

Coal Age - A Longwall Look at Tomorrow

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INTRODUCTION

Longwall mining has been the dominant global coal mining method for decades. However, not until 1994 did longwall mining surpass continuous miner room and pillar extraction tonnage in the United States. This significant event, occurring in the most cost driven market in the world, confirms the efficiency and effectiveness of longwall mining.

Free market economics, with respect to energy costs, is replacing government controlled energy policies, siege mentality and early 20th century isolationist policies. Coal, as an energy source, is challenged by competing fuels and technologies. The twin threat of price and environmental bias will continue to pressure the industry. Hopefully coal's abundance, reliability and low cost can off-set the eventual increase in compliance costs.

A recent Coal Age global longwall census indicated there are 1,712 fully mechanized longwalls operating in the 12 major underground coal producing countries and that the number of mechanized longwalls is increasing in China, Australia, South Africa and India. It is clear that longwall mining methods will continue to produce coal safely, at low cost and in large volume

With the acquisition of Dobson Park by Harnischfeger Industries Inc. and the merging of Longwall International into Joy Mining Machinery, Joy now manufactures all the major elements of a modern longwall system. The challenging task of integrating roof supports, armored face conveyor (AFC) and shearer into a single operational system fell largely to the operating coal companies. Their ability to optimize system performance against a background of competing commercial imperatives as well as technological incompatibilities, was and continues to be difficult. A step change in reliability and productivity is seen at hand by Joy through the supply of complete longwall systems. from Joy Mining Machinery.

However, the changing relationship between coal mine operator and equipment supplier will be as important as improvements in the equipment features and system integration.

There has been a continuous process of rationalization in the coal mining industry affecting both mining companies and machinery manufacturers. In the USA, the number of underground mines has fallen from 2,008 in 1981 to 885 in 1996. There were 946 underground coal mines in the UK in 1945 and this number now stands at 25. The competitive pressure has resulted in the emergence of a few big players and the loss of many small independents.

On the longwall equipment supply side there are only two major 'high-tech' suppliers of roof supports and face conveyors four suppliers of shearers. This rationalization is the result of the contraction in the coal mining industries in the United Kingdom and Germany, and the diminished ability of these markets to support multiple suppliers. In addition, today's equipment produces more coal per unit of production which reduces the number of opportunities and therefore the available market for suppliers. This industry rationalization in both coal production and equipment supply suggests that alliances between machinery manufacturers and coal producers are the way of the future.

BACKGROUND

Joy Mining Machinery was founded by Joseph Joy in 1919 and over a period of years became the major coal mining machinery supplier in the United States. Until the introduction of longwall in the 1960s the principal mining technique was

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room and pillar extraction. Equipment suppliers sought to mechanize the individual operations; drilling, blasting, loading and conveying. Joy successfully met this challenge with equipment colloquially referred to as a “conventional face”. This consisted of a drilling unit, undercutter, loader and shuttle cars. The mechanization process continued with the introduction of the continuous miner, so called because the drilling, undercutting, blasting and loading operations could be done by a single machine. Although longwall was introduced in the 1960s room and pillar was still the predominant method until the 1990s. The productivity and competition from room and pillar accelerated many of the advances in longwall mining. Joy entered the longwall market, as a manufacturer, in 1975 with the introduction of the 1LS shearer. This was the first multi-motor, all-electric, shearing machine and broke with the traditional single motor, hydraulic designs of the day. By the late 1980s Joy had become the major supplier of shearers in the US market.

In 1995, Joy merged Longwall International into its organization with the acquisition of Dobson Park, a United Kingdom conglomerate. Longwall International was itself the product of the long rationalization process of the UK coal machinery supplier industry. The latest merger before the Joy acquisition was between the globally-recognized manufacturers Meco International and Gullick Dobson. Joy is the only manufacturer of all the major elements of the longwall system (see Photo 1) which includes shearers, roof supports, face conveyors, stage-loaders, crushers and pump stations, and is now the largest supplier of underground coal mining equipment in the world.

INSTALLED BASE

A Coal Age census (September, 1997) of the top 12 longwall producing countries is presented in Table

Table 1 - Major Longwall Producers (1996)

Country	Number of Longwalls*	Average Production per Longwall per Shift (tonnes)	Average Production per Longwall per Year (000) tonnes
USA	69	3,475	2,502
Australia	30	2,360	1,558
United Kingdom	36	1,667	1,157
China	244	1,511	1,070
Canada	2	1,499	1,138
Germany	66	1,423	966
South Africa	8	1,236	1,020
Poland	350	1,190	744
Russia	432	696	418
India	6	686	371
Kazakhstan	40	634	475
Ukraine	429	520	312
Total	1712		

* Only fully mechanized faces included.

Joy has been successful selling its equipment to customers that are market driven. These operators must produce coal at the lowest cost over the life cycle of the equipment in order to survive.

Installed base (see Table 2), as defined by Joy, refers to equipment in use at the time of a particular census. This figure is lower than machines in service which includes units under rebuild or idled, spare capacity. Installed base varies from month to month as a result of new faces starting up and old panels being worked out.

Table 2 - Installed Base

Country	Number of Longwalls	Joy Shearers	Joy Roof Supports	Joy AFCs
USA	65	52	35	31
Australia	30	8	28	22
UK	33	14	33	26
South Africa	8	3	7	7
Total	136	77	103	86

PERFORMANCE

The achievements of the world-class performers is presented below:

Upper big branch - performance coal

The achievements at A T Massey's Performance Coal Company in the USA are significant. This is A T Massey's first longwall operation that within less than three years achieved world class performance. At the Upper Big Branch Mine a complete Joy installation averages 620,000 t/month, with a best month performance of 640,000 tonnes. The 305m wide face is typically 1.83m thick and retreated 40.6m in one 24 hour period during April, 1997. The face equipment includes a JOY 4LS9 high voltage shearer with 725kW total installed power. The 175 shields constituting the set of roof supports each 1.75m wide with twin 800 tonne leg capacity. The JOY AFC is powered by three 522kW drives.

In addition, the advance achieved with JOY 14CM miners and 10SC32 shuttle cars in the "super section" longwall gate development remains well above industry average. The three entry super section has two miners and three shuttle cars operated by a single crew. The system is designed to eliminate time lost between cuts. When a cut is complete the mining crew leaves the continuous miner and moves to the second miner situated in another roadway. The work place is bolted and made ready for production. Three road gate advance averages 83m/shift and has reached a best of 152m/shift.

West elk - mountain coal company

In Colorado, the West Elk mine, operated by Arco's subsidiary Mountain Coal Company, achieved excellent shift and monthly production using a JOY 6LS3 shearer. Mining a 3.3m to 3.96m seam on a 290m face, they have produced 796,000 clean tonnes in a single month. The single face mine with a workforce of 280, has an annual production target in excess of 6 million tonnes.

Mountaineer mine - Mingo Logan

More recently in the eastern USA, Mingo Logan's Mountaineer mine produced 969,911 raw tonnes in a month. This was achieved in a 1.65/1.8m seam where, during the month the face retreated 730m, with a daily best of 38.1m. The face equipment consisted of a JOY 4LS9 operating on a JOY conveyor with Ultratrac haulage. The supports were fitted with the RS20 roof support control system, and the face availability was recorded at 96.7%.

FMC Corporation

In Wyoming, notable production feats are being achieved through the use of longwall mining systems in non-coal applications. A longwall system consisting of JOY roof supports, AFC and shearer has been installed at FMC Corporation's trona mine in southern Wyoming and the 3.65m seam of hard (48.3MPa) mineral is being mined with a JOY 6LS6 shearer (See Photo2). The 190.5m face is using a set of JOY, 2X680 tonne shields, has a best month's production of

236,365 tonnes with a best shift of 6,365 tonnes. The use of longwall mining in the trona basin is increasing with Solvay's recent decision to purchase a JOY roof supports and 6LS6 shearer.

South Bulga - Cyprus

Australia is the largest growth market for world class longwall systems. At Cyprus's South Bulga mine, single month mine production of 493,453 tonnes has been achieved from a 200m face in the 2.4m Whybrow seam. JOY 940 tonne 2 leg shields with LI10 controls complement the JOY AFC, which is equipped with a twin 42mm chain. The 1000 mm wide AFC runs at 1.6m/sec and is powered by 2x750kW drives through 5665 Voith 1000BP couplings. South Bulga has achieved a 24,793 tonnes/employee-year, 2.5 times the Australian average.

Matla Colliery - Ingwe

In South Africa, the longwall face in 4 Seam at Ingwe's Matla Colliery is equipped with a JOY 6LS5 shearer. The shearer set a South African production record of 343,649 tonnes in a single month in September 1997. The previous South African record was held by a JOY 4LS shearer.

Daliuta - Shenhua

High production equipment has been supplied to China. A JOY 6LS3 on a JOY AFC operating in a 4.0m seam at Shenhua's Daliuta mine achieved a Chinese record by mining 14,907 tonnes in a two-shift period. The tough Jurassic coal in this shallow deposit is difficult to cut and a second Joy shearer and AFC combination, with more power, capable of extracting 5.0m has been installed at the neighboring Bulianta mine. With 610kW cutter motors and a total installed power of 1500kW the JOY 6LS5 is one of the most powerful shearers in the world.

China is the world's leading producer of coal, mining about 1.4 billion tonnes raw coal a year. The industry can be divided into State owned and operated mines and a non State sector operated by a variety of entities (i.e. provincial governments, counties, towns, collectives and individuals). State owned mines produce about 40% of the country's total output and account for nearly all the investment and mechanization. The non-State sector mines are smaller and less mechanized. There are new laws in place designed to limit the growth of this sector and to stop mining activities where they are dangerous or sterilize the reserve base. The problem for the authorities is that this non-mechanized, lower invested segment is producing the lowest cost coal.

In China 70 - 75% of electric generation is produced by coal fired utilities. This share of electricity production will continue for the next twenty years despite Kyoto initiatives and the Three Gorges hydro-electric project.

CURRENT TECHNOLOGIES

Longwall Shearers

The most significant development in the design of shearers was the introduction of the JOY multi-motor all-electric shearer in 1975. This innovation brought a new level of reliability and maintainability to the machine. The advantages of the modular, all-electric concept and the benefit of eliminating complex hydraulic circuits from the underground environment were quickly recognized. Since that introduction, advanced shearer manufacturers have adopted the concept.

Joy's modular design consists of five main structural elements (see Photo3). The body of the shearer normally consists of three high tensile steel fabrications bolted together to form a slim main section with no under-frame. This design provides maximum under-body clearance for coal passage in a given seam thickness. The elimination of the under-frame also enhances underground transportation. The Joy design eliminated face-side access to the electrical controller section which means that normal maintenance can be carried out in a safe working environment. Two traction sections are bolted and doweled to each end of the controller case. Each traction section houses a haulage motor, primary traction gear case and

hydraulic system for moving the ranging arm and rotating the cowl. The controller case, which forms the center section, contains the electric control system including, vacuum contactors, transformers, SCR bridge or AC drive, microprocessors, control circuitry and data display screen.

The secondary traction gearcases (or down-drives) are bolted to the traction cases in an arrangement which permits the custom fitting of the shearer within the AFC and roof support envelope. A wide selection of down-drives can be fitted to the shearer to suit individual haulage preference.

High tensile steel ranging arm castings house the cutter motor and cutter gearcase. Joy manufactures its own gears using high performance, alloy steel. Custom design, coupled with exacting heat treatment processes, has made 6 million tonne design life a reality.

In the 1920s Joy developed a relationship with Reliance Electric to maintain the latest electric motor technology. This on-going relationship has enabled Joy to combine the motor specific skills of Reliance with Joy's own application and design expertise. The incorporation of specially formulated varnishes and specific baking techniques have produced motors that are suited to the rugged mine conditions and machine duties.

The main driver of design development over the past twenty years has been the requirement for higher installed power (see Figure 1). Installed power has more than doubled in the last 15 years and high voltage (2,300V/4160V -60Hz, 3,300V/50Hz) electrical supplies are essential in the top producing faces. Total installed capacity on the JOY 6LS5 has reached 1610kW.

Recently there has been a trend in the application of AC haulage drives with on-board variable frequency controls. The JOY 7LS, scheduled for start-up in mid- March 1998 at Canyon Fuel's Sufco mine, and the 6LS5 for Moranbah are equipped with this feature. These AC drives are used for applications where there is a need for high cutting and flitting speeds. High speeds typically are required in narrow web operations or where 'uni -di' cutting on long face widths is practiced. Uni-di refers to cutting in a single direction and then flitting back the entire length of the face before cutting the next pass.

Roof supports

Roof supports for high capacity longwalls are custom designed to meet exacting cycle requirements (up to 50,000 cycles) and operating requirements (over 1,200 tonne yield). Finite element analysis along with prototype static and dynamic load testing are essential in the design processes. Joy has introduced the design failure mode and effects analysis (DFMEA) process. This is a design analysis methodology that looks at possible failure mode and weights the severity and the probability of occurrence. These factors are combined to define an index for each component or sub assembly of the equipment. This approach is extremely beneficial in the prioritization of design efforts and resources.

Today's heavy duty supports are twin-leg design(see Photo 4), the diameters of which have increased to 450mm. Joy's first 450mm leg face is to be delivered in June 1998 to Moranbah North, a new mine, in Australia. Large leg diameters require that shields must be positioned on 1.75m support centers to accommodate the leg pockets. The growing demand for +1000 mm web cutting increases canopy length and this increases support rating to maintain densities. Longer, wider canopy dimensions add weight to each shield heavier which makes installation and face move logistics more difficult. Thick seam supports now typically weigh more than 25 tonnes. However, an advantage of wider supports is a reduction in the number of shields per unit face length and this increases the overall system reliability.

The hydraulic legs or jacks used to set the canopy to the roof generally are double telescopic to provide maximum open to closed height ratio. Joy legs are back extruded which enables large diameter, in-casing drillings for fluid flow. The elimination of welded stack pipes increases reliability and fatigue life, and the large diameter drillings improve flow and leg cycle times. The extruded design also reduces the leg constant for a given stroke and enables the leg to be positioned closer to vertical which improves performance. Other features include a variety of base lift arrangements to free the base from soft floor conditions and reverse force advance ram and relay bars for specific applications.

All the hydraulic functions of the JOY roof support are actuated through the Compak Valve, which consists of three sections; the solenoid manifold, main valve block and return manifold. The solenoid valves are the link between the

electronic control system and the function linked spool valves. The major advantage of the design is its ability to operate at pressures greater than 31MPa on a supply of 6 to 15 volts. This allows the solenoid to be activated on demand unlike other systems which require the hydraulic feed to be interrupted by a control solenoid. This improves cycle times and the ability to control multi-function activities. The valve block comprises up to 14 spool valves which provide a greater degree of reliability than the more contamination sensitive ball and seat designs.

Armored face conveyors

Armored Face Conveyors (AFC) serve a dual purpose; to convey coal and to provide a track on which the shearer can operate. As production requirements have grown and face lengths have increased, so too have AFC chain dimensions. Current high production AFCs (see Photo 5) utilize twin 42mm chain in 1000mm wide (raceway) pans with total drives rated at 1500kW. Such conveyors are designed to convey 4,500 tonnes per hour on faces up to 300m long. AFCs of these capacities require high voltage electrical supply (2300/4160V-60Hz and 3300V-50Hz).

Full load starting power requirements, on these high production faces, are considerable. To meet this challenge, Joy developed the JOY TTT (Turbo Transmission Technology) system, a microprocessor controlled fluid coupling which effectively provides a progressive start -up load (see Photo 6). The closely monitored flows and temperatures enable the unit to provide enhanced control and refined water management. In addition the system brings soft-start benefits of longer chain, sprocket and gearbox life, as well as reduced pan wear.

The off-load starting and load sharing characteristics of the system bring several benefits, including reduced electrical demand at start-up, the ability to use non matched motors, and reduced motor specification with associated cost savings. The double 562 turbo coupling increases and limits torque, improves thermal characteristics and is contained in a smaller envelop. The hydro-dynamic features are a function of the fluid circuit design and the precisely controlled fluid levels. These result in proactive load sharing and a controlled soft start.

The JOY AFC design uses cast steel sigma sections of exacting tolerances to eliminate the need to weld clevis and mating arrangements, and the high specification abrasion resistant upper deck plates enhance pan life and maintenance free fabrications.

The AFC-shearer mechanical interface through the haulage system is an important factor in optimizing operations. A variety of haulage systems have been developed to cope with greater haulage forces. Joy's latest, Ultratrac 2000, the latest version of the proven Ultratrac haulage (+ 50 installations), is a forged rack and heavy duty sprocket system, with increased sprocket and trapping shoe life, capable of negotiating severe seam undulations.

Heavy duty AFCs utilize a single or twin, in-board chain configuration depending on capacity requirements and chain diameter. The sprocket designs and manufacture are a significant product differentiation with special consideration required for pocket design, machining and flame hardening. An important factor in achieving good chain life is an effective chain tensioning system. Joy offers two automatic chain tensioning devices. One mechanism relies on conveyor-chain slack in catenary to activate the tensioning rams, the other operates via load transducers on the rams which indicate variations in chain loading and cause the tensioning rams to extend, returning the chain to the nominal settings.

Electronics

The introduction of multi-microprocessor-based, embedded control systems on the JOY ILS4 in 1980 was an important advance in shearer control technology. Since then, the increasing power of these microprocessors has enhanced their capacity and functionality. In addition to enabling cybernetic operation, these on-board control processing units (CPU) provide a variety of diagnostic features.

Joy is devoting an increasing amount of R&D investment to system integration through electronic standardization and advances in remote control techniques are enabling a cable-free environment. Cables in the underground environment are vulnerable to damage and the removal of these cables has increased system reliability. In the design of underground mining equipment, 'space saving' technologies also bring several benefits. Miniaturization has allowed smaller component design and these new, smaller components (e.g. valve banks and electro-hydraulic controls) generally can be placed in less vulnerable locations. These safer locations mean higher reliability and give operators ergonomic work environments,

resulting in greater safety and productivity. A second advantage of miniaturization is the ability to create space within a given design envelope to add new features. It also may be possible to make the case smaller and bring performance enhancements through redesign (e.g. thinner shearer body to permit more coal clearance).

There have been many technological innovations in shearer electronics, including optical encoders, serial data communication (which eliminates hard wiring in the controller case), face conveyor feedback loop, memory cut and the JNA control system. The JNA control system enables operating parameters to be changed using specific access codes. A shift supervisor can change operational inputs while an engineering manager has access to overload parameters and circuit timing. Using the JNA memory cut, a complete cut sequence including gate-end cuts can be programmed into an operator friendly system. This produces cleaner coal, improved machine operating efficiency, higher levels of automation and better roof and floor control. Cutting speeds, drum and cowl positions and undercut depth can be reconfigured via a menu roll-down option or this can be programmed into the JNA. This technology is being refined for those operators who want to view all the face data on surface in real time. Shearer data can be transmitted to the head-gate via ether a pilot core or the power cores and from there to surface by telephone line.

A common specification today is shearer initiated support advance (SISA) which can be supplied in either infra-red or digital/serial data communication systems. The market trend is toward the digital/serial system since this also provides a means to identify shearer position on the face and is not a function of clear line-of-sight constraints. Both systems operate by sending a signal from the shearer to the roof supports to activate a selected shield sequence.

Joy also has made progress in shearer steering technologies particularly in supplying a reliable 'memory cut' system. Joy's first successful application of this having been on a 4LS shearer at R.J. Budge's Wistow Mine in the Selby Complex. With it, the shearer operator creates an initial profile or template under manual control, and the machine then automatically replicates the profile on subsequent cuts until conditions change. The operator then updates the profile by manually cutting a new pass.

In roof support electronics, the JOY RS20 (see Photo 7) represents state-of-the-art, electro-hydraulic, control systems. In electro-hydraulic controls, as with most mining equipment features, a balance must be struck between proven technology and innovative design. The RS20 control system meets this criterion in the use of field tested microprocessors and software developed by mining experts. The flexible architecture used in the design of the RS20 also ensures expansion capability to meet future requirements. The benefits of the electro-hydraulic system are that the operators can remain in dust free areas while the system can operate close to the shearer which improves roof control.

The RS20 system consists of a set (one for each support) of intrinsically safe (IS) shield interface modules (SIM) linked in series and connected to the shield control center (SCC). The SIM has buttons to operate all the functions on that support as well as the support on either side of it. In addition it is possible to use the SIM as a support fault diagnostic aid for the support and the complete system.

The SCC is housed in an explosion-proof enclosure and provides the central automatic control facility and operator interface for the roof support control system. It consists of the sequence or control computer, color display, keyboard interface and intelligent power supply interface.

Integrated Longwall systems - the future

Shearers will continue to increase in power but the rate of increase will be slower than has been experienced in recent years. Haulage systems will trend to on-board variable frequency, variable voltage, AC drives. Electronic systems will continue to be developed to enhance automation.

There have been several attempts to introduce self-correcting shearer steering systems. These systems rely on a sensor that detects the coal/rock interface. Two main types of sensors have been used in the industry. The most common system is based on natural gamma radiation detection and measures the difference in gamma radiation characteristics between coal and rock strata. These readings are calibrated to give coal thickness to the interface. One drawback of this technology is the loss of data or spurious readings in areas of broken roof conditions. In addition the technology does not function when a thick coal roof must be left or the overlying rock does not emit radiation (e.g. sandstone).

A second technology used to automate horizon control depends on either a sensitized pick or machine vibration analysis. This system can produce confusing readings in conditions where floor and coal are of almost equal hardness or where rock bands are present in the coal. Future steering solutions are likely to utilize a new enabling technology and eliminate operating anomalies through smart software.

A significant improvement in longwall performance will be achieved as a result of mechanically and electronically integrating the longwall face. If optimization of current equipment, as a system is to be attained, common protocol electronic communication between all the elements of the system will be necessary. That is, if the system bottle neck is the panel belt then the stage loader must be able to slow the AFC to match this constriction. At the same time, the AFC must be able to communicate with the shearer to control its cutting speed to match this rate and also to compensate for the shearer's position on the face to eliminate surges. Communication between the shearer and the roof supports is necessary to achieve automatic face advance. Communication between the AFC and the roof supports must be refined to enable AFC steering. A continuous two-way communication between all the longwall equipment must be established and maintained, and an optimization logic must permit the face to produce the optimal tonnes under changing conditions. This type of three way dialogue might permit operational changes and allow the use of a sumping shearer, which eliminates the time lost at the gate ends.

Electronic control and automation of the coal face are the key to future advances and step changes in longwall mining productivity and performance. The achievement of 100% reliability through the life of the panel must be the goal.

When that target is reached through a combination of new technology, innovation and the use of redundant systems, the next step will be to fully automate the longwall face can be attacked.

In the UK automated faces have been sought since the early 1960s. These efforts usually have been undertaken with the aim of removing people from the face either as part of a safety/environmental directive or to meet economic targets. Both goals are valid; though, both miss the major advantage in attaining a truly automated face.

When a longwall face is made 100% reliable and automated, people will be required on the face for face installation and limited work between shifts. Eventually it will be possible to eliminate the roof supports walkway and this will radically reduce the leg-to-tip distance and give significant improvements in roof support design. The shields will be smaller and lighter, and the legs can be positioned closer to the vertical for better mechanical effect. The reduction in size will bring improved performance at reduced cost, shorten face installation time, and reduce face-move transport issues.

AFCs with capacities up to 7,000 tonnes per hour will be needed for longwalls up to 400m long. This will require individual transmissions of 1500kW. Although Joy's current soft-start technology can handle this power, new gear box designs will be required. In time, the development of variable speed, variable voltage, AC drives will eliminate couplings, and allow AFC speed to vary with the shearer and production needs.

AFC improvements can be realized with fundamental changes in materials and conveyor design. At present, coal is not conveyed by the AFC (in the manner of a belt conveyor) but pulled and pushed along the AFC deck plate by steel flights bolted to ever larger combinations of single and twin strand chain. Friction between the flights and the deck plates, particularly at the pan joints, requires significant power to overcome the resistance and to move the chain and flights. The use of materials such as nylon and carbon fiber composites has resulted in greater strength and lightness in other industries and could present an opportunity for mining equipment designers. In addition, materials with sufficient strength and lower coefficients of friction need to be considered. A rethink of the task at hand and how it might be accomplished by carrying the coal on a strong, lightweight, flexible, sprocket-driven mat within the AFC race could reduce power requirements. Research is required to find ways to capture the AFC energy wasted when no coal is being conveyed.

In the United States, environmental pressures will place a premium on the extraction of low sulfur coal primarily found in low seam deposits. Technology must be developed which will allow these thin seams (1.0 - 1.2m) to be mined economically. Obviously this will mandate a fully automated face.

The ultimate technological key to improved longwall performance will be the development of an integrated electronic system which will control all the elements of the longwall face in a self optimizing mode. Such a system will be reliable to aero-space standards and require zero maintenance. The face will be 100% automated requiring no workforce on the face

during cutting, and all functions will be controlled and monitored from the gate-end, surface, or any location selected by the user.

CONCLUSIONS

Longwall mining will be the dominant underground coal mining method worldwide for the foreseeable future, and productivity improvements will continue to be realized. These are likely to be the result of technological improvements in the design of the electro-hydraulic and mechanical features of the various elements making up the longwall system. These design improvements will focus on reliability and capacity. System improvements gained from the electronic and mechanical integration of the longwall system components will be realized. Improvements in the reliability of equipment and system integration will lead to the fully automated face, and this in turn will permit a complete redesign of the longwall system. These new system designs will bring greater reliability, productivity and lower costs to mine operators.

However, of equal and perhaps greater impact will be the development of a new relationship paradigm between the equipment manufacturer and the coal mine operator. This new paradigm is the result of the enormous pressures and changes which the coal industry has had to endure. The most significant pressure is the price squeeze. During the last twenty years the average price of coal has increased only 4% against 51% for oil and 211% for natural gas. The second major change is the shift in focus from individual pieces of equipment to complete systems. Individual pieces of equipment have reached stand-alone availability in the high 90% range but system availability, which is a compounding of these individual availability figures, typically is much less than 80%. Hence, system integration rather than individual product improvement is the key to competing in the future.

The new relationship paradigm will create a seamless existence between user and supplier, and will focus on the system life-cycle costs. The customer-supplier relationship will become more anticipatory, less reactionary and place greater strategic focus on shared interests. This more holistic approach (i.e. Life-Cycle Management) is evolving in the mining industry. Paying on a cost per tonne basis, rather than being invoiced for discreet sales or services, complements this approach to business and is growing in acceptance. This new approach provides a genuine flexibility and the means to better match costs to the revenue stream.

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