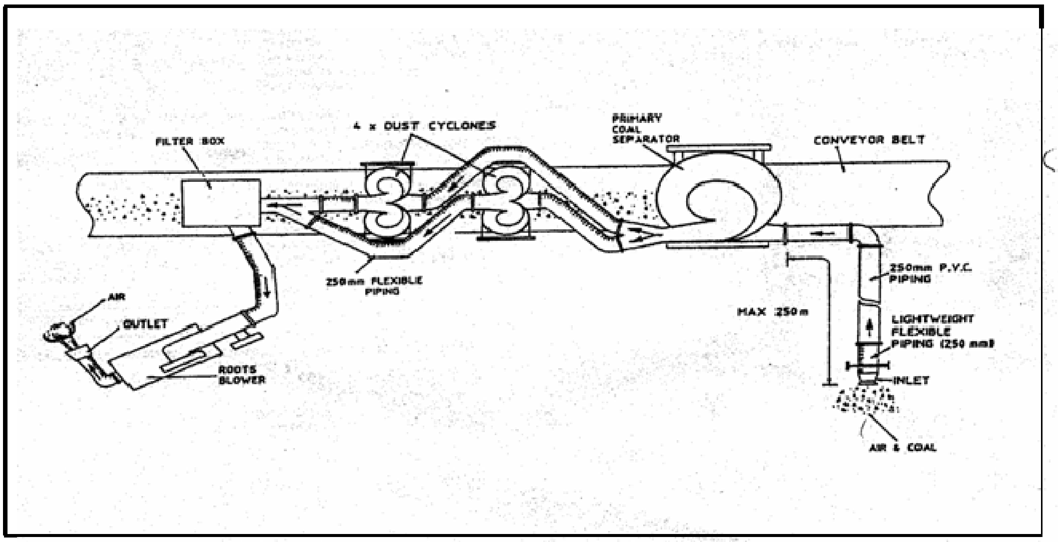

Figure 5-1: The layout of the pneumatic system used in Hlobane (courtesy of Kilbridge, 1989)

The fundamental problem with this system was that a large amount of energy was required to pump air through the pipelines with enough speed to carry the broken coal. Moving air at high speeds is mechanically inefficient because of internal friction and shock losses that limit the conversion of mechanical energy into fluid flow (at the blower) and fluid flow energy into mechanical energy (transporting the coal particles). The high-speed particle impacts caused significant wear in the pipe: at the flanges, elbows and valves. These were some problems associated with the system that led to its minimal application in the coal industry.

5.2 Face conveyor systems

These systems are designed to accommodate all seams, long and short coalfaces. They are normally used with shearers or ploughs. To maintain a safe working environment, powered supports have to be advanced sequentially at the same rate as the face. DBT and JOY face conveyors have carrying capacities greater than 5 000 tons/h and can achieve lengths of up to 450 m. These systems could be designed with drive frames, stage loaders, transmissions, crushers and belt tailpieces. Figure 5-2 shows a typical armoured face conveyor (AFC).

The AFC runs along the face with the mining machine mounted on it. This AFC is made up of short sections, called “pans”, which allow the conveyor to follow along the face as the supports are progressively advanced. Each of the powered supports is pinned into a pan, which uses chains for the coal transportation. There are three different configurations of these chains for the AFC: twin in-board chain, twin out-board chain and single in-board chain.

Figure 5-2: Armoured Face Conveyor (courtesy of JOY Mining Machinery)

The pan length can vary from 1.5 to 2 m depending on the width of the powered support. Powering the AFC are drive units located at either the maingate or tailgate ends or at both ends. The chain is driven along the face by using a gear and sprocket drive system that transports the coal at speeds of about 1 m/s. However, some face conveyors can reach speeds of up to 1.6 m/s. The power and speed of these systems depend on the specifications of the driving motor.

5.3 Scoops

These are used to transport their load from the working face to the feeder/breaker. The scoop fulfils the dual function of a gathering arm loader and a shuttle car. These are available electrically powered with trailing cables, diesel powered or battery powered. They are normally used for face cleaning in conventional and mechanised mining. The unit cost for a scoop is about R2.5M.

The DBT scoop, the Un-A-Trac, is battery operated. The models 488L and 488-6 have heights of 1 170 mm and 1 245 mm respectively. These machines have respective payload capacities of 9.1 and 14.5 tons. Figure 5-3 shows the 488L model. Fairchild International also manufactures thin seam scoops as low as 50 cm in height, with a 2.83 m^3 capacity centre eject bucket.

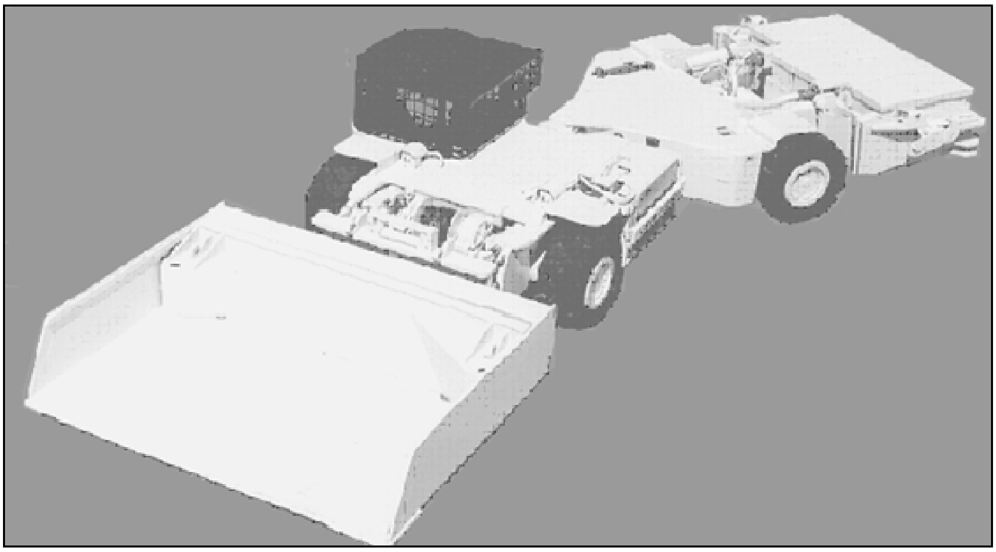

Figure 5-3: DBT Un-A-Trac model 488L (courtesy of DBT)

5.4 Gathering arm loader

JOY designed the 14BU10 (AN or CN) model that was used with four-ton capacity tractor-trailer units. The minimum working height for this equipment was 1.1 m. Hlobane Colliery reached production levels of 87 000 tons per month in seven sections using this method. Each section used a gathering arm loader.

This equipment is used to load coal from the working face to the shuttle car. Gathering arm loaders could be obtained from the manufacturers in heights as low as 600 mm. They are normally powered by electricity using trailing cables thus limiting freedom of movement. The unit cost of gathering arm loaders is around R2.2M. JOY manufactures the gathering arm loader, but it is no longer used because of the phasing out of conventional mining.

6 IN-SECTION TRANSPORTATION SYSTEMS

6.1 Bridge conveyors

This haulage system is commonly used with continuous miners. The coal is loaded directly from the back of the continuous miner onto the chain haulage system from where it is transferred to the section conveyor belt. Most of these types of coal conveyors have proved unreliable in the past and hence have not been extensively used in South Africa.

Bridge conveyors consist of three main components i.e. an inby mobile bridge carrier, the intermediate mobile bridge carrier (MBC) and the piggyback bridge conveyor. The inby mobile bridge conveyor offloads material from the continuous miner to the first piggyback bridge conveyor. The coal is then discharged onto the intermediate mobile bridge conveyor, which takes it to a second piggyback bridge conveyor. Material is then dumped onto the section conveyor. These systems are suitable for applications of 0.76 m to 4 m in seam thickness. The Long-Airdox continuous haulage unit has haulage capacities of over 30 tons/min and tram rates of up to 26 m/min. Figure 6-1 shows the JOY bridge continuous conveyor.

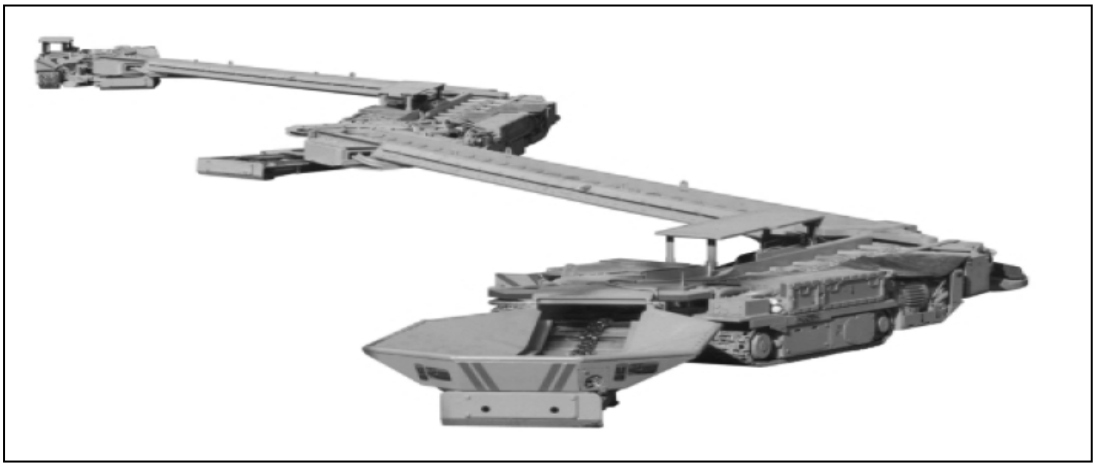

Figure 6-1: The JOY Bridge Continuous Conveyor (courtesy of JOY Mining Machinery)

A JOY bridge continuous conveyor has conveying capacities between 17.7 tons/min to 34 tons/min. The models using a 762 mm or 965 mm wide JOY miner/loader chain can handle the system capacity of the biggest of the current generation high-production JOY continuous miners. The swinging front of the system provides unsurpassed manoeuvrability and ease of operation even at 90^0 cross-cuts. Less time is wasted in manoeuvring behind the miner as the MBC operator can easily keep the hopper under the miner conveyor. An available voice communication link allows operators to talk to one another and current systems have panic bars and emergency stops for improved safety. Up to five operators can be used per system. The bridging units are available in interchangeable lengths of 9.1 m and 12.2 m. In some related systems, a feeder-breaker is added just behind the miner to size the coal. The system usually consists of several mobile bridge carriers and several bridge conveyors, one bridge behind every mobile bridge carrier. The number of units varies, depending on mining requirements and the configuration of the mined area.

6.2 Chain continuous conveyors

The chain continuous conveyor is normally applied just behind the continuous miner, in highwall or room-and-pillar operations. The automated Archveyor Mining System using Archveyor Technology, for instance, utilises a continuous miner, a stageloader, a feeder breaker, the continuous chain haulage system, a belt conveyor and the loadout vehicle for highwall mining operations.

The coal is cascaded from the continuous miner to the continuous haulage chain conveyor hopper. This machine is steered from either end and has a self-tracking mechanism. The chain-conveying system is used for both machine tramming and coal conveying at respective speeds. For coal conveying, the chain conveyor is lifted approximately five inches off the ground by hydraulic cylinders located at every other pan on either side of the machine. In the tram mode, the machine is dropped onto the ground through the retraction of the hydraulic cylinders. The entire chain haulage system is controlled through onboard process logic controllers (PLCs). Shown in Figure 6-2 is a chain continuous haulage system attached to a continuous miner.

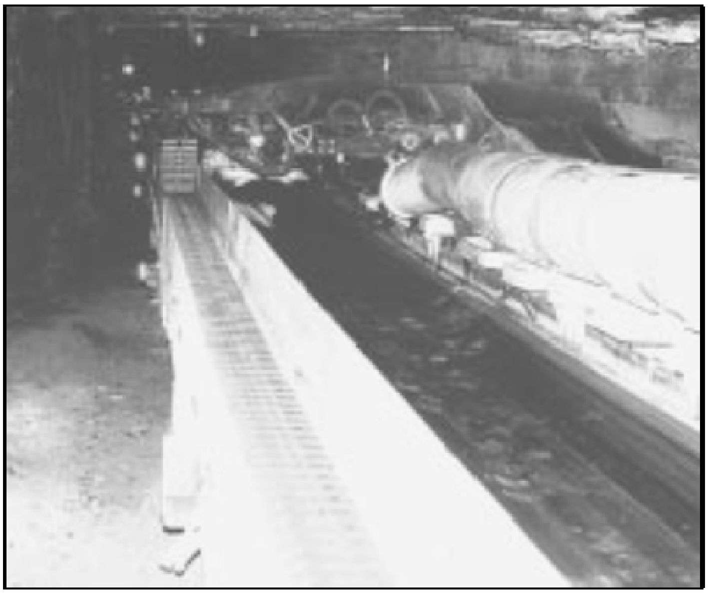

Figure 6-2: The continuous chain haulage (courtesy of Arch Coal Inc.)

The continuous chain haulage has tramming capabilities of up to 720 horsepower. The continuous haulage chain is connected to the stage-loader by a tongue and groove arrangement that ensures that the two systems remain parallel to each other. From the stageloader, the coal flows onto the feeder breaker and then onto the belt conveyor, which transports it to the loadout vehicle. The overall monthly productivity of the whole system is about 135 000 tons.

6.3 Addcars

Another thin-seam transportation method is the addcar highwall mining system. This system consists of five main elements; i.e. a continuous miner, addcars (conveyor cars), a launch vehicle, an elevating stacker conveyor and a wheel loader with a forklift attachment. These addcars form a modular conveyor, which transports the coal from the back of the continuous miner to the surface. These cars are added back-to-back behind the continuous miner as it cuts into the seam, in a manner that does not interrupt the flow of the coal. Each standard addcar has a steel frame, rubber wheels, its own motor, conveyor belt, gearbox and is about 12.5 m in length.

The conveyor belts reduce degradation of the coal greatly during transportation and also provide greater transport capacity with a lesser chance of clogging. Starting just behind the continuous miner is the lead addcar, which is about 9 m in length and has features similar to those of the standard addcar. The design of the connection of these cars is such that horizontal movement is limited, which ensures that the push applied to the cars by the hydraulic cylinders on the launch vehicle is transmitted effectively to the back of the miner. The stacker conveyor receives coal from the belly belt of the launch vehicle and discharges the coal onto the ground where it is loaded by a wheel loader onto the trucks. For each 500 m entry, about 40 of these addcars are required to cover the coal transportation line.

A wheel loader/forklift is used to move the cars individually during maintenance and pit-to-pit relocation. This arranging technique creates a major disadvantage as a string of rigidly connected cars have to be guided along the floor entry. The application of the thrust forces from the forklift increase the chances of buckling the string or misaligning the entire system.

6.3.1 Self-propelled conveyor cars

In 1998, RAHCO International mentioned the following shortcomings in existing addcars:

- Persistent problems with system entrapment;
- Limited recovery in mineral extraction; and
- Out-of-seam dilution and generation of coal fines.

RAHCO International's design focused on addressing these shortcomings, which included navigation, tramming, conveying and cutting machine performance. The result was the NEXGEN Highwall Mining system.

In this system, each of the 6 m long cars drives the wheels of both axles. Each of these self-propelled cars provides approximately five tons of tractive force to the string. These cars are mechanically coupled to preclude wheel spin and coordinate advancement and retrieval of the string. As a result, the NEXGEN Highwall Mining System becomes stronger with each addition of a self-propelled car, until the torsion limits of the drive shafts or the available power from the tramming drive motor is reached, and the control cable length is exceeded. The NEXGEN Highwall Mining System is shown in Figure 6-3. The initial continuous miner selected for the system was an EIMCO Dash Zero with a 0.76 m head. This was expected to accommodate minimum seam thicknesses of as little as 0.86 m cleanly, and even thinner seams, depending on the amount of seam rolling involved.

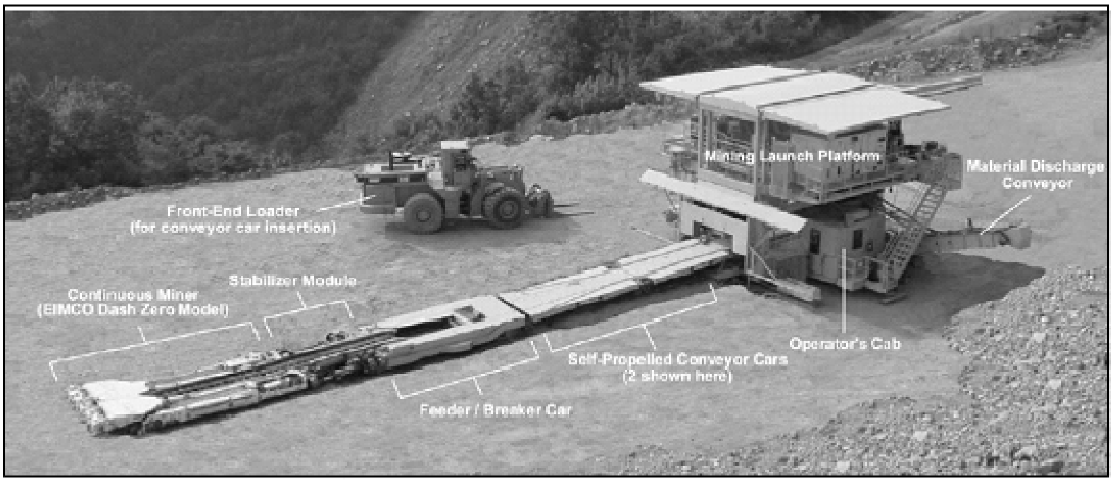

Figure 6-3: The complete NEXGEN system layout (courtesy of NEXGEN Highwall Mining Systems)

The cars are combined with a stabiliser to help minimise forces acting on the cutting machine, which assists the system in maintaining its desired direction. The entire system helps in deeper penetrations and assists in increasing coal recovery in areas not previously unrecoverable through highwall mining. Since these cars are covered, draw rock contamination is reduced.

6.4 Shuttle cars

This is the most common method in South Africa of transporting coal from the mining machine or loader to a secondary transportation subsystem, mainly because of the comparatively low capital/operating costs associated with the cars. These machines have capital costs of between of R2M to R4M. The primary use of these machines is to transport coal from the face to a feeder breaker, which delivers it onto the section conveyor.

For conventional mining, a “gathering arm loader” loads coal onto the shuttle car. Currently, the continuous miner loads directly onto the shuttle car. For a 921 mm tram/body height shuttle car (JOY model 21SC03M), the canopy height can vary between 1 045 mm and 1 195 mm. These cars can carry seven tons at a time with a conveyor discharge time of 30-45 seconds. The normal loaded tram speed is about 5 km/h. A typical shuttle car is shown in Figure 6-4.

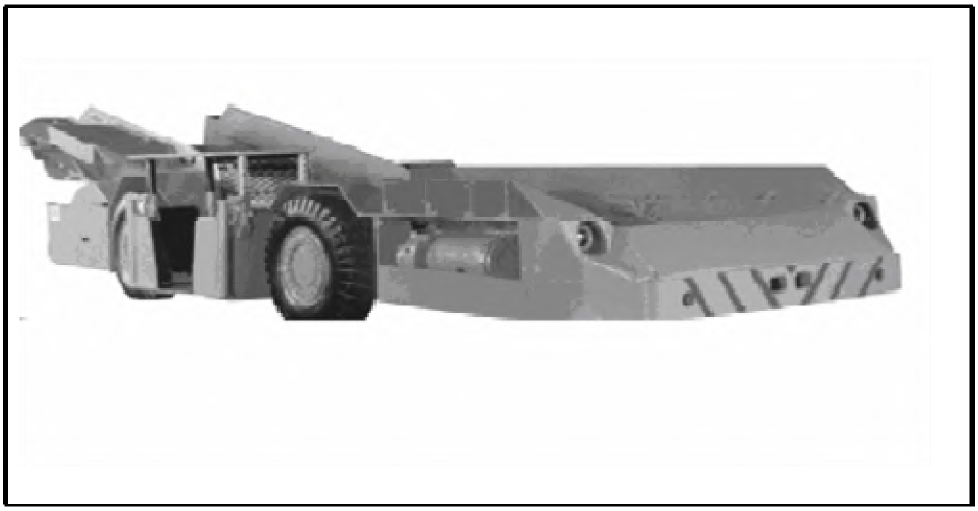

Figure 6-4: JOY shuttle car (courtesy of JOY Mining Machinery)

Shuttle cars are commonly used for conventional and mechanised room-and-pillar mining. Typically, two or more shuttle cars are required for this mining method per section, which normally introduces problems relating to cable handling and change-out times. The equipment layout of this system is not conducive to continuity in the total mining process, hence shuttle cars are unsuitable for autonomous mining in a thin-seam environment. The relevant mining system for shuttle cars could be conventional or continuous mining (using continuous miners).

6.5 Battery cars

As the name suggests, batteries are power sources for these cars. The use of batteries eliminates the limitation in travel brought about by trailing cables and the emissions associated with diesel engines. These cars are also used for transporting material/equipment for the mine, and for transporting the coal from the back of the continuous miner to the feeder/breaker.

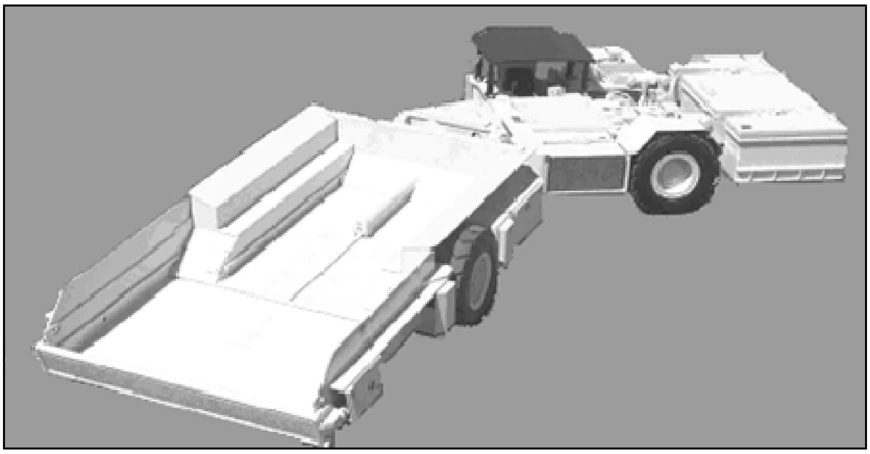

Figure 6-5: DBT CH816L Un-A-Hauler (courtesy of DBT)

The CH816L model (Figure 6-5) carries 14.3 tons and has a height limitation of 965 mm. This machine has a full shift battery operating time.

6.6 Feeder/breaker

The load from the shuttle car or scoop is discharged directly onto the conveyor or via a feeder/breaker. The feeder/breaker can also be used with other mining systems as required. This machine feeds the in-section conveyor at a favourable rate. The feeder/breaker also crushes large lumps of coal to a size of about 200 mm, which is more suitable for conveyor transport where it is necessary.

The Rhino feeder/breaker from DBT can discharge up to 1 800 tons/h of coal onto the conveyor. The overall system heights for these Rhino feeder/breakers are 860 mm and 1 040 mm with respective widths of 2 845 mm and 3 250 mm. The Rhino feeder/breaker has a hydraulically adjustable ground clearance mechanism. It has a pick force of about 270 kN. Buffalo, JOY and DBT are some known manufacturers of these systems. Buffalo designs this equipment according to a mine’s needs and are about 300 Buffalo feeder/breakers in operation in South African coal mines. Feeder/breakers are generally incorporated into most mining systems. The capital unit cost of this system is about R1.5M. Shown in Figure 6-6 below is the DBT Rhino Feeder/breaker.

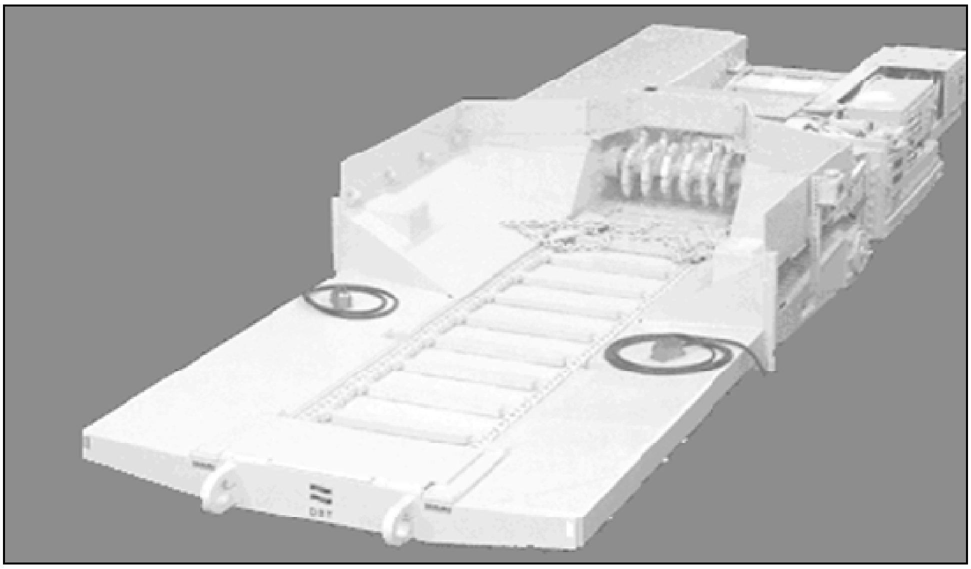

Figure 6-6: The DBT Rhino feeder/breaker (Courtesy of DBT)

7 OUTBYE TRANSPORTATION

7.1 Belt conveyors

Another type of continuous haulage conveyor is the low-low belt conveyor. Over the past 20 years, these systems have evolved and reached technical excellence. MacNulty (1999) reported that, in normal operation, belts could run at grades of up to 22°, and at maximum speeds of 2.5 m/s (9 km/hr) for personnel transportation and 5.0 m/s for rock transportation. Baker (1981) estimated the heat output to be 30% higher than that from a locomotive system. Associated with this heat is the risk of fire, and in 1981, 15% of all underground coal mine fires in the USA were a result of belt conveyor ignition. For underground conveyors, fire resistance characteristics are given preference to cut, gorge and abrasive resistance. South Africa uses belt conveyors in most coal and platinum mines and some gold mines. A typical belt installation is shown in Figure 7-1.

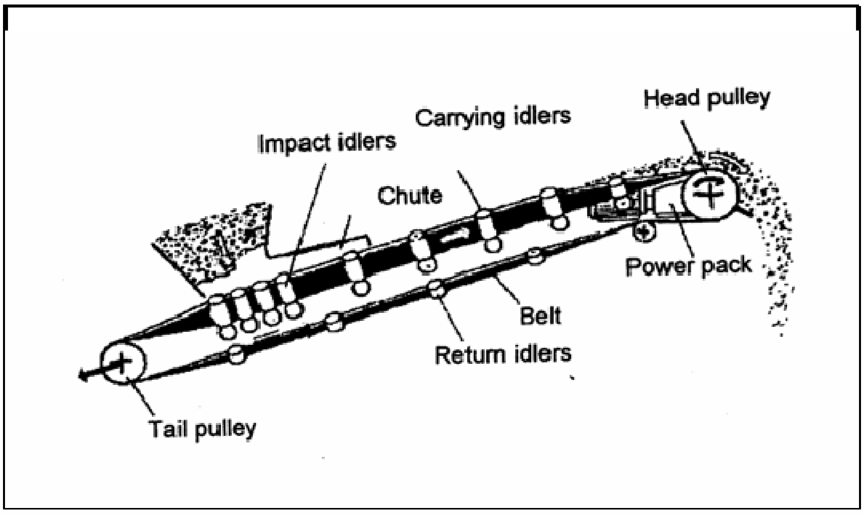

Figure 7-1: A belt conveyor system

In this method, a common conveyor belt travels the low-low structure and the outbye conveyor system. The low-low structure uses steel slide bars instead of rotating components, such as idlers. The result of using the rotating components is that there are significant drag forces and belt misalignment within the conveying line, which lead to design limitations in terms of belt length and the need for support from additional outbye conveyors. Furthermore, belt conveyors cannot be used to transport mine infrastructure such as supports of trackless transport systems.

MacNulty (1999) listed some advantages of conveyor belt transport as being:

- Specific energy consumption less than other haulage systems;
- Reduced operating cost and skilled labour costs; and
- The possibility of automating the system.

The disadvantages included (MacNulty, 1999):

- High initial capital investment;
- Lack of ability to negotiate curves and inclinations greater than the angle of repose of the material being conveyed;
- Sensitivity to large particle size and abrasive material;
- Breakdown results in a ‘standstill’ of the conveyor system;
- Directional changes requiring tipping and loading facilities; and
- Fire risk.

Capacity rates could reach values of 1 000 tons/h (16.7 tons/min) depending on the system

7.2 Pipe conveyors

In this technology, a belt is wrapped into a cylindrical pipe form. In this form, the conveyor can negotiate inclines of up to 30^0 and be curved in both horizontal and vertical planes through angles up to 90^0. This geometrical advantage helps the pipe conveyor to negotiate obstacles that would obstruct a conventional straight conveyor. The pipe conveyor can replace conventional belt conveyors, and has the following added advantages:

- Degradation of the product is reduced at repeated transfer points;
- Contamination and spillage are minimised;
- One or more drive units are eliminated, as well as the additional power for lifting the material; and
- The cost and maintenance of transfer chutes is eliminated.

The pipe conveyor layout is shown in Figure 7-2 below.

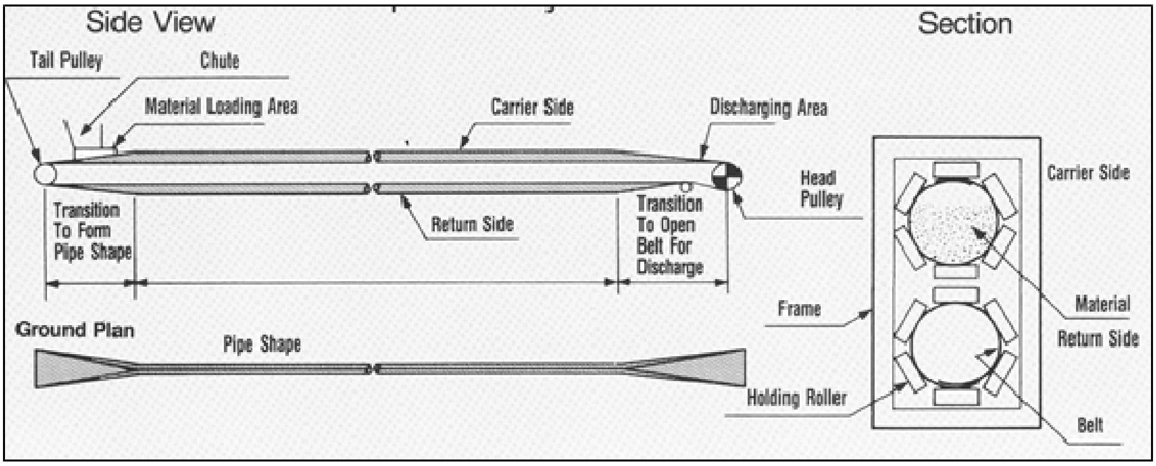

Figure 7-2: Bateman pipe conveyor layout (courtesy of Bateman Engineering Technologies)

Bateman Engineering Technologies installed a 300 mm diameter pipe of 143 m in length in Vereeniging with horizontal and vertical curves. This system reached carrying capacities of up to 900 tons/h at a maximum belt speed of 3.2 m/s. A number of these systems have been installed with reasonable success in South Africa (See Appendix B).

7.3 Hydrohoisting

Currently, the only sludges pumped in all mining sectors are ultra-fines. Underground milling would therefore be necessary to produce these ultra-fines (less than 2 mm) for reliable hoisting with conventional displacement pumps. Hydrohoisting of coarse coal was initiated in the Hansa Hydromine in the 1970s for a depth of 850 m, but faced some geological shortfalls, which eventually led to the mine's closure. In this project, mining was done by waterjets, which created the slurry from the face (Figure 7-3).

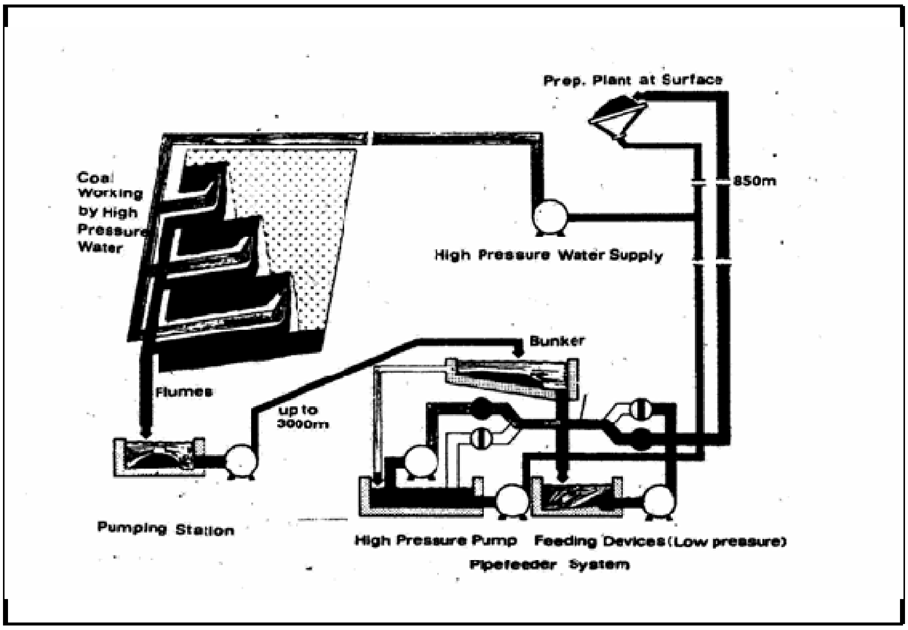

Figure 7-3: Hansa Hydromine slurry pumping layout (courtesy of Ilgner, 2002)

The usual problem faced in hydrohoisting coarse coal is the settlement of the coarse particles. To overcome this challenge, fines are normally added to form a dense matrix that embeds the larger particles and forms a partly stable mixture. The systems for transporting coarse coal generally operate by centrifugal pumps and are confined to shorter distances. The USSR and the US have been exceptions to this rule though. For instance, the Loveridge Mine in West Virginia pumped ROM coal for 3.8 km at 13 tons/min.

Another problem concerns the dewatering of the coal when reaches the process plant. This process would normally require a dewatering plant. Furthermore, emergency dump reservoirs, water-return piping and controls, and additional labour would be essential for efficient operations.

Wood (1986) suggests the following methods of lifting coal according to the vertical height (Table 7-1).

Table 7-1: Methods of lifting ROM coal at different heights

Vertical Height (m)	**Pump type**	**Application**
260	Centrifugal pumps in series	Loveride Mine USA
320	Airlift system	Krasnoarmeyskaya USSR
518	Hydrohoist	Sunagawa Mine Japan
847	Three-chamber pipe feeder (3CPF)	Hansa Hydromine Germany

In Australia, a pilot plant was established at the West Cliff Colliery in Wollongong, which utilised a special pump, the Rotary Ram Slurry Pump, developed by ABB, to pump <60 mm coal through a 300 mm pipeline at concentrations close to the packing condition of coal. These concentrations result in low specific energy consumptions.

In South Africa, test work on coal pumping was performed by Verkek (1986) with particular focus on disposing coal slurries with maximum particle sizes up to 50 mm as waste. Several mixtures of fine and coarse coal were tested in industrial pipe loops. The different mixtures of particle size distribution allowed for pumping and suspension of particles at high concentrations, as well as easy start-up after emergency shutdown of the pipeline (Ilgner (2002)). Two pipeline options were proposed from Ellisras to the West Coast but neither was implemented.

7.4 Air-lift hydrohoist

The air-lift hydrohoist (ALH) concept is similar to the conventional hydrohoisting technique described in 7.3 above. It was initiated by the US Bureau of Mines in an effort to improve safety and efficiency in coal transportation. The fundamental concept was hydraulically hoisting a coal water slurry in a riser pipe by injecting compressed air micro-bubbles. The ALH is a U-tube running vertically from surface to mine level. An injector screw-feeder mechanism is used to move coal from the surge bin to the ALH (Figure 7-4).

Air is compressed into one column of the U-tube which creates a pressure differential between the two columns. This differential causes the slurry to move up the riser pipe, and a corresponding water flow is created in the other column. This three-phase mixture is discharged into a storage tank on the surface where the air separates from the coal slurry. From this point, the slurry could be transported overland in a low-pressure pipeline to a cleaning plant or dried on site at a mobile preparation plant. The entire system could also be used to transport waste rock from surface to underground if found to be environmentally unfriendly on land. The ALH arrangement is suited for coal because of its comparatively light density and normally hydrophobic characteristics (repels water and attracts air).

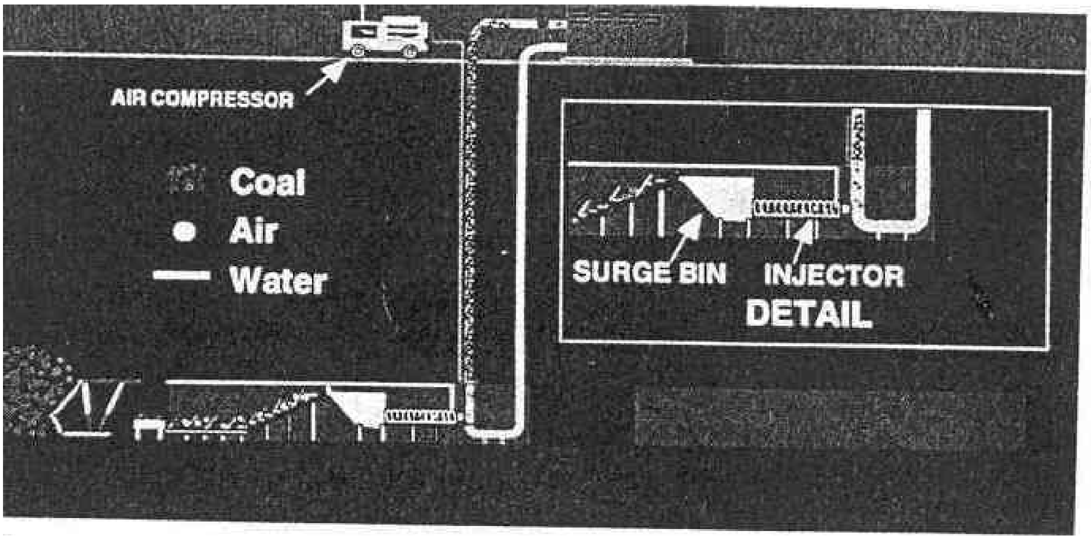

Figure 7-4: The air-lift hydrohoist concept (courtesy of Lindahl et al., 1995)

The ALH piping could be designed to fit an existing mining layout without requiring a separate haulage entry. This piping could be inserted through an existing shaft or two surface drilled holes connecting surface and mine level. Safety hazards eliminated in this arrangement include coal dust, methane generation, traffic congestion and the danger of moving parts associated with belt or rail haulage. The only disadvantage with the ALH layout is the addition of moisture, which can lower the coal's Btu value. The common methods of removing water from the coal could be screening, gravity separation, filtration and thermal drying.

Other problems associated with the system include pipe blockages and wear. These could be solved by optimising the design. The efficiency of the design depends mainly on air-water ratio, specific gravity and shape of solids, pipe diameters, initial air-bubble size, and method of air injection and level of air-water-solids mixing.

An initial prototype manufactured by the US Bureau of Mines comprised a 200 mm diameter riser pipe and a screw injector compacting 50 mm of coal at a time. The production rates reached 40 tons/h. An improved version of a pilot model was made 32 km northwest of Denver in the US. It was a 50 m high model designed to hoist 25 tons of 50 mm or less ROM coal in 15 minutes (110 tons/h). The tests proved successful but system optimisation was essential to improve the efficiency of the ALH.

8 POTENTIAL SYSTEMS FOR THIN-SEAM APPLICATIONS

8.1 Bateman chain conveyors

The material in these conveyors is chain-driven and enclosed in metal casings. The casing could vary between 200 and 600 mm in height. These conveyors are manufactured and designed by Bateman Engineered Technologies, which has a branch in South Africa. These systems can be designed to be horizontal, inclined or vertical in orientation. These conveyors can be used to convey most materials including grain, barley, woodchips, sand, lime and coal.

The entire system has an inlet and outlet hopper for product deposition and discharge respectively. Contamination of product is therefore minimal in this type of conveyor. Figure 8-1 shows the vertical chain conveyor.

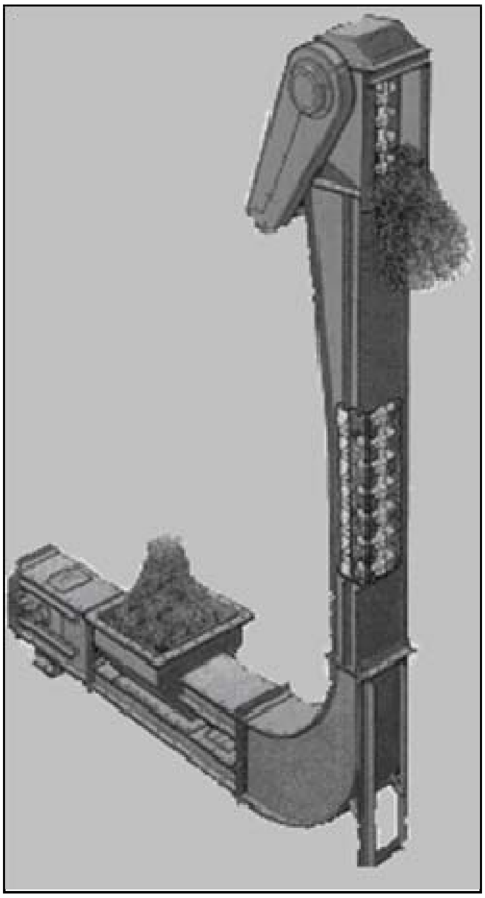

Figure 8-1: The vertical Bateman chain conveyor (courtesy of Bateman Engineering Technologies)

Its robust arrangement allows for low maintenance costs. It can be designed to be controlled automatically or manually. Conveying capacities could reach up to 300 tons/h, and the favoured choice for this application would be outbye transport.

8.2 Bateman pan conveyors

The pan conveyors are also manufactured by Bateman Engineered Technologies. The conveying capacities can reach up to 1 000 tons/h. The pans are driven by a continuous rope mechanism that could be designed to provide opposite conveyance. See Figure 8-2. These systems can be designed to have multiple discharge stations.

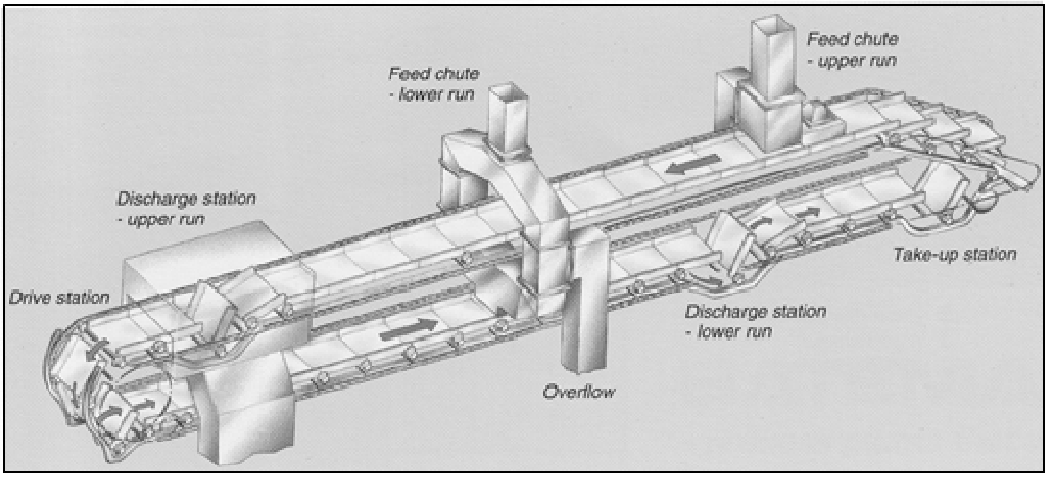

Figure 8-2: Bateman pan conveyors (courtesy of Bateman Engineering Technologies)

8.3 EJC 88 XLP loader

This loader was designed specifically for extra-low profile applications in platinum mines. It also has much potential for application in thin seams in the coal industry. Its standard operating height is 1.1 m with a tramming capacity of four tons (Figure 8-3). It is remote controlled by a single operator and has a bucket volume of 1.5 m^3.

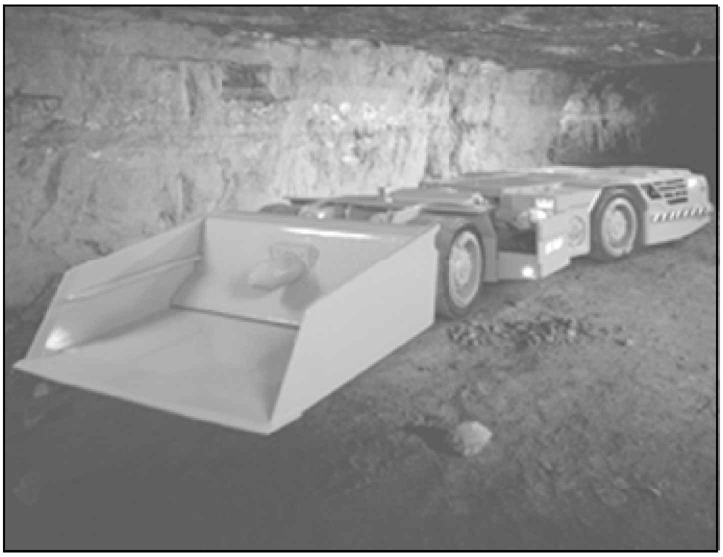

Figure 8-3: The EJC 88 XLP loader (courtesy of EJC Mining Equipment Inc.)

This machine can reach loaded forward and reverse speeds of up to 10 km/h with bucket discharge times of five seconds. EJC Mining Equipment Inc. manufactures this equipment. Anglo Platinum has used this equipment with reasonable success, and it was found to have minimal waste dilution.

8.4 EJC 115 low profile LHD

This low profile load haul dumper has a maximum tramming capacity of 5.5 tons. Its bucket capacity is 2.3 m^3 and it can load up to 3.67 m in height, which makes it versatile for medium and higher seam applications. It has a standing height of 1.4 m.

This machine can reach loaded speeds in forward and reverse of up to 21 km/h, which is far more than a scoop or shuttle car can travel.

Figure 8-4: The EJC low profile LHD (courtesy of EJC Mining Equipment Inc.)

This equipment is diesel powered and turbo charged, with a direct injection combustion engine. The driver's seat is positioned in such a way that he need not raise the operating height of the machine. The LHD's exhaust is purified by an Engine Control Systems (ECS) catalytic purifier. The total motion time of the bucket is about 12 seconds. This equipment is shown in Figure 8-4. Again, the manufacturer of this equipment is EJC Mining Equipment Inc., and it has been applied in chrome mines with success.

8.5 Flexible conveyor train

The 4FCT01 is a brand new type of haulage system designed by JOY Mining Machinery. The system is currently not available in South Africa, but there are negotiations with potential customers. It could sell for between R25M - R35M, depending on mine layout and customer requirements. This system is commonly used with continuous miners for longwall entry development or room-and-pillar extraction.

The system has an over pickbreaker height of 1.524 m, and a conveying rate of up to 27.2 cubic m/min (Figure 8-5). The maximum belt speed is 3.5 m/s. The system is remote controlled by a single operator, which allows for reduced manpower in the section. This conveyor train has standard machine diagnostics with a read-out screen monitor, which means that trouble-shooting time can be reduced.

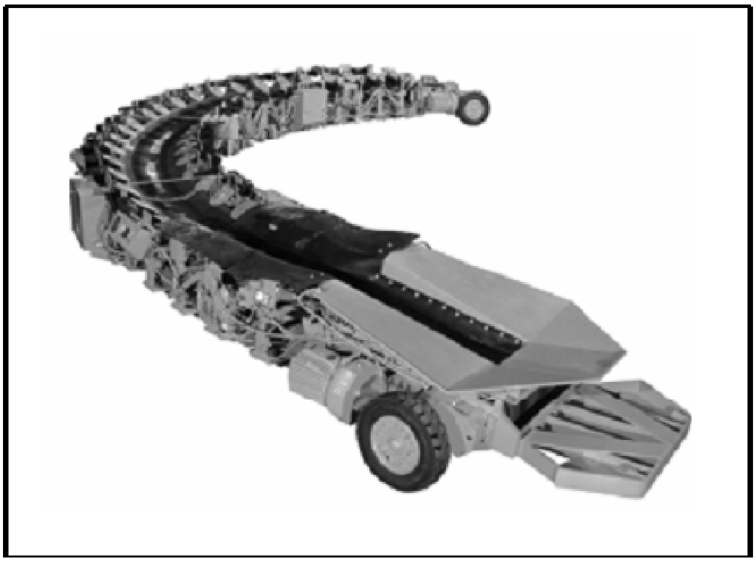

Figure 8-5: The 4FCT01 flexible conveyor train (courtesy of JOY Mining Machinery)

The 1.07 m wide belt provides tonnage capacities of 24.5 tons/min, which have proven to be an ideal match for the new JOY 12CM27 continuous miner. This system is available in belt widths of 0.94 m and 1.067 m and in system lengths of up to 128 m. It is unmatched in its capacity for uninterrupted conveying of mined material from the continuous miner to the panel belt. This system could be applied to thin- seam transportation with some height modifications.

9 SUMMARY OF EVALUATION OF TRANSPORT EQUIPMENT

This section gives a brief summary in table form of all equipment evaluated for thin-seam applications**.** Tables 9.1, 9.2, 9.3 and 9.4 show face clearance equipment, in-section coal transport, outbye coal transport and potential machines for thin-seam transport respectively. The equipment has been evaluated between continuous and batch hauling.

Table 9-1: Face clearance systems

Face Cleaning Systems				
	Continuous hauling		Batch hauling	
Equipment Factors	Armoured Face Conveyor	Pneumatic Conveyor	Scoops	Gathering arm loader
Conveying/loading capacities	33 tons/min	less than 4 tons/min	9.1 tons	N/A
Estimated capital cost per unit	100 m long RM 11	R116 000 in 1989	RM 2.5	RM 2.2
Advantages	Higher conveying capacity	Continuous hauling	Comparatively cheaper to continuous haulers	Comparatively cheaper to continuous haulers
			Could be easily moved to other sections	Could be easily moved to other sections
	Robust arrangement allows for lower maintenance costs		Does dual function of shuttle car and gathering arm loader	
Disadvantages	Only for longwall/shortwall applications	Wearing of pipeline	Change-out time	Change-out time
	High capital cost	Low efficiencies due to air compressibility	Working cost increases with increase in hauling distance	Working cost increases with increase in hauling distance
	Time taken to transfer system to other sections results in higher downtimes	The system 's efficiency depends on size distribution	Requires skilled labour for maintenance purposes	Requires skilled labour for maintenance purposes
	Comparatively higher capital costs	High maintenance costs		
Mining method application	Longwall/shortwall	Room and pillar	Room and pillar	Room and pillar
Coal winning technique (flexibility)	Shearer,plow	Continuous miner, drill and blast, ram-plough	Continuous miner, drill and blast	Continuous miner, coal cutter, drill and blast
Complete mining system	Shearer or plow, powered supports, stageloader, pump station face end equipment haulage system	Ram-plough and pneumatic conveyor systems	Coal cutter, mobile drill, feeder/breaker, roof bolter	Coal cuter, shuttle cars, roof bolter, mobile drill, feeder/breaker
Capital cost estimate (MS)	RM 200	R366 000 in 1989	RM 17	RM21
Working cost at 1.4m seam (R/ROM ton)	41	N/A	43	43
Minimum height (mm)	1000	400	1170	1000
Model	Electra EL600 series	N/A	UN-TRAC-488L	14BU10/LCLP

Table 9-2: In-section transportation systems

In-Section Transportation Systems						
	Continuous Haulers			Batch Haulers		
Equipment / Factors	**Bridge Continuous Conveyor**	**Continuous Chain Conveyors**	**Addcars**	**Shuttle Cars**	**Battery Cars**	**Feeder Breaker**
Conveying/loading capacities	17.7 to 34 tons/min	N/A	100 000 - 200 000 tons/month	7.7 tons	13 tons	30 tons/min
Capital cost per unit	RM 13.5	N/A	N/A	2.5		1.5
Advantages	Ease of operation even at 90 degree cross-cuts	System is flexible, it therefore snakes along corners	System can be easily disassembled	Cheaper compared to continuous haulers	No limitation in travel as compared to shuttle cars	System supplies section conveyor at required conveying rate
	No time wasted since operator can easily keep hopper under the miner conveyor	System can be used for tramming	Continuity in coal transportation	Could be easily moved to other sections	Could be easily moved to other sections	System controls coal size
	No change-out time	No change-out time	Some cars apply tractive forces in all wheels		Comparatively cheaper to continuous haulers	
Disadvantages	Expensive system in comparison with belt conveyors	Expensive system in comparison with belt and batch haulers	Needs a wheel loader for manoeuvring	Cables limit radius of travel	Change-out time	Out of seam contamination
	Many operators are required depending on length of system	Time taken to transfer system to other sections results in higher downtimes	Car string may buckle due to forces of wheel loader/forklift	Lower capacity compared to continuous haulers	Lower capacity compared to continuous haulers	An additional cost to mining system
	Time taken up transfering system to other sections results in higher downtimes	Out of seam contamination	In some cases, entire system may need a stabiliser to control forces pushing the mining machine (extra cost)	Change-out time	Requires skilled labour for maintenance purposes	Requires skilled labour for maintenance purposes
	Out of seam contamination		Out of seam dilution and coal fine generation unless using the covered version	Requires skilled labour for maintenance purposes		
Mining method application	Room and pillar	Room and pillar, longwall/shortwall,highwall	Highwall	Room and pillar	Room and pillar	All mining methods
Complete mining system	Continuous miner,shuttle cars, feeder/breaker, bridge continuous conveyor	Continuous miner, feeder/breaker, chain conveyor	Continuous miner,feeder breaker, addcars, mining launch platform and wheel loader/forklift	Continuous miner, shuttle cars, feeder/breaker	Continuous miner, battery cars, feeder/breaker	Could be used with numerous mining systems
Capital cost estimate (MS) (RM)	RM 200	N/A	N/A	RM 21	N/A	N/A
Mininum height (mm)	1029	N/A	860	921	965	860
Model	Mobile bridge module	N/A		21SC3A	CH816L	4MFB
Supplier	JOY	Arch Technology	NEXGEN	JOY	DBT	DBT

Table 9-3: Out-bye transport

Out-bye Transportation				
	Continuous Haulers			
Equipment Factors	Belt Conveyor	Pipe Conveyor	Air-Lift Hydrohoist	Hydrohoisting
Conveying/loading capacities	10 to 16.7 tons/min	15 tons/min	1.83 tons/min	Loveridge Mine in W. Virginia = 13 tons/min
Advantages	Specific energy consumption lower than other haulage systems	Protects environment from spillage and product contamination	Protects environment from spillage and product contamination	No contamination of transported coal
	Lower operating and skilled labour costs	Belt can negotiate inclines up to 30^0 and be curved up to 90^0 in vertical and horizontal plane	Could be designed to fit existing mining layout	Protects environment from spillage and product contamination
	Relatively easy to make belt length changes because of user friendly components	Reduces product degradation at repeated transfer points	Safety hazards such as methane and dust are eliminated	Reduces product degradation at repeated transfer points
		Reduces number of drive units and additional power to lift product	Reduces number of drive units and additional power to lift product	Reduces number of drive units and additional power to lift product
Disadvantages	Lack of ability to negotiate curves	Sensitive to large particle sizes and abrasive materials	Sensitive to large particle sizes and abrasive materials	Higher capital expense compared to conveyors
	Sensitive to large particle sizes and abrasive materials	Risk of fire	Moisture addition may lower Btu value	Sensitive to particle size distribution
	Directional chages require tipping and loading facilities		Possible blockages in pipes	Wearing of pumps and piping
	Risk of fire present			Requirements of dewatering plants, emergency dump reserviors and water-return piping
Mininum height (mm)	1050	800	N/A	N/A
Potential improvements in system	System could be automated		Current technology in pumps can improve system efficiency	Current technology in pumps can improve system efficiency

Table 9-4: Alternative systems

Alternative Coal Clearance Systems					
	Continuous Haulers			**Batch Haulers**	
Equipment **Factors**	**Bateman Chain Conveyors**	**Bateman Pan Conveyors**	**Flexible Conveyor Train**	**XLP (EJC 88L) Loader**	**XLP LHDs**
Conveying/loading capacities	3 to 5 tons/min	10 to 16.7 tons/min	24 tons/min	4 ton capacity	5.5 ton capacity
Capital cost per unit (RM)	N/A	N/A	RM 25-35	USD 290 000	N/A
Advantages	Designed to be covered to avoid contamination	Could convey material in opposite directions	Consists of a fire suppression system	Single operator remote-controlled	Has relatively higher speeds, up to 16.6km/h
	Low maintenance due to robust structure	Discharge points could be anywhere along the conveyor	Single operator remote-controlled	Has relatively higher speeds compared to normal scoops	Has quick bucket motion times, which reduce change-out time
	Could be horizontally mounted, vertically mounted or inclined	Remote-controlled	Relatively higher conveying capacities	Diesel powered system, no trailing cables to limit radius of travel	The LHD could be used for higher seam heights because of bucket travel
	Low risk of fire from friction since all moving parts are enclosed	Low maintenance due to robust structure	System is designed to snake along curves (flexible)	Has a bucket discharge time of 5 seconds, which is better than conventional systems	High conveying rates due to higher speed
			The machine has a lumpbreaker inbye unit	System bucket is equiped with electronically controlled automatic load assist system	
				System is locally available	
Disadvantages	Favourable for permanent installations Comparatively lower conveying rates	Coal may be contaminated since conveyors are open	High capital cost No readily available system for thin-seam applications	Diesel results in emissions Requires skilled labour for maintenance purposes	Diesel results in emmissions Requires skilled labour for maintenance purposes
Mining method application	All mining methods	All mining methods	Room and pillar, longwall development	Room and pillar	Room and pillar
Complete mining system	All mining systems	All mining systems	Continuous miner, flexible conveyor train, roof bolter	Coal cutter, mobile drill, feeder breaker, roof bolter	Coal cutter, mobile drill, feeder breaker, roof bolter
Minimum working height (mm)	200	900	1524	897	1400
Potential improvements in system	System could be improved on increasing the conveying capacity by installing larger drive motors	System could be designed with cover to minimise contamination	Could be designed to fit thin-seam height requirements	A battery powered system could be a better option	Could be designed to be lower in height to fit low seam requirements
Model	En-masse conveyor and en-mass elevator	Pivoting pan conveyors	4FCT01	EJC 88 XLP	EJC 115
Supplier	Bateman Engineered Technologies	Bateman Engineered Technologies	JOY	EJC Mining Equipment	EJC Mining Equipment

10 BATCH HAULER ANALYSIS

The findings of this study relate mainly to the technical evaluation of machines applicable or potentially applicable to thin-seam clearing. The common method of coal extraction in South Africa is room-and-pillar mining. This mining method makes use mostly of the shuttle car and continuous miner. This combination is in itself a limiting factor in production because of the discontinuity inherent in the batching process. The capacity of the miner is therefore only partly utilised as a result of the interruptions in production or cutting time for shuttle car change-outs.

Table 10-1 shows capacity utilisation and tonnage capacity calculations for various batch haulers for thin seams. Availability, utilisation, distance and bucket-fill factor have all been assumed equal for the different technologies. The distance shown is the total distance for loading and unloading the batch hauler. Availability, utilization, distance travelled and bucket fill factor have been assumed constant for all batch haulers. For calculating the capacity utilization, the following equation was used:

[(Capacity) x (Availability) x (Utilization) x (Bucket fill factor)]/(Cycle time) = Capacity Utilization

Table 10-1: Batch haulage equipment capacity utilisation for thin seam applications

Batch Haulage System Capacity Capacity Utilization					
Equipment Factors	Scoops	Shuttle Cars	Battery Cars	XLP (EJC 88L) Loader	XLP LHDs
Capacity (tons)	9.10	7.70	13.00	4.00	5.50
Availability	0.90	0.90	0.90	0.90	0.90
Utilization	0.70	0.70	0.70	0.70	0.70
Distance travelled (m)	120.00	120.00	120.00	120.00	120.00
Speed (m/min)	83.33	120.00	120.00	166.70	350.00
Travel time (min)	1.44	1.00	1.00	0.72	0.34
Loading time (min)	0.50	0.50	0.50	0.50	0.50
Unloading time (min)	0.75	0.75	0.75	0.25	0.20
Cycle time (min)	2.69	2.25	2.25	1.47	1.04
Bucket fill factor	0.75	0.75	0.75	0.75	0.75
Capacity Utilization (tons/min)	1.60	1.62	2.73	1.29	2.49

High capacity utilisations are noticeable in battery cars and the XLP LHD as a result of different variables. The battery cars' high-capacity utilisation is due to high volumetric capacities, while that of XLP LHDs is due to high speeds. These are variables that could be useful in manipulating batch hauler capacity utilisations.

As an example to illustrate the effect of speed on capacity utilization, shuttle cars will be compared to the XLP LHD. Figure 10-1 shows a shuttle car's utilization plotted against distance travelled, using data obtained from Table 10-1. It is clear from this graph that there is an exponential decrease in tonnage capacity with increase in distance. A review of mining practices with regard to this feature would greatly improve production levels. Furthermore, the trailing cables limit travel, which is the case with most batch hauling systems.

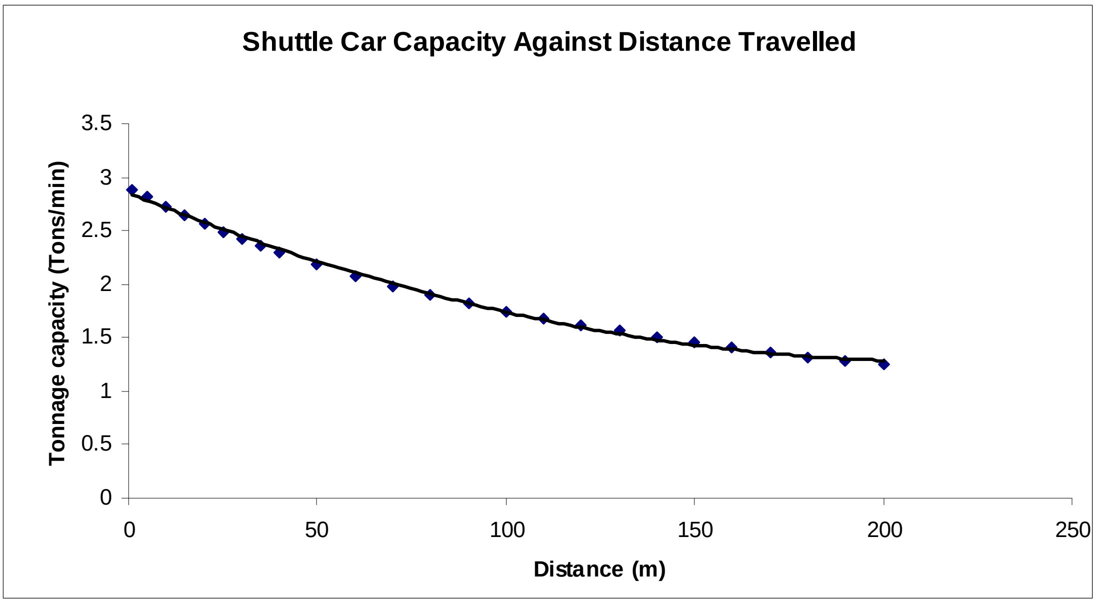

Figure 10-1: Shuttle car capacity with distance variation

Considering the review of all the systems, it is obvious that the immediate solution to this problem would be to increase the number of shuttle cars as the distance increases, or to increase their speed to maintain their numbers constant. There are practical problems associated with increasing the number of cars, such as trailing cable control. More labour would be required to perform this task, and there would also be a limit on the method of travelling.

Some transport equipment such as the extra-low profile loader and LHD could enhance the performance of this method through its higher speed and lack of trailing cables. The higher speed would decrease the cycle times and in this way increase conveying capacity (see Figure 10-2).

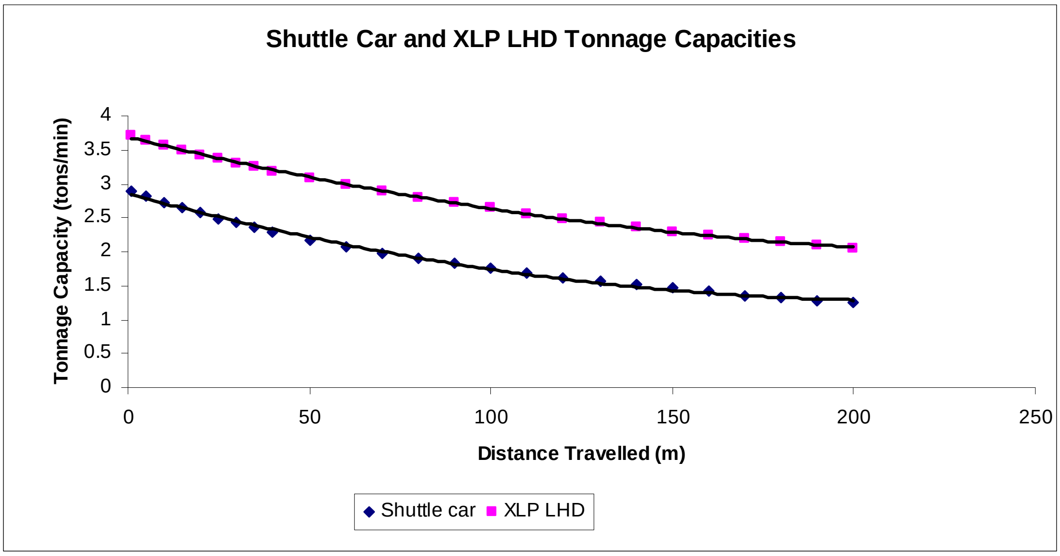

Figure 10-2: Comparison of shuttle car and XLP LHD tonnage capacities

A substantial difference in capacity utilisation is observed between the shuttle car and the XLP LHD. For instance, at 100 m the shuttle car conveys coal at 2 tons/min while the XLP LHD conveys coal at 3 tons/min. There would also be a limitation with using high speed batch haulers as the they cannot be driven at full speed consistently.

Another alternative would be to replace the shuttle cars with continuous haulage behind the continuous miner. But the capital expenses of such a system would be problematic.

11 DISCUSSION OF THE RESULTS

The systems reviewed for thin-seam transportation do provide a basis for meeting the anticipated benchmark for the coal-winning machines. Various machines currently available for thin-seam application have revealed conveying capabilities that could meet the winning machine's target. For instance, the bridge continuous conveyor and the flexible conveyor train have tonnage capacities that could match those of the winning machines. It is important to match these potential systems with associated mining methods and mining systems.

The fundamental operating principles of a machine dictate its conveying efficiency. For continuous haulers, the conveying efficiency remains largely uniform throughout its conveying length. Batch haulers have been shown to have an exponential decrease in tonnage capacity with an increase in distance. It is therefore important to identify the optimal effective distance for batch haulers if they are to be the preferred means of transport.

However, technical improvements may have to be made to some equipment if the flow bottleneck along the coal transport route is to be eliminated.

12 CONCLUSIONS AND RECOMMENDATIONS

This technical review of thin-seam clearance equipment revealed that:

- Adequate thin coal-seam winning machinery is available in the global market to fulfil the required production expectations of the South African coal industry.

- The three main factors, i.e. mining method, overall transportation systems and mining system integration, cannot be ignored when a coal clearance system is selected. These factors are interrelated and they form a fundamental criterion for the selection process.

- The early mining systems form a basis from which technological developments in thin-seam clearance systems have emerged. These systems show an evolutional trend in systems that exist in today's applications. The longwall shearer method, for instance, may have evolved from full face miners with improvements in economics and intelligence in the system.

- The problem associated with non-matching tonnage capacities between the winning machine and the clearance system depends on the system type, i.e. batch or continuous. Continuous systems are more reliable than batch haulers in conveying efficiency. The tonnage capacities of batch systems have been shown to have an exponential decrease with an increase in distance travelled. Higher-speed or capacity systems could be used to make up for this decrease. It is important to note, though, that thin seam transport systems for ROM coal that match tonnage capacities of the reference winning machines are available on the market.

- Intermediate material transfer equipment such as the feeder/breaker and stageloader are necessary requirements for controling size and flow between face and in-section clearance systems. These machines perform their respective tasks at an added cost to the complete mining system. An ideal system would entail a continuous transportation line from coalface to surface minimising such expenses.

- The hydrohoisting and air-lift hydrohoisting techniques are methods that could be effective in direct transportation of ROM coal from face to surface. The transportation efficiency of such systems would be enhanced if a favourable mining technique is applied. This was the case with the Hansa Hydromine in Germany. Water jets are preferred to all other mining techniques since the coal takes the slurry form at the face. Maintaining the right particle size is an important aspect of this process, as is dewatering on surface.

- Pneumatic conveying is another method that could be used for direct coal transportation from face to surface. Again, the efficiency of this system depends on particle size distribution. At Hlobane, this system was used with the ram-plough, which created the suitable particle size. Today, it could be applied with mechanised techniques, as well as drill and blast techniques with the right crushers at the mouth suction pipe. Another feature that could be improved in this system is its conveying capacity.

- The pipe conveyor is an economical system for out-bye transport as it can withstand far greater horizontal and vertical angles than its conventional conveyor belt counterparts. The pipe conveyor also offers the additional advantage of protection from product contamination and spillage.

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Appendix A: Specifications of the Transport System with Roots Blower and Centrifugal Fan System

Roots Blower System	Centrifugal Fan System
Roots blower Operating pressure : 18 – 38 kPa Flow : 1.51 m^3/s Installed power : 110 kW **Filter box** Number of filters : 30 Filter area : 54 m^2 Filter cleaning : 700 kPa reverse pulse **Dust cyclones** Number of units : 4 Height : 2 300 mm Diameter : 400mm Efficiency : 90% **Primary coal separator** Height : 2 500 mm Diameter : 1 200 mm Pipe diameter : 250 mm Capacity : 1 080 kg **Coal conveying pipeline** Diameter : 250 mm Material : PVC class 9 Coupling : Victaulic joints Bends : Steel at 2 m radius Air velocity : 25 m/s	**Donkin fans** (two off) Pressure developed by one fan : 12 kPa Pressure for two series fans : 22 kPa Volume drawn by two fans : 1.2 m^3/s Electric motor (per fan) : 55 kW **Dust handling** Discharged to return airway and rendered incombustible by addition of stone-dust from a trickle duster **Dust Cyclones** Number of units : 4 Height : 2 300 mm Diameter : 400 mm Efficiency : 90% **Primary coal separator** Height : 2 500 mm Diameter : 1 200 mm Pipe diameter : 250mm Capacity : 1 080 kg **Coal conveying pipeline** Diameter : 250 mm Material : PVC class 9 Coupling : Victaulic joints Bends : Steel with 90^0 bend Air velocity : 17 – 33 m/s

Appendix B: Some Typical Pipe Conveyor Installations in South Africa

Pipe Diameter (mm)	Length (m)	Product	Capacity (TPH)	Location	Special features
150	25	Slaked lime	22	Richards Bay	High angle 31^0
150	216	Dolomite and limestone	250	Pretoria	Horizontal Curves
150	50	Gypsum	112	Pretoria	High angle 28^0
250	34	Coal	300	Witbank	High angle 29^0
300	322	Coal	400	Witbank	Crosses rail siding no spillage
400	137	Granulated slag	1000	Newcastle	High angle 28^0
350	114	Coal	725	Witbank	Vertical and horizontal curves