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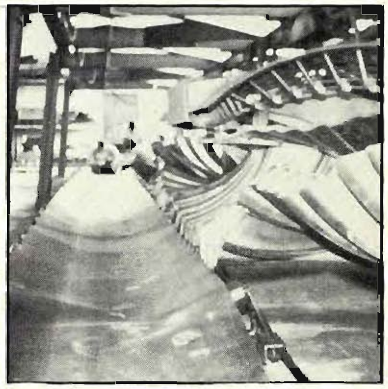

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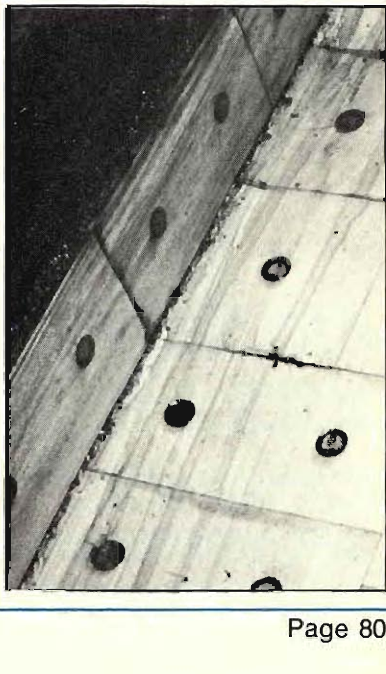

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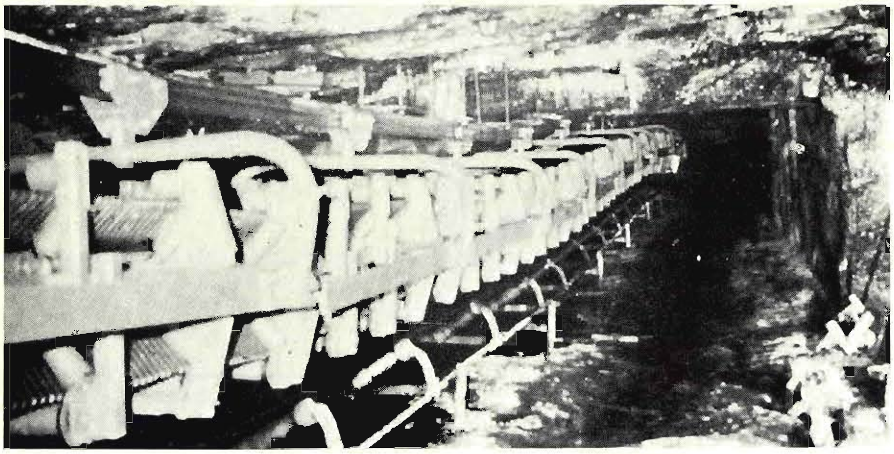

Joy Manufacturing Co.'s Flexible Conveyor Train, shown underground at a Laurel Run mine.

Breaking Bottlenecks at the Face With Continuous Haulage

William D. Mayercheck

Introduction of continuous mining machines in the late 1940s created a new production bottleneck in room-and-pillar sections—the shuttle car. While continuous miners could cut and load coal at a nearly constant rate, the mining sequence was repeatedly interrupted as fully loaded shuttle cars changed places with empty ones. This wait-for-the-shuttle delay period forced the coal industry to reassess the shuttle's batch-type procedure with an eye toward continuous haulage systems that would allow uninterrupted coal flow from face to portal.

In 1976 a total of 7666 shuttle cars transported most of the 168 million tons (186 million st) of coal cut by 2366 continuous mining machines. Only 5.1%, or 8.6 million tons (9.5 million st), of this coal was transported from the miner to outby haulage via a continuous haulage system.[1]

Recent studies have shown that nearly 25% of the continuous miner cycle time is consumed by delays in the haulage system, usually waiting for shuttle cars. Computer simulations of a face operation indicate that up to a 45% increase in coal production may be realized with a continuous haulage system, assuming that the outby haulage system can handle this increased tonnage.

Coincidently, some mines using continuous face haulage claim a 50% production increase over shuttle car haulage.[2] One mine operator has reported section productivity of up to 91 tons (100 st) per face per man via continuous haulage.[3] These documented production records and computer simulations, along with common sense, indicate the potential of continuous face haulage in room-and-pillar coal mining.

The late 1960s and early 1970s saw several mining machinery manufacturers introduce mobile bridge carrier/piggyback bridge conveyor types of continuous haulage systems for underground coal mines. These systems have shown limited potential in some operations and outstanding success in others. Since it appears that no one type of system is universally applicable to all underground mining conditions, the US Bureau of Mines in 1975 began a long term effort to investigate continuous haulage concepts that would provide operating alternatives in various coal mining conditions. Following creation of the Department of Energy, this program work was transferred from the Bureau to DOE in October 1977.

Besides the large R&D effort devoted to hydraulic pipeline transport of coal underground, DOE has funded numerous other continuous haulage projects in both room-and-pillar and shortwall mining plans. This article will focus on those developments that are most topical or have progressed to a hardware stage.

Continuous Face Haulage Study

A *Study of Continuous Face Haulage Systems* report was completed under government funding by Joy Manufacturing Co. in December 1975.[4] At that time the most promising continuous face haulage systems were the bridge carrier/piggyback bridge conveyor, such as Joy's Flexible Conveyor Train, and the flexible conveyor belt systems, such as those manufactured by Serpentix. Hydraulic conveyor systems had high potential, but on a longer term basis.

Since then, however, other system concepts have been generated by DOE and private industry. Such work supports the study's conclusion that increased use of continuous haulage in underground coal mines is contingent on the availability of several types of systems to cover the wide range of mining conditions encountered.

Flexible Conveyor Train

The roof-mounted Flexible Conveyor Train (FCT) developed by Joy Manufacturing Co. was installed underground with USBM funding at a Laurel Run Mining Co.

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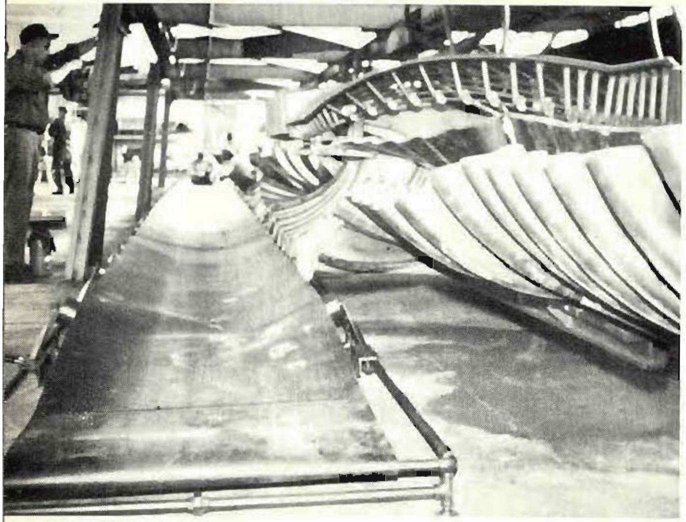


The Sideloader developed by Joy uses a roof-mounted monorail for continuous haulage in seam thicknesses of 1220 mm and more.

mine in April 1977. It was patterned after an earlier version that was rubber tired and maneuvered on the mine bottom. Overall length of the FCT is 125 m (410 ft), plus a 9.1-m (30-ft) bridge conveyor. The inby end of the latter is attached with two chains to the miner tailboom. The FCT is suspended from a 127-mm (5-in.), 4.5-kg (10-lb) I-beam monorail which is attached with roof bolts over the panel belt and extended into the entry. The entire FCT is self-propelled by multiple traction-drive units on the monorail, referred to as "mules." The outby portion of the FCT, which discharges onto a panel belt, requires an entry height of 2030 mm (80 in.).

Calculations indicate that this roof-mounted Serpentine flexible belt can handle 545 t/h (600 stph) while negotiating several non-90° pillar corners at a minimum turning radius of 9.1 m (30 ft).

Conditions worsened as mining advanced in the eleventh butt, three-entry development section of the Laurel Run mine. Up to several feet of water on the mine bottom and a top weakened by a local fault zone largely precluded testing the FCT's overall potential. Shuttle car haulage under these conditions, however, would be extremely difficult.

A monorail gradient of 6½% encountered toward the end of the underground trial period created tractive problems in moving the system inby/outby. Average production prior to the demonstration with shuttle cars was 234 tons (258 st) per shift. Using the FCT, production in the same mine section averaged 110 tons (122 st) per shift, while the projected FCT results were estimated to be 550 tons (606 st) per shift. Adverse mining conditions in the fault zone area contributed largely to the difference in projected shift tonnage. The FCT was removed from the mine in November 1978.

System designers concluded that the FCT needs additional testing to establish an effective operating cycle, determine Serpentine belt life, and evaluate the tractive effort required.[3]

Sideloader

The Sideloader concept developed by Joy Manufacturing Co. uses a roof-mounted monorail for continuous haulage in seam thicknesses of 1220 mm (48 in.) and more. With USBM funding, Joy is assembling components and will later test the Sideloader concept in a low coal seam. A version of this design was exhibited by Joy at the 1976 AMC Coal Show in Detroit.

Several design modifications have since been made to this unit. General specifications include a conveyor length of up to 122 m (400 ft), conveyor capacity of 6.8 t/min (7.5 st per min), 0.9-m-long (3-ft) conveyor pans, conveyor speed of about 122 m/min (400 fpm), and a minimum operating seam height of 1220 mm (48 in.). Multiple traction mules will power the Sideloader system on the roof-mounted monorail.

Shortwall Face Conveyor

To expedite shortwall mining, a contract was awarded to Joy Manufacturing Co. to build and test an armored face conveyor in a shortwall panel, using some of the proven technology from longwall mining. Joy's shortwall face conveyor was installed in August 1976 at a 45.7-m-wide (150-ft) face in the Valley Camp No. 3 mine. After encountering some adverse seam and top conditions, the face conveyor was removed from the mine in October 1976 for equipment modification.

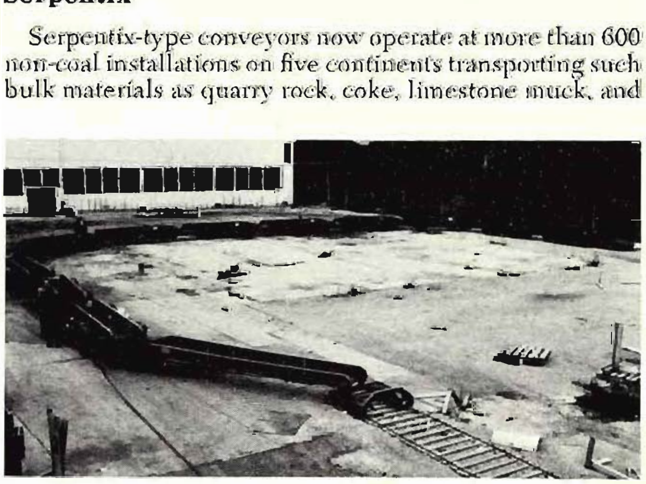
Maximum shortwall production using this conveyor set a mine section record of 567 tons (625 st) in one shift, and demonstrated the potential of continuous haulage in shortwall mining. However, the average shift production using this conveyor was about 25% less than that using shuttle car haulage.

This system utilized a face conveyor—instead of the conventional spillplate—and a mobile transfer conveyor mounted on roof-hung monorail. The face conveyor was placed between the chocks and the continuous miner along the entire length of the shortwall face. It was connected to the chocks and advanced by the ram cylinders in the same way that a spillplate is advanced.

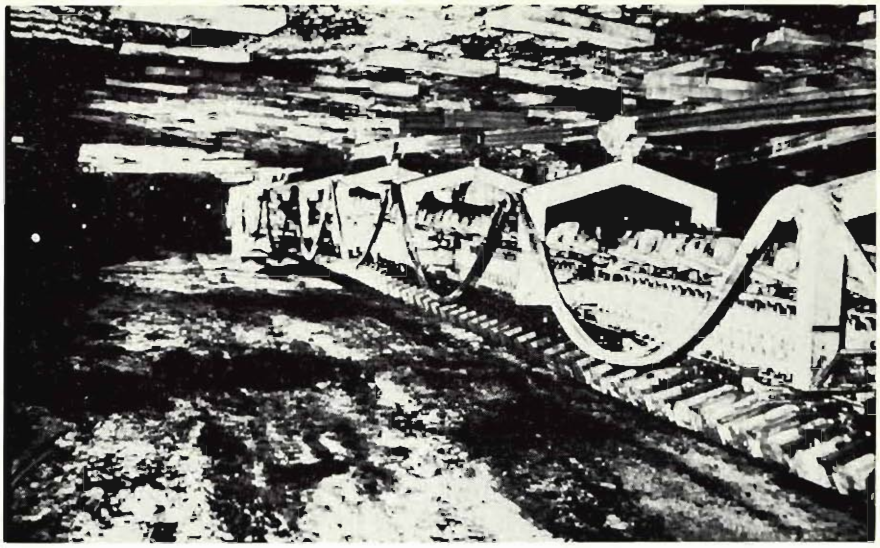
The 711-mm-wide (28-in.) shortwall face conveyor used a single-strand, articulated conveyor chain similar to the type on loading machines and continuous miners. Chain link on both the face and the gob sides connected the individual 2590-mm-long (102-in.) pans to provide the required flexibility when the pans were pushed forward. Each pan was connected to two chocks by the ram cylinders. The face conveyor was powered with a 93-kW (125-hp) drive and had a chain speed of about 61 m/min (200 fpm).

Serpentix

Serpentix-type conveyors now operate at more than 600 non-coal installations on five continents transporting such bulk materials as quarry rock, coke, limestone muck, and



Preliminary surface testing of Jeffrey's MUCH system for coal transport.



The Serpentix conveyor is mounted to the mine roof with monorall and pulled by an inby surge car.

sludge cake. There have been hundreds of Serpentix-type installations in Europe, although these are permanently floor-mounted types.[6]

Serpentix Conveyor Corp., Joy Manufacturing Co., and Peabody Coal Co. introduced this type of conveyance into underground coal mining by initially installing one each at three of Peabody's mines. The Serpentix is mounted to the mine roof with monorail and pulled by an inby surge car. It bends around non-90° pillar corners with a minimum turning radius of 4.6 m (15 ft) to carry the coal away as it is cut by a continuous miner. Numerous design changes have been made to optimize the operation of the Serpentix haulage system for underground coal mines since the first installation in 1973.

The Serpentix "belt" is corrugated to permit expansion and contraction as the vertebrae assembly bends around curves. Accordian-type steel-reinforced rubber pans—up to 1020 mm (40 in.) wide and 250 mm (10 in.) long—are bolted together to make an endless flexible belt that is fastened to a tensioned chain and driven by a sprocket drive. From the outby end of the Serpentix, coal is transported via a short cross conveyor belt. Due to the height of the feed end and tension station, a coal seam must be at least 1880 mm (74 in.) thick to allow the Serpentix room to operate.

With DOE funding, Peabody Coal is collecting operating and maintenance data and evaluating the Serpentix conveying system for use as a continuous face haulage system in underground coal mines. Peabody is also conducting a concept review of a continuous haulage system in which the Serpentix is suspended underneath chocks in a shortwall mining plan.[7]

MUCH System

Under a DOE contract, Jeffrey Mining Machinery Division of Dresser Industries has designed and built a multiple-unit continuous haulage (MUCH) system for coal transport. An artist's rendition of the MUCH system in a mine section and the fabricated system during preliminary surface testing are shown in the accompanying photographs. The system is patterned somewhat after the Moleveyer which was originally built and tested in the early 1950s.

The MUCH system consists of a redesigned train of self-powered lead, intermediate, and discharge vehicles. Coal cascades from the inby to the outby end of each vehicle via chain conveyors. An operator in the lead vehicle of the train keeps the system behind the continuous miner, while a special linkage between the vehicles is designed to permit the entire train of vehicles to track after one another.

The MUCH system was built by Jeffrey and first surface tested in September 1977. Some redesign and surface testing are still necessary to refine the self-tracking ability of the vehicles. A mine site is being sought to eventually test this system underground in either a continuous or shortwall section.

Some of the MUCH system specifications include a coal carrying capacity of 10.9 t/min (12 st per min); conveyor chain speed of 85 m/min (280 fpm); vehicle tram speed of 24 m/min (80 fpm); and a system overall height of 1 m (39 in.). The existing 12-unit train is about 76 m (250 ft) in total length and can negotiate a minimum inside turn radius of 3.35 m (11 ft).

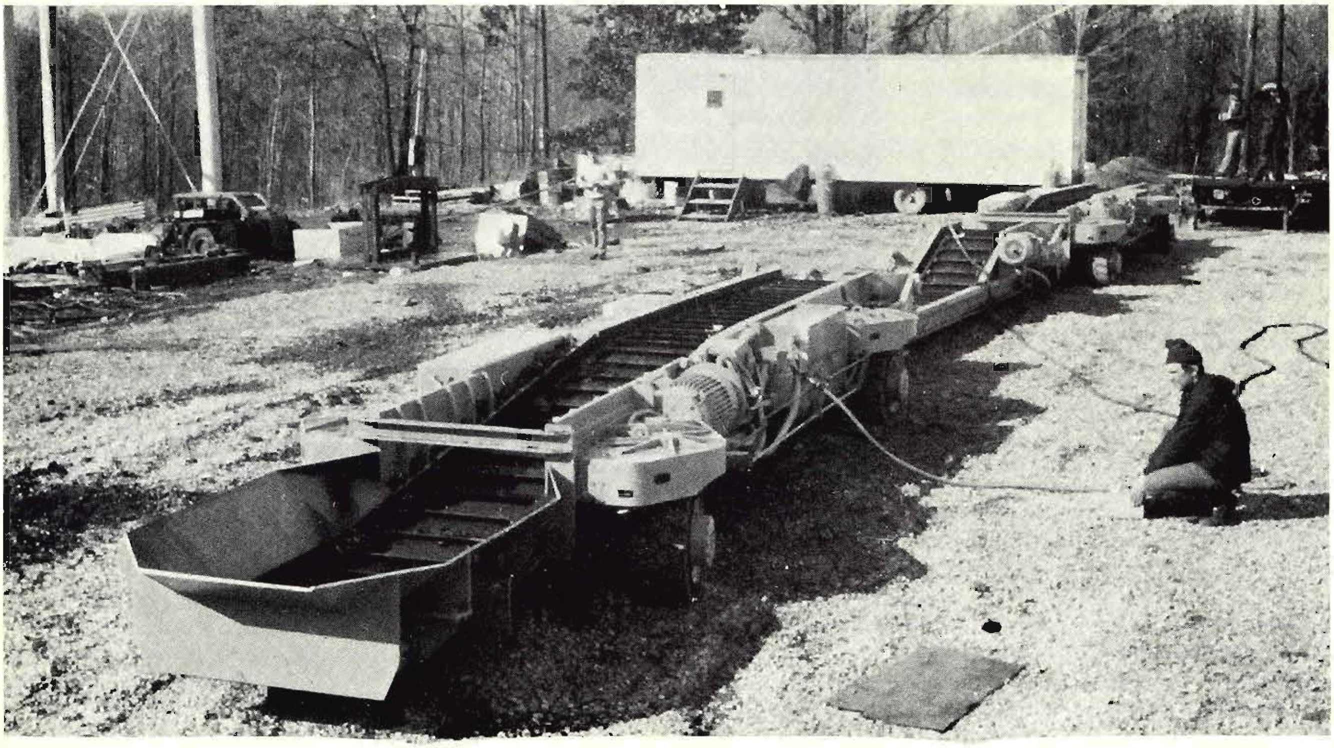
ABCT

The Auto-Track Bridge Conveyor Train (ABCT) was designed under a DOE contract by Foster-Miller Associates, with Long Airdox as subcontractor for fabrication and Lee Engineering as consultant to the project. The first two pairs of units built by Long Airdox have undergone preliminary surface testing at Oak Hill, W. Va. This system features a series of special rubber-tired mobile bridge carriers and chain bridge conveyors that are guided automatically with a 5 kHz signal emitting cable. The inby mobile bridge carrier lays down a signal emitting cable, and sensors on each carrier in the train follow the cable down entries and through 90° crosscuts by sending appropriate steering signals to the wheel units. Thus, a train of ABCT units up to 152 m (500 ft) long may be automatically guided inby and outby to follow a continuous miner.

The system is designed to carry up to 10.9 t/min (12 st per min) of coal with a conveyor chain speed of 91 m/min (300 fpm). Mining plans for the ABCT call for a minimum of 4.9-m-wide (16-ft) entries on 18.3-m (60-ft) centers, 90° crosscuts, and 1270 mm (50 in.) coal seam height.

Monorail Bridge Conveyor

The concept of a series of roof-hung monorail cascading belt bridges has been pursued since 1975 by USBM and



A three-element set Auto-Track Bridge Conveyor Train (ABCT) undergoes preliminary surface testing at Oak Hill, W.Va.

now by DOE for application as a continuous haulage system in low coal seams. Goodman Equipment Co. was awarded a cost-sharing development contract by DOE in September 1978 to improve upon the DOE design concept, fabricate a prototype system, and ultimately test it for performance in an underground mine section. Studies show that this generic type of monorail-hung haulage system has significant production advantages and can be cost-effective when compared to traditional shuttle car haulage.

The monorail bridge conveyor (MBC) concept consists of a series of cascading belt conveyors that travel beneath special mine roof-mounted monorail. Individual belt conveyors are utilized in the design for system reliability, ease of maintenance, and low noise level. A special transfer point design will direct up to 5.4 t/min (6 st per min) of cascading material onto outby belt conveyors to minimize coal spillage. System suspension from monorail trackage will eliminate guidance and tracking problems associated with mine-bottom-type haulage systems. Standard low-cost conveyor belting will be employed in the design in lieu of special belting that is steel reinforced or of unusual cross section. This system should be able to operate in coal seam thicknesses of 1220 mm (48 in.) or more.

Hopper-Feeder-Spillage Cleaner

In recent years, operational experience with continuous haulage systems has uncovered the need to develop a proper interface between the continuous mining machine and any type of continuous face haulage. A separate vehicle located between the continuous miner and an outby continuous haulage system would fulfill this need. The interface vehicle could receive coal directly from the miner, level coal surges via a hopper with feeder, feed coal from the hopper to a breaker, break oversize lumps, clean up coal spillage left by the miner, and provide tractive capability if needed to move the outby continuous haulage system.

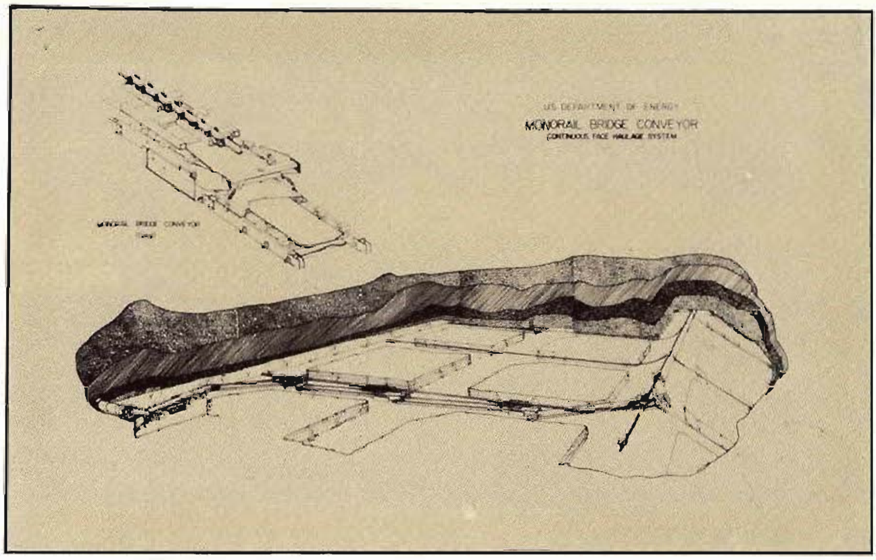
If roof-bolting capability can be added to this interface vehicle, the room-and-pillar mining plan could be modified to a reduced place changing system where mine roof conditions are favorable. This type of vehicle concept has been comprehensively evaluated by FMC Corp. under DOE funding and revealed potential coal production increases from 12.7% to 32.4%.[8] Economic analysis of the concept using Pennsylvania State University's UGMHS computer simulator indicated that the machine cost payback period would be less than one year.

Production Increases With Continuous Haulage

The accompanying table provides a scenario of possible production increases in room-and-pillar continuous coal

Potential Production Increases in Room-and-Pillar Mining

Mining plan	Average shift tonnage
Base Case I Basic mining cycle and cut sequence using shuttle cars. Assume 6.1-m-deep (20-ft) cuts before place changing, five-entry section, two-pass mining plan, 32 cuts per mining cycle.	x
Case II Using continuous face haulage. Assume same cut sequence and mining cycle as for Case I (50% potential increase over Case I).	1.5x
Case III Using continuous face haulage in a reduced place changing system, e.g., mining break-to-break. Assume roof-bolting capability on continuous miner or outby interface vehicle, nine cuts per mining cycle (32.4% potential increase over Case II).	2x



Artist's rendition of the monorail bridge conveyor concept—a series of cascading belt conveyors that travel beneath special mine roof-mounted monorail.

mining using specific equipment and/or mining methods. Case III suggests that the use of continuous haulage in a reduced place changing mining plan could almost double shift production in low- to mid-height coal mines. The impact of continuous haulage in high coal seams appears to be less dramatic, since large shuttle cars may operate with larger payloads per cycle.

Outlook

A recent DOE study revealed that 58% of all US underground coal mined in 1976 came from seams measuring 1520 mm (60 in.) or less in thickness. The trend toward mining thinner underground coal seams lends itself to the use of continuous haulage, since shuttle car haulage in these lower seams becomes a less attractive alternative both from a safety and a productivity viewpoint.

In 1976 about 5.1% of all underground coal cut by continuous mining machines was transported by some type of continuous haulage system. In 1977 sales of continuous face haulage systems amounted to $5.5 million.[9] These figures are likely to increase markedly in the years ahead once coal mine operators appreciate the production and safety advantages of continuous haulage and are willing to adopt slightly different mining plans to accommodate it. Although no single system has universal application to optimization of coal production at the face, each proven system will have a place in the varying conditions that exist in underground coal mining. The best continuous haulage system selected by present and future mine management will be the one with the most advantages and fewest drawbacks in a mine engineered for its use under the prevailing geological conditions. □

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