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Continuous Conveying in Open Pit Mines

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Summary

Various open pit mining systems with hard rock and unconsolidated overburden are analyzed and the main differences between discontinuous, semi-continuous and fully continuous mining and transportation methods are outlined.

It is demonstrated that future open pit mining systems will tend to use continuous or semi-continuous haulage and mining operations in which detailed, long-term economic and technical planning and evaluation with the help of computer programs will play a major role.

1. Introduction

When analyzing the various opencast mines it can be established that there exist only two basic types of mining systems, i.e., the discontinuous strip mining system as used in the USA (Fig. 1) and the continuous mining system as is commonly applied in Europe (Fig. 2). The reason why these two mining methods have been developed parallel to and independently of each other to such a high technical standard results from the varying geological conditions of the mineral deposits.

Whereas pay minerals such as coal, phosphate, bauxite, iron ore and copper ore are mined in the USA from relatively thick and horizontal seams with low to moderate overburden depths, the mineral deposits in Europe lie at much greater depths and usually not in homogeneous seams. Due to the very favourable overburden to coal ratio of 2:1 in the USA, mining and haulage are possible by means of shovel excavators and draglines and heavy trucks, whereas the considerably higher mass movement in European opencast mines, with an overburden to coal ratio of up to 10:1, can only be mastered by continuous haulage systems. In the meantime the conditions in the USA have also undergone a change to such an extend that it is no longer possible to uncover usable coal seams without removing increasing depths of overburden, while coal quality often deteriorates. Therefore several opencast mines in the USA are becoming deeper and the volume of material that has to be moved increases accordingly. Higher production rates are also a consequence of the substitution process of the expensive oil by coal.

During recent years the opencast mining scene in the USA has altered and the first steps towards continuous haulage have been made. The authors are of the opinion that this development will continue in the future due to the fact that governments, not only the American government, have introduced environmental laws and regulations which require very high standards of reclamation of mined-out areas.

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2. Truck Haulage System

Considering the overburden and intermediate coal seams that have to be exploited and the various good and medium quality coals, which to a certain extent have to be mined selectively, the classical truck haulage system shows an ever increasing uneconomical tendency as the price for diesel fuel, labour costs and the necessary costs incurred for land reclamation as well as the overburden depths increase.

Increased haulage distances will result in an expansion of the truck fleet even for constant production rates. With the aim of decreasing production costs in this important indus trial field, national and international institutions have conducted investigations to minimize operating costs. These investigations do not concentrate only on individual pieces of mining equipment but stress an analysis of various opencast mining operations and their planning and control by means of computer programs.

The necessary preliminary investigations were based mainly on individual systems in view of the costs for haulage per ton kilometer. These economic diagrams can only be used in a qualitative sense and in most cases results cannot be generalized since the conditions in each opencast mine are quite unique, i.e., parameters such as length of mine, its width and depth, the volume of material to be moved, reclamation requirement, lifetime of the pit, type of man power available etc.

It can be established that within the last ten years the operating costs as well as the haulage diagram for individual systems as a function of haulage distance show a detrimental result for the truck/shovel or truck/dragline systems especially for opencast mines with unconsolidated overburden (Fig. 3).

Fig. 1: Typical strip mining operation with dragline

Fig. 2: Mining operation with bucket wheel excavator, conveyor belt system and stacker

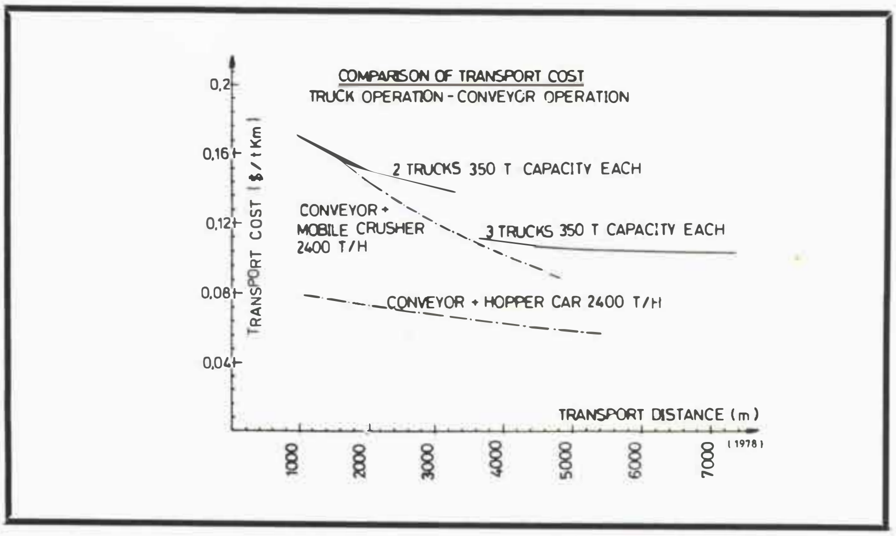


Fig. 3: Comparison of transport costs: truck vs conveyor operation

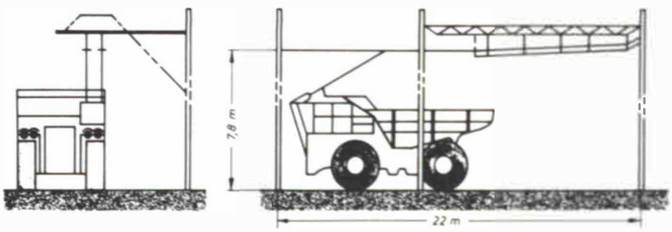


Fig. 4: Trolley-operated truck system

The classical mining method for hard rock open pit mines is the truck/dragline or truck/shovel system which nowadays calls for an increased number of graders and dozers due to the reclamation regulations.

In order to keep down the operating costs for such systems as far as possible, larger trucks are nowadays built with up to 350 t capacity and, for instance, trolley operated (Fig. 4). In this manner a decrease in operating costs of up to 35 % is possible. Much work has also been done in order to increase the capacity of draglines and shovels and to lower their operating costs, for instance by increasing dragline working radius and bucket capacity.

However, when handling more than 1 million bank m³/year over a haulage distance in excess of 1,500 m from a pit depth of over 80 m, this system is uneconomical when compared to semi — or fully continuous mining operations. Particularly detrimental to the extensive use of the truck system is the necessity to provide and maintain the necessary access roads. It should also be mentioned that long distances to overburden dumping areas have a negative operating cost effect even if the haulage distance for the mined coal should be short.

If reclamation of the spoil area is required it becomes apparent that costs involved for levelling by means of draglines, dozers and graders are considerably higher than if these operations were carried out by stackers in the form of a precultivated dump.

Of course open pit mines exist, for instance Phalabora in South Africa, where due to the inherent conditions only a truck haulage system can be used, and a change to a combined mining system would no longer be economic, but in other instances, as for example the SWICC, a change of mining system proved to be necessary.

3. Combined Mining Systems

The combined mining system was introduced in order to cope with the deteriorating overburden to coal ratio and with the reclamation regulations. The conveying system was introduced for handling the overburden whereas exploitation of the pay mineral, i.e., coal, is handled by a shovel/dragline and truck system. Conveyor belts can be introduced according to the so-called "around-the-pit" or "cross-the-pit" method.

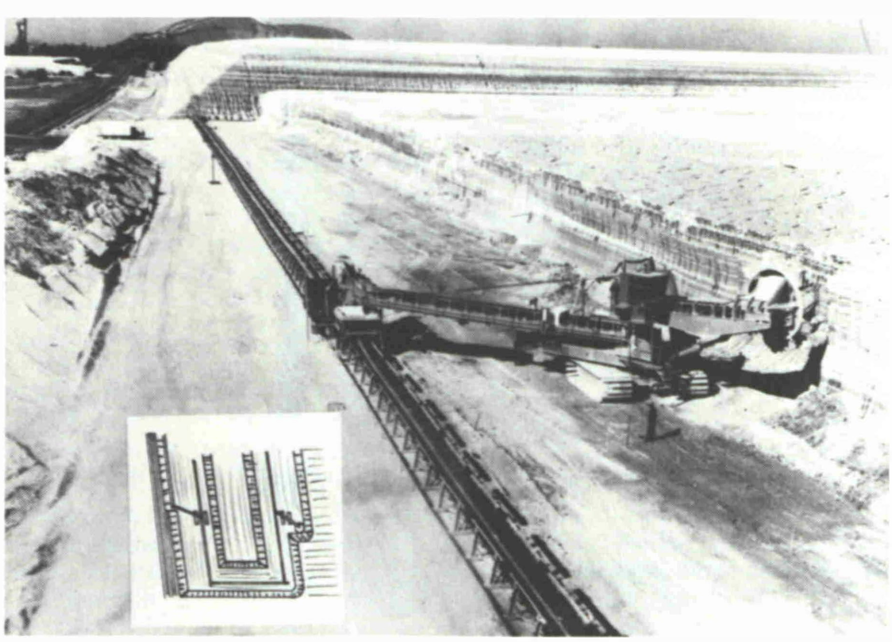
With the "around-the-pit" system a shiftable conveyor is fed with overburden via a hopper car. The hopper car can travel on the sleeper-supported rails of the conveyor system or alternatively as an independent crawler-mounted unit. The hopper car can be fed directly by means of a shovel or a dragline but also by means of a bucket wheel excavator (Fig. 5).

If the overburden and interbedded material which has to be removed requires blasting, a mobile crushing unit should be incorporated between the reclaiming unit and the conveyor system in order to reduce the size of the material to enable conveyor haulage thus also reducing costs for additional blasting.

The advantage of truck haulage lies in the fact that oversize material can be transported without the necessity of primary crushing. However, this will lead to considerably higher costs for reclamation or the dumps will have to be built up selectively.

The outgoing pit conveyor transfers the material onto a mainly stationary belt conveyor which in turn passes the material to the dump conveyor and then onto the travelling stacker which evenly distributes the material so that a homo-

Fig. 5: "Around-the-pit" mining method



geneous dump with a precultivated surface is built up. In American open pit mines the conveyor system usually takes a U-shaped form while the dump generally travels parallel to the exploitation. In European opencast mines the belt conveyor systems can take any required form as the dump can be built up at any required position. However, in the planning stage it is made sure that the turning point is built so that the outgoing conveyors coordinate in a circuit with the recovery and convey the material to a stationary conveyor system that is connected with the shiftable dump conveyor (Fig. 6).

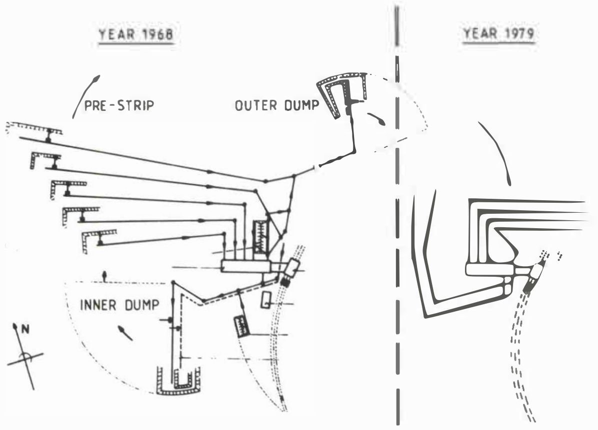


Fig. 6: Open pit conveyor system at Ptolemals, Greece

The previously mentioned "around-the-pit" system is practiced by SWICC and is also planned for NCPC.

The "cross-the-pit" system was applied in an extremely compact form by Peabody, for example, or in a very flexible form by Blue Circle, the latter being influenced by the German lignite opencast mining systems with conveyor bridges and bucket wheel excavators. These systems were introduced in the 1920s. With the cross-pit mining system the material is mined by means of shovels, draglines or bucket wheel excavators. These machines are followed by a mobile, crawler-mounted bridge conveyor which is supported on the lower pit bench and the dump bench (Fig. 7).

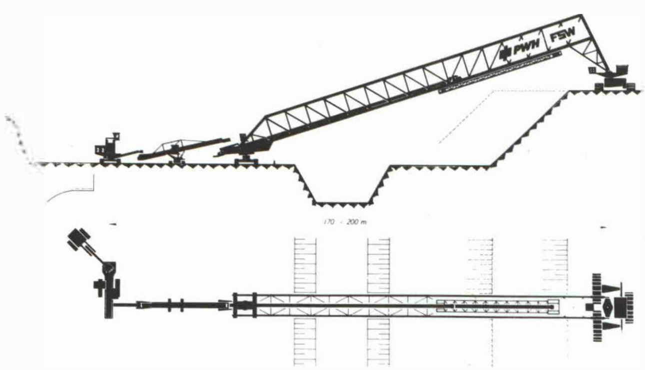


Fig. 7: "Cross-pit" mining at Blue Circle open pit mine

An essential criterion for this mining system is the distance between the face front and the subsequent bench. A new cross-pit system built by PWH was commissioned in December 1981 in England. The conveying capacity is 2,800 t/h with a conveyor bridge length of 145 m and an elevation of 26 m. Similar systems were built for irrigation projects in Iraq and are also successfully used in South Africa and Canada. A precultivated dump is achieved by the around-the-pit system due to the shuttle conveyor, which is located before the crawler unit on the dump bench, or as a slewing boom behind the travel assembly.

In combined systems for mining solid material, in-pit-crushing has meanwhile been introduced, for instance by Foskor in South Africa for handling phosphate or in Grooteluk for handling overburden with capacities of up to 3,000 t/h (Fig. 8 & 9). It remains to be seen if and when in-pit-crushing will be accepted in continuous open pit mining transportation systems. A novelty in this respect is a bucket wheel designed for a European country in which crushing of the mined material is incorporated directly adjacent to the bucket wheel of the wheel excavator. The continuous mining system transports the overburden and pay minerals continuously to their final destination and thus replaces the dragline, shovel and truck operations in the case of mining unconsolidated materials. In hard rock mining, blasting must take place and the material must be transferred by means of a dragline or shovel into the crusher from where it is fed onto the belt conveyor.

4. Shiftable Conveyor Systems

The shiftable conveyor systems in use today present no problems and achieve a utilization index of 98 %. The lateral movement of the conveyor line is executed by pipe-laying bulldozers whereby shifting is effected at rates of up to 2,000 m²/h and more. The drive and return stations of the conveyor system are moved by dozers, by crawler mechanisms or by hydraulic walking pads, and in the past they were also shifted into position on appropriate rail paths.

Today the elongation of the longitudinal axis of a shiftable belt conveyor no longer presents problems. Three different principles are in use whereby the rear sections of the conveyor line are taken out and placed into the advancing front section of the line.

Without the necessity of splitting the rubber belt the drive and return stations are moved in the direction of advance in the transverse position of the shiftable belt conveyor. Subsequently the additionally required idler sections are fitted in.

A further technique is to use a very long reserve belt loop in the lower belt run which can be paid out in accordance with the advance. Here, however, the longitudinal movement is limited by the length of the reserve belt loop. The extension of a conveyor line by means of new conveyor frames and belts is the method usually used.

As conveyor systems do not require a specially prepared ground level, the expensive construction of truck haulage roads is not necessary. The belt conveyor system must be maintained and held clean with special equipment but ordinary maintenance vehicles fitted with additional equipment can also be used.

In semi-continuous mining systems the overburden and interbedded materials are transported by a conveyor system while coal is transported by trucks. In fully continuous systems the coal can also be transported by separate belt conveyors to its final distination. This, however, involves a

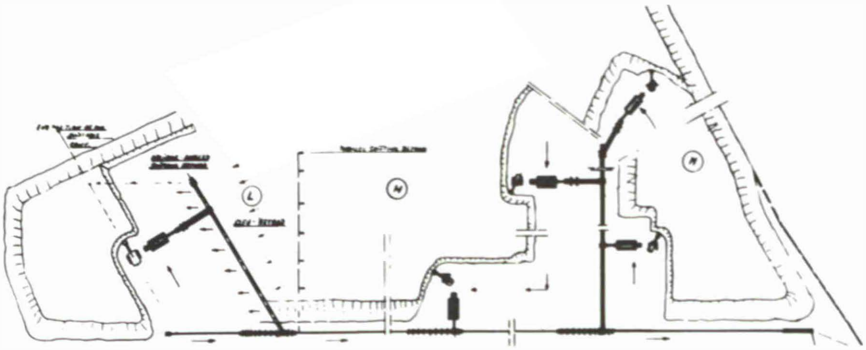


Fig. 8: Mining plan of Foskor Phalabora, South Africa

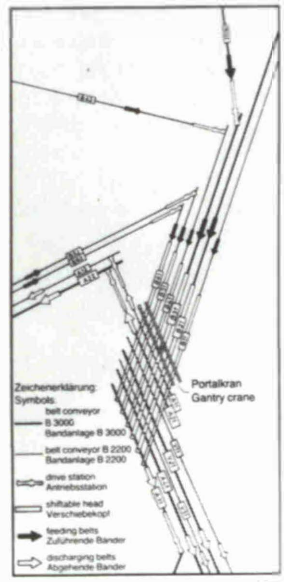


Fig. 10: Conveyor distribution point

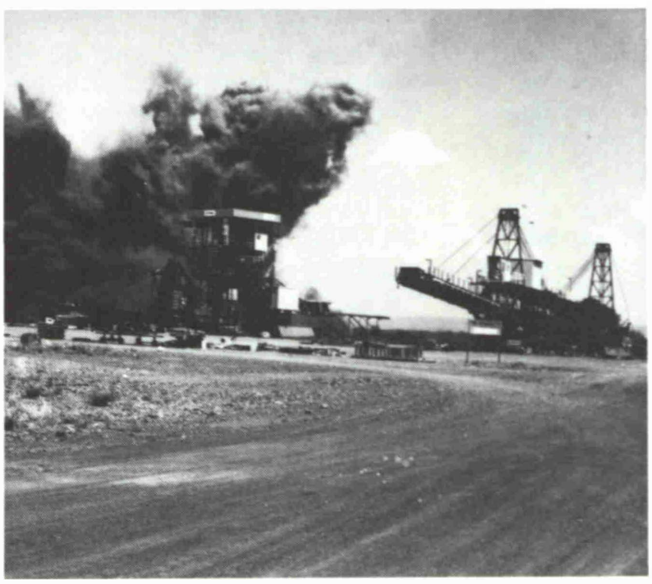


Fig. 9: Blasting, in-pit crushing and conveyor system at Grooteluk South Africa

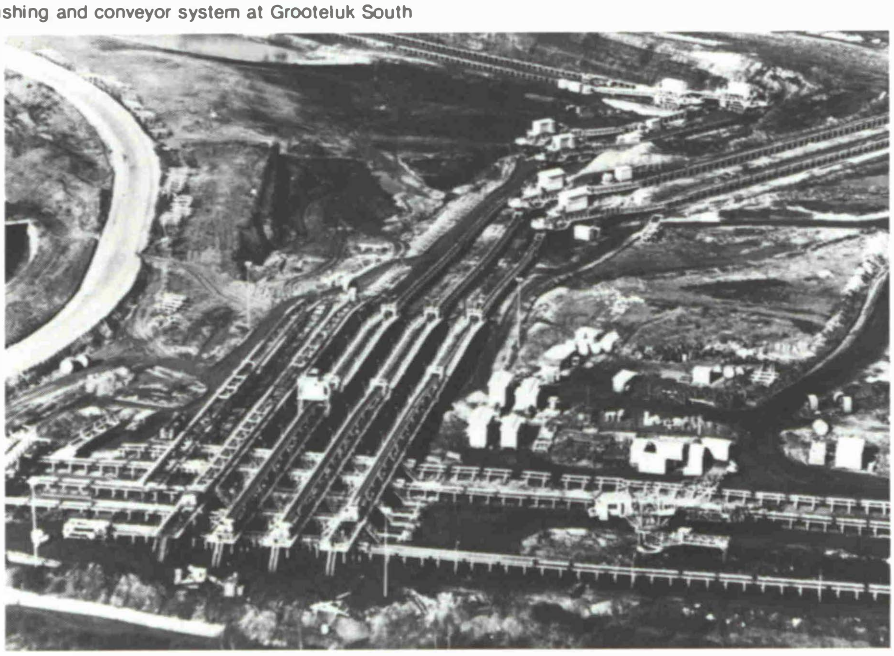


Fig. 11: Conveyor distribution point with extending conveyor heads

high investment and increased operating costs, but results in the highest degree of flexibility. In order to utilize the conveyor systems to an optimum extent and to reduce the investment cost as much as possible, conveyor systems with extensible conveyor heads are built into the system. This allows only one conveyor system to cope with two varying types of material (Figs. 10 & 11). The flow is directed by means of the extending conveyor heads at conveyor distribution points onto subsequent conveyors.

In the following, a few examples of systems designed and built by PWH will be discussed.

5. Captain Mine Conveyor System 1978

The Captain Mine consists of three sub-systems each with a total length of approximately 4.4 km (2.7 miles). Each system includes three shiftable conveyors: one face conveyor, one connecting conveyor and one dump conveyor (Fig. 12). Additionally, two elevating conveyors can be employed in the sub-systems. Each sub-system operates together with one bucket wheel excavator on the digging side and one spreader on the spoil side.

The unconsolidated overburden with depths of up to 12.8 m is mined by bucket wheel excavators. The top soil is transported via a crawler-mounted bandwagon (mobile bridge conveyor) to the hopper car feeding face conveyor A. From here the top soil moves via a conveyor bridge or directly to the connection conveyor C and further on to the spoil conveyor D. On the dump side the material leaves the conveyor via a rail-mounted tripper car with slewable discharge conveyor towards the stacker/spreader unit. The top soil is then positioned on top of the consolidated overburden and recultivation for agricultural purposes in then easily possible.

The consolidated overburden, blasted hard rock, is dumped directly across the pit by the main stripping machine, i.e., the shovel, from the virgin to the spoil side of the pit. The coal is excavated by shovels and transported by 130 ton capacity haulage trucks and by 150 ton coal carriers to Southwestern's 2,800 t/h preparation plant.

The main specifications of the conveyor system are:

Belt width	54 inch (1,400 mm)
Belt speed	950 ft/min (4.8 m/sec)
Design capacity	4,800 loose y³/h (4,400 m³/h)
Max. installed power per conveyor	4 × 400 HP (4 × 300 kW)
Total installed power approx.	12,000 HP (8.8 MW)
Number of conveyor flights	11
Total final length approx.	7.5 miles (12 km)
Troughing of upper belt	35 degrees
Troughing of lower belt	10 degrees
Type of carrying idlers	garland of 3 idlers
Type of return idlers	garland of 2 idlers
Type of impact idlers	garland of 5 idlers
Type of steel cord belt	St 1850—St 825
Cover plate thickness	3/8″—15/64″ (9.5 mm—6 mm)

The main technical data of the conveyor bridge are:

Conveyor length	266 ft (81 m)
Elevation height	60 ft (18 m)
Conveying capacity	4,800 y³/h (4,400 m³/h)
Belt width	54 inch (1,400 mm)
Troughing angle	35 degrees
Belt speed	950 ft/min (4.8 m/sec)
Conveyor drive unit	2 × 300 HP (2 × 220 kW)

The availability of the complete system, from the bucket wheel excavator (BWE) on the digging side to the spreader on the spoil side, is 75 % on a monthly average for the first few months of operation and is bound to increase with the operating crew gaining experience and after the start-up delays are phased out.

The conveyor systems advance in steps of 60 m (200 ft) at an estimated frequency of four to five times per year depending on mining conditions. The shifting process takes 2—3 days at the Captain Mine, and again this time might be reduced with increased experience.

The complete system from the BWE to the spreaders is operated by a crew of 5 and a shift supervisor. Two beltmen control the conveyor system. Electricians and welders are provided from the mine pool when they are needed. There is one master mechanic on the day shift assigned to the complete system.

Daily maintenance of the conveyor system includes cleaning, checking belt cleaners and idlers and this is executed by the beltmen. The oil level in the conveyor drive gears is checked and the belt drive shaft is greased once a week.

Overall, the introduction of the new conveyor system was not completely free of difficulties. At the beginning some specific operational and soil problems were realized and had to be solved.

6. Opencast Mine Most, Czechoslovakia 1979

A new shiftable conveyor belt system with the following main technical data was installed in the lignite open pit mine at Most (Fig. 13).

Total length	8 km (5 miles)
Installed power	23 MW (31,000 HP)
Number of belt conveyors	9
Belt width	2,200 mm (84 inch)
Belt quality	St 2500
Rated conveying capacity	17,000—20,000 t/h
Belt speed	5.2 m/s (1,024 ft/min)

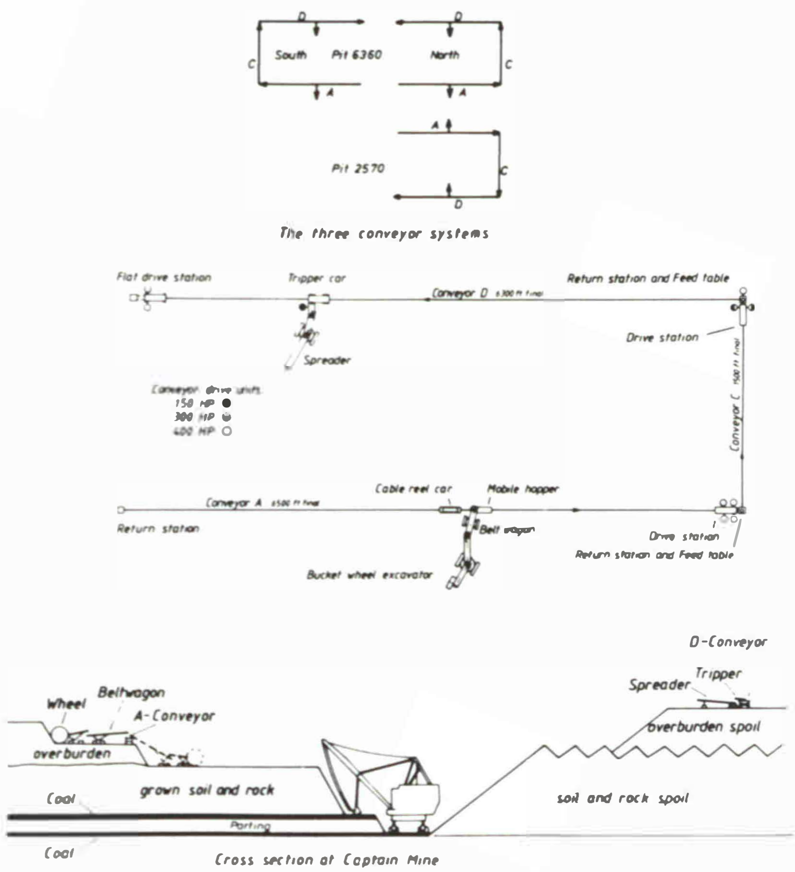
The steadily increasing depth of the overburden from initially 60—70 m (190—230 ft) to finally 200 m (660 ft) led to the installation of a conveyor system between the excavators and the spreaders for handling overburden, in 1978. The overburden above the coal is stripped and transported to an inner dump behind the coal seams. This system is now in operation since January 1981 and has fulfilled all expectations in respect of efficiency and utilization factor. Belt conveyors achieved utilization factors of 94 % of the available shift periods.

The computer-controlled central monitoring system switches all operating sequences when required. Defects and downtimes are automatically recorded, mathematically evaluated and compared with previously determined criteria so that written reports are not necessary any longer.

7. Goonyella Mine, Australia, 1980

One of the most important high-quality coking coal deposits in the world is located in the Bowin Basin in Queensland, Australia and is exploited by Utah Development Company (UDC) in the Goonyella Mine and by three other opencast mines.

Fig. 12: Mining plan with conveyor system at Captain Mine, Illinois, USA



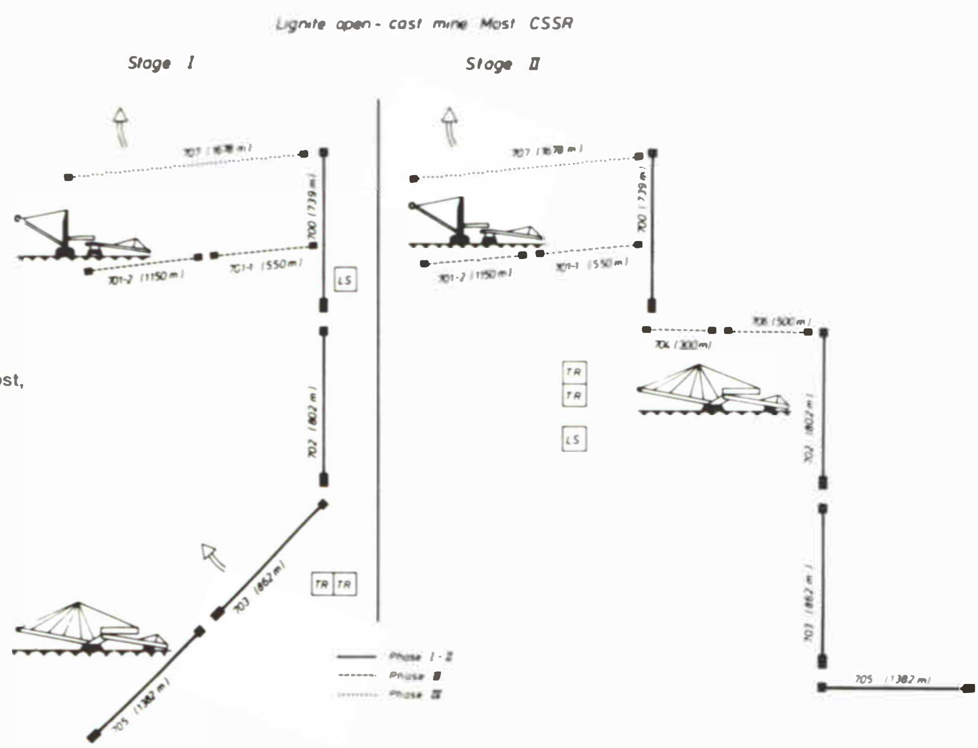


Fig. 13: Lignite open pit mine at Most, Czechoslovakia

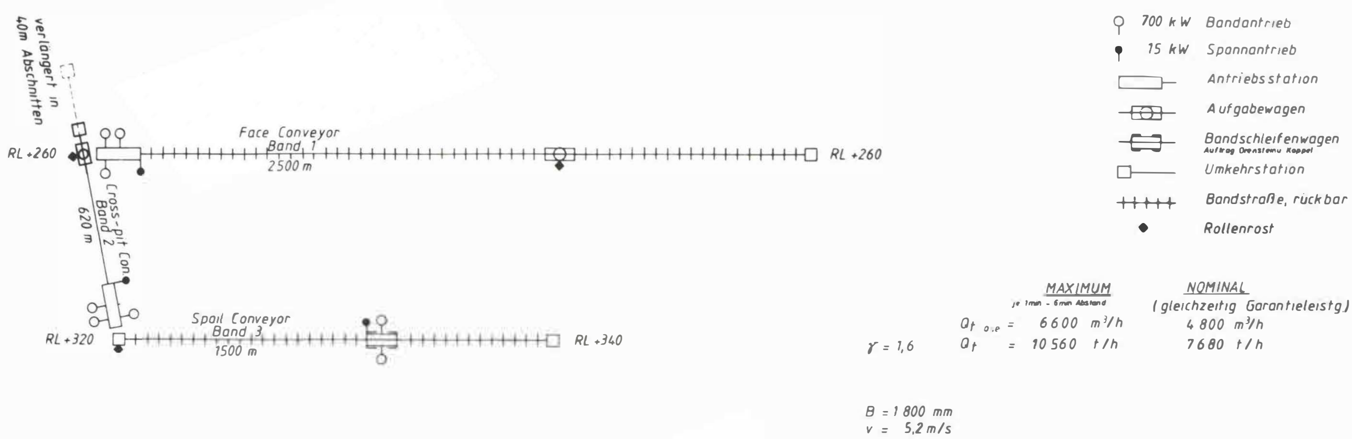


Fig. 14: Conveyor system at Goonyella Mine, Queensland, Australia

In the Goonyella Mine, the traditional American strip mining method with dragline operation for overburden removal and face shovels and truck haulage for coal extraction is used. Due to the increasing depth of the coal seam, however, the overburden cannot be handled by the dragline in a one-bench operation. Various operating alternatives for overburden removal were considered and evaluated econometrically as well as technically. The outcome of these investigations led to the decision to use a mining system with bucket wheel excavator, shiftable conveyors and spreader to mine the top bench of overburden with a thickness of up to 36 m (120 ft).

PWH supplied the conveyor system which must be capable of carrying blasted material with lumps of up to 500 mm (20 inch) diameter and a mass of 300 kg but also extremely moist and sticky material, (Fig. 14). This equipment consisted of:

2 hopper cars

1 bench conveyor; 2,400 m long; 1,800 mm wide; St 2200

1 transverse conveyor; initially 620 m long and in the final stage 1,200 m long; with 102 m lift; width 1,800 mm; St 4000

1 dump conveyor; 1,500 m long; 1,800 mm wide; St 2200.

The entire system is shiftable with hydraulic walking mechanisms for the 300 t drive head stations and a "shiftable head" installed on a crawler tractor to shift the conveyor. Transfer points are equipped with roller grates to protect the belt and impact idlers when blasted material is conveyed. The transverse conveyor has a reserve belt loop 80 m to permit simple extension.

The main technical data are:

Capacity:	7,680 t/h (average) and 10,560 t/h (maximum) with a belt speed of 5.2 m/sec 2,000 t/h with a belt speed of 2.6 m/sec creep speed for inspection purposes 1 m/sec
Drives:	700/350 kW (950/475HP) at 1,500/750 rpm
Idlers:	3-roll carrying garland idlers, 45 degree troughing 2-roll return garland idlers, 15 degree troughing

The design was based on the following data: Calculated expected lifetime: 5,000 hours/year for 20 years. The ambient temperature was assumed to be 45°C; a maximum wind velocity of 200 km/h (124 miles/h) was used. Several cold starts were carried out successfully and the system was taken into operation in late 1981.

8. Outlook for the Future

The above mentioned PWH installations illustrate the different structure and philosophy which are inherent to the continuous mining system. While previously short term planning was performed for the truck, shovel/dragline system with the basic thinking of "... this mine has coal deposits for x number of years at a certain output, let's mine it with a dragline or shovel and several trucks...", the planning periods for continuous mining systems continue to extend and modern electronic data processing equipment will be used for planning and evaluating the economic feasibility of various alternatives. These procedures will also be used in the future to continuously monitor and compare operating data of conveyor systems, bucket wheel excavators, crawler-mounted bridge conveyors, mobile inclined conveyors and spreaders etc, as well as compact mining machines with integrated crushers and such equipment which can be powered via trailing cables and by electric motors instead of diesel-mechanical or diesel-electric means.

Fig. 15 shows the open pit mine of the future. At the focus of this system is the continuous miner which is capable of mining the hardest coal layers with depths ranging from a few centimeters to up to 4 meters.

With this machine one has worked on the assumption that proven underground mining machines with capacities of up to 1,200 t/h can also be used in open pit mining, where the limited space of underground mining is of no consequence. Machines with capacities of 2,000 t/h and a deadweight of about 200 t are conceivable. After modification of the mining method, such a machine will prove successful once it has completed its trials. The machine is designed to be able to load trucks and conveyor belts and is capable of handling fine grained material (Fig. 16).

Summing up, one can observe that many open pit mines, especially in North America, the majority of which operate with truck/shovel or truck/dragline configurations, will for economic reasons switch over steadily to the combined conveyor-truck-shovel-dragline or conveyor-bucket wheel excavator — truck — dragline configuration to achieve an automated fully continuous mining operation with the cross-pit method in unconsolidated overburden formations.

In the field of open pit hard rock mining, a semi-continuous operation with conveyor systems, conveyor distributor stations and extending conveyor heads, continuous miners and trucks as well as shovel/dragline plus in-pit crushers

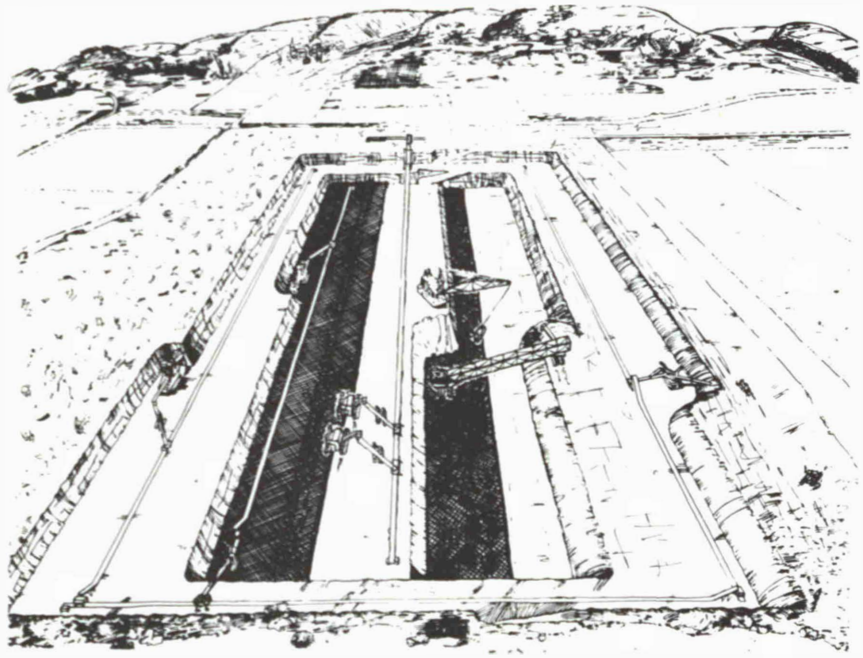


Fig. 15: Open pit mining system of the future

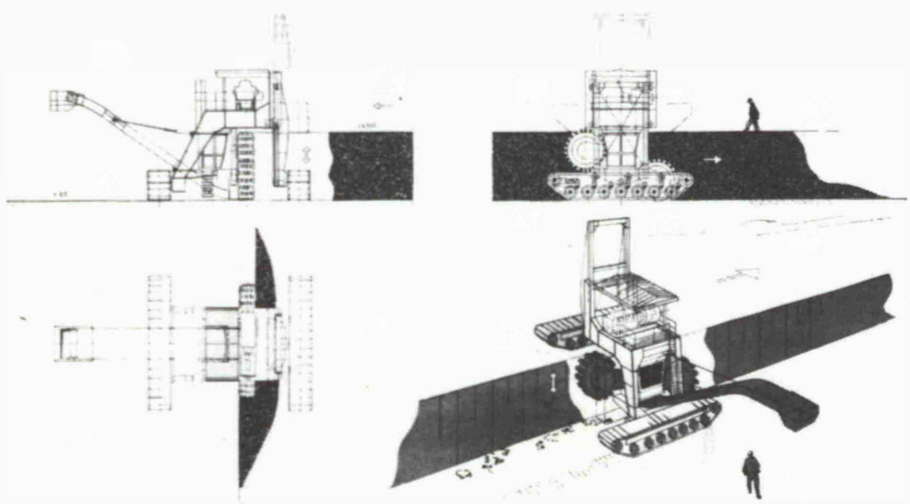


Fig. 16: Open pit continuous coal miner of the future

and mobile conveyor bridges/steep conveyor configurations will become an established practice.

For these types of open pit mining systems, project design and routine operation with respect to short, medium and long-term planning, control, monitoring and the acquisition of working stock-data as well as machine assignment schedules will be taken over to an increasing degree by main computer centers.

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