# Efficient Mining of High Seams with Automated LTCC Operations

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# Abstract

Longwall mining is an expensive undertaking – from the preparation of the site to capital investment in the equipment. That is why longwall owners have high performance expectations, especially in tough economic times when commodity prices are low. One of the ways longwall mines achieve or exceed their owners' expectations is through the use of high efficient Longwall Top Coal Caving (LTCC) technology production, in combination with the extensive use of automation. LTCC remains a seldom used method for mining high seams efficiently and ecologically with sustainable use of deposits. If this mining methodology is used in combination with the advantages of automated longwalls, these technologies enable longwall mines to use the deposits in the most efficient and sustainable way possible, which reduces operational costs, improves profitability and boosts efficiency.

# Introduction

Today's longwall mines are safer, more productive and more efficient than ever before. Over the years, longwall machinery has grown more complex, forcing manufacturers to optimize interaction between systems and machines such as roof supports, conveyors, beam stage loaders and shearers.

In the past decade, these systems became even more complex with the professional introduction and extended usage of the Longwall Top Coal Caving technology (LTCC). In combination with traditional longwall technologies (Figure 1), these systems also significantly increase productivity by mining more coal in a given lease area.

# The principle of top coal caving technology

LTCC is a special type of longwall mining used in very thick seams, typically bigger than 6 m. In these geological conditions, the resource coal is often left unmined because conventionally used equipment cannot operate successfully beyond 6 m mining height. This may cause further geological problems later on in the mining process and also result in an extremely inefficient and nonecological treatment of natural resources.

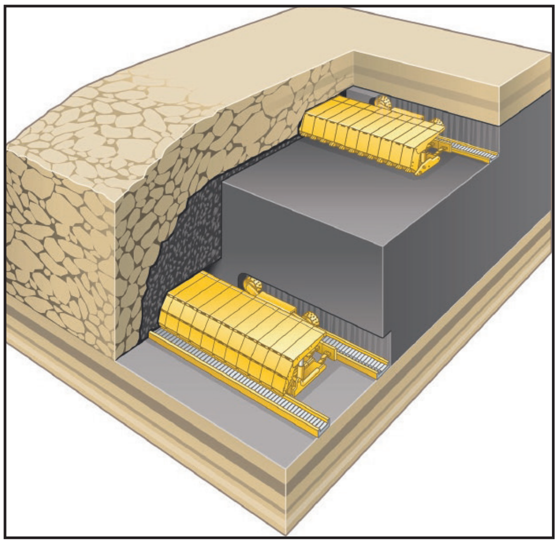

*Fig. 1. Multilevel Longwall Top Coal Caving (LTCC)*

There are also longwall systems available for large seam areas, mainly from the Chinese market, operating at cutting heights of up to 7.5 to 8 m (Figure 2). However, these systems offer some major disadvantages. The 7 to 8 m roof supports reach an extremely high weight, are difficult to handle in underground transportation and may cause ground damage during operation. The large equipment size also increases the investment cost and offers less flexibility in lower seams or varying geological conditions. All auxiliary equipment of the longwall system typically needs to grow with the size of the face. This results in the use of extremely large leg cylinders, which further require larger pump stations. The cutting height can only be supported by a relating immersive cutting machine that is able to mine the full cutting height in one cut, without any other additional mining equipment. Furthermore, the extreme face height causes an added risk for miners at the face who must work at a dangerous height to access all equipment areas in the operation, such as the canopy. Due to the extreme seam front size and height, the possible risk of roof falls and collapsing face must also be handled proactively, resulting in the need for additional preventive equipment, such as chain curtains or other guards. This makes the entire operation more complex and costly.

*Fig. 2. 8 m roof support at China Coal Show*

All of these problems could be eliminated by using LTCC equipment, which is based on normal, manageable equipment size for underground longwall operations and can be used in more common seam heights without significant changes or investment.

Top Coal Caving uses the natural forces of gravity to aid mining the coal above the roof supports.


*Fig. 3. Cat Longwall Top Coal Caving Equipment*

LTCC systems are based on a conventional longwall system setup with roof supports, AFC, BSL for material handling and shearer as mining machine. The roof supports have an extended rear canopy with sliding functions and caving doors, which are situated behind the base into the gob. A second AFC is attached to the rear of roof supports – running directly below the canopy openings. This AFC feeds into the main BSL at the main gate side of the longwall, so that both material flows are merged before conveyed into the crusher and further onto the mine belt systems. Caterpillar considers LTCC systems to have two mining machines, the shearer and the automated operated caving doors set (Figure 3).

These are the typical sequences of LTCC operation:

- The lower section of the seam is cut by the shearer at a set height.
- New roof in front of the canopy is supported by flipper and or sliding canopies.
- The front AFC transports the coal out of the face.
- Conventionally the system moves towards the next web cut.
- The coal left in the above section cut by the machine is induced to cave.
- The coal falls onto the rear canopies.
- The sliding rear canopies are sequentially opened.
- The coal falls through onto the rear mounted AFC conveyor.
- The rear canopies are opened and closed in a controlled manner to ensure the conveyor is loaded efficiently and to prevent stone from being taken out when all coal has been recovered.
- The rear AFC transports the coal out of the face.
- The rear conveyor is pulled towards the roof supports.
- Final cavity will fill with caved stone as the stone is drawn out (“the gob”).

The beam stage loader at the main gate is extended beyond the face conveyor to enable the rear mounted conveyor to discharge coal directly onto it and carry the coal to the belt conveyor system.

In this type of LTCC longwall, the shearer continues to play a key role. As the basic cutting machine, it dictates the rhythm of production and face advance. If the shearer is operated at productivity, all other longwall subsystems must follow in an efficient manner. Unlike conventional longwalls, the caving operation may cause the shearer to wait until the upper seam section is mined out sufficiently. This results in a higher level automation strategy, and the mining rhythm may need to be adjusted by the automation system of the whole LTCC longwall.

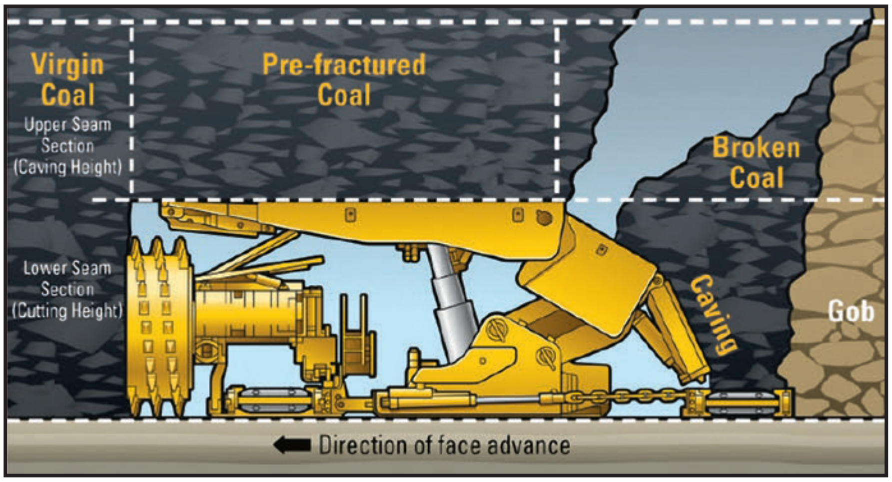


*Fig. 4. Cat LTCC system*

While the shearer is mining the lower seam section at his nominal or adjusted cutting height, the upper seam section remains until the roof support continues to support this area (Figure 4). The movement of equipment and changed load during the advance cycles prefractures the coal in this area. Once the canopy is preceded, the coal starts to break and is prepared for the caving process (2).

Typical cutting heights in LTCC operations are 2.5 to 4 m. In contrast, typical caving heights are in the range of 2.5 to 8 m in some operations. Cat customers do not currently have experience in these higher caving heights, but more meters may be possible after a geological expert investigation. Today mines equipped with Cat equipment are used in seam heights of 5 to 12 m.

# Technical specialities for LTCC coal clearance

As mentioned, three conveyors are used in material handling in an LTCC operation. While the known front face conveyor (front AFC) uses conventional overhead discharge, the rear caving conveyor (rear AFC) uses overhead or alternative crossframe discharge. Before both material flows are mined conventionally and caved, they run through the shared crusher and are fed further onto the mine's belt system (Figure 5).

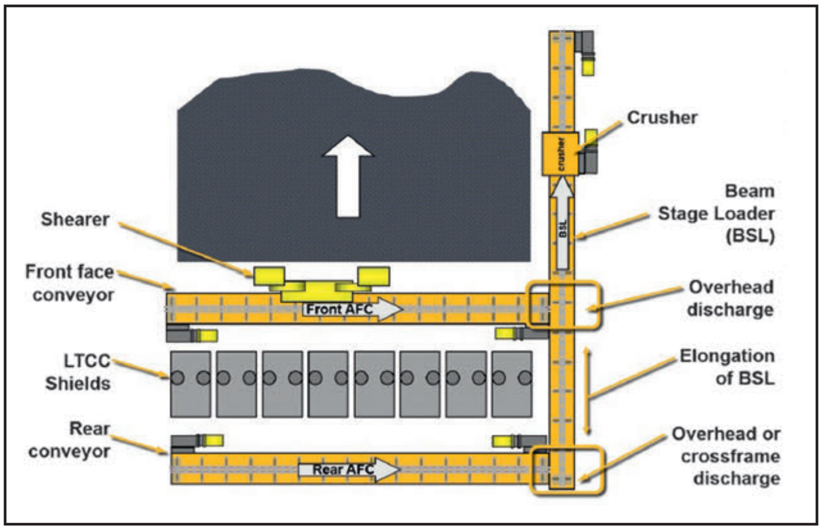


*Fig. 5. LTCC coal clearance system – top view*

Since all equipment in operation must be covered sufficiently by stable and reliable shelter, gob shield extensions are used to cover the drive systems of the rear conveyor. To reduce the design effort for this shelter, a minimum width of the drive equipment is beneficial. In order to prevent parallel positioning of gearbox and conveyor end frame, a specific gearbox has been developed and brought successfully into operation that enables the mine to position the gearbox and motor assembly in line with the rear conveyor (Figure 6). This intermediate gear, called Z65, allows operation of the conveyor with a KP 65 at the conveyor's upstream side, while full CST 65 power and torque rating is applicable (Continuous power at 1,500 rpm: 1200 kW and max. torque: 650.000 kNm).

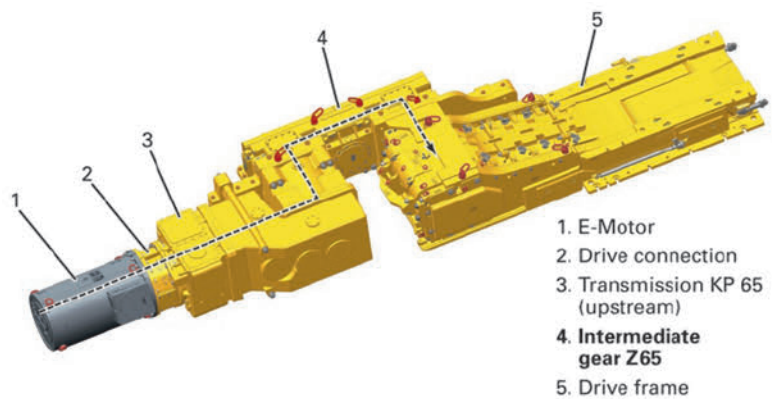


*Fig. 6. LTCC specific drive design for rear AFC prevents drive system from being too extended in the gob*

# Multi-level LTCC operation

In extremly high seams, such as 12 m and above, a "Multi-Level LTCC"-operation may be used. This mining procedure starts with a conventional longwall operation on the top level of the seam just beneath the rock roof. Here a defined undercut is made. Such a cut would typically be 2.5 to 3 m in height and would not impact the lower area. Finally, it follows the usage of LTCC operations in the lower layer (Figure 7). After this operation, the full seam height is mined out or another LTCC operation may follow in a third level.

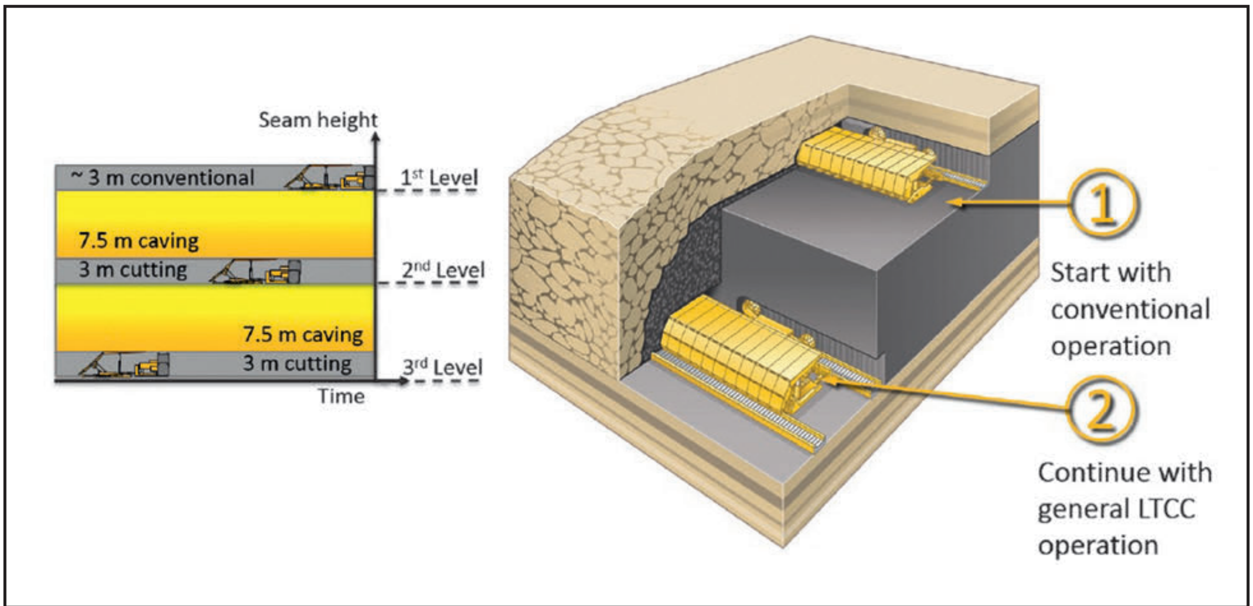


*Fig. 7. Multi-level LTCC operation – exemplary cutting and caving heights*

# Geological footprint for top coal caving

Since LTCC systems are designed to mine extreme high seams, not all underground coal mining areas are suitable for this type of operation. In addition to China, Russia, Australia and Turkey own high coal seams, which allow this type of operation (Figure 8). China already uses this technology extensively and Australia uses it in a couple of very productive installations. Two years ago, two LTCC operations were started in Turkey with the intention of using the multi-level LTCC method. Twenty years ago in Slovenia, a slightly different equipment than shown here was used successfully in a lenticular deposit. Here the caving doors are situated in the center of the main canopy.

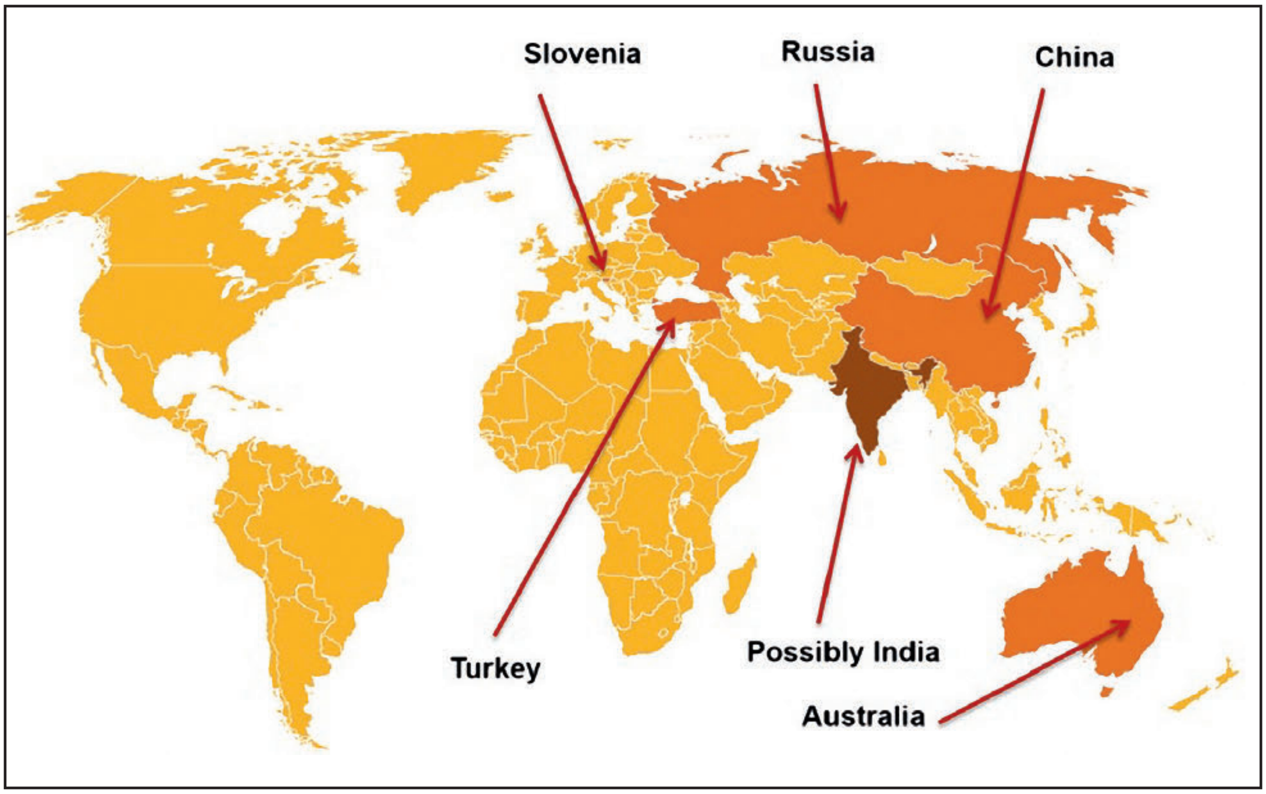


*Fig. 8. Geological suitability of coal mining areas for LTCC operation*

# Production rates in existing applications

In addition to the sustainable usage of the deposit, a LTCC operation offers the advantage of increased production. As long as the shearer and caving operation do not have to wait for each other and produce in parallel, the production rate realized will be higher than with conventional shearer mining alone. However, LTCC operations do not advance as fast as pure shearer faces of similar dimensions, but they also do not slow down to the half or less in daily advance.

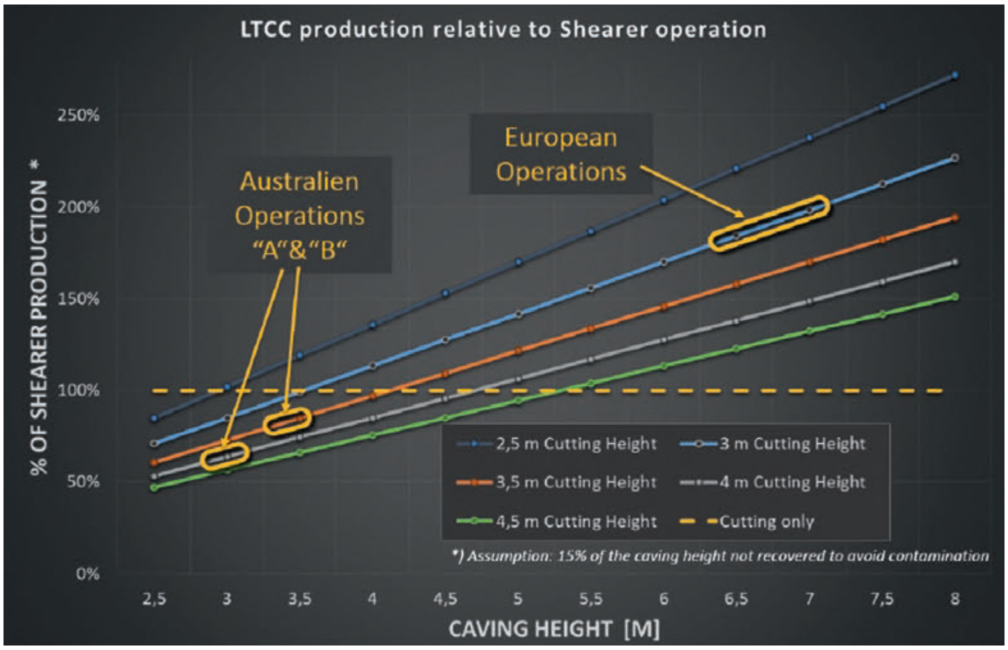


*Fig. 9. Theoretical production rates – relation of caving to conventional cutting*

Over a one month period within an Australian 6.4 m high seam, a production rate of 1,500 to 3,500 t/h was reached. In this Operation A, the lower seam section was mined out by 3.9 m nominal. In addition, 2.5 m were mined with the caving principle. This equals a production ratio of about 61 % from front mining system to 39 % of the rear mining system. In Operation B, similar figures of 1,500 to 3,500 t/h were achieved for the month, where the seam relates to a production ratio of about 57 % for shearer mining and 43 % by caving.

Around the same time period, a European operation was operated at 10.6 m in a Multi-Level LTCC method. Here the production ratio with 3.1 m traditional mining and 7.5 m LTCC based caving was about 29 % front to 71 % rear. Overall, production of the face was about 1,000 to 2,500 t/h (Figure 9).

# Automated Cat longwall top coal caving

With the automation of equipment, it is important to know and manage the controllable degrees of freedom in the system. While roof support and conveyor show several degrees of freedom, such as shield height and the canopy position, they also show the distance between conveyor pan and pantoon. There are additional degrees of freedom to be steered in an LTCC system (Figure 10). Beside the caving door 1 , the sliding canopy position 2 and the rear conveyor advance 3 are the defined and controlled degrees of freedom in an LTCC system. When automating and managing the production rate of the caving system, it is also important to consider the total shield height 4 and canopy angle 5 .

Steering the first three degrees of freedom is possible by closed loop position control. All three degrees related to the caving doors, caving slides and the conveyor position are equipped with relating displacement sensors, providing real time feedback during any movement. It then becomes possible to perform various LTCC procedures, such as

- Standard LTCC procedure, for BiDi method;
- High Flow LTCC procedure, for UniDi method;
- Staggered LTCC procedure, used for UniDi method (preferred).

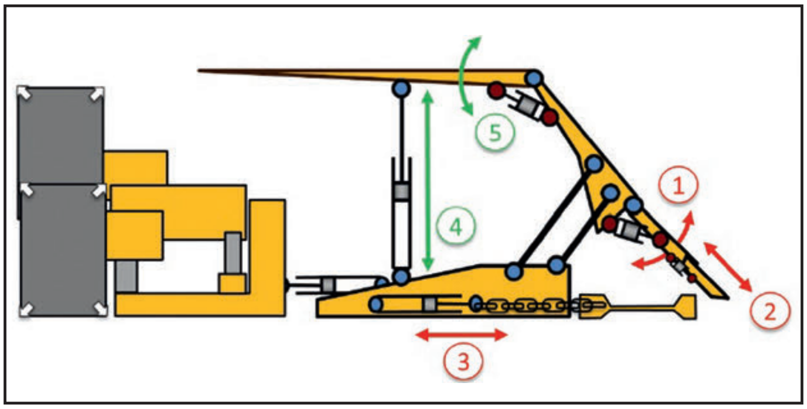


*Fig. 10. Controlled degrees of freedom in a LTCC system*

These automation methods are applied in combination with general automation modes and features for roof support and for the shearer. The roof supports in these types of installations are operated in an Shearer Random Batch (SRB) mode in combination with a shield height control. In parallel, the shearer is operated in State Based Automation (SBA) to run repetitive extraction cycles. In parallel the Shearer is operated in SBA to run repetitive extraction cycles while in best case as well the extraction- and horizon-control mode is active and finally all equipment participate to realize active face alignment (3, 5). Optimally the shearer is further operated in extraction- and horizon-control mode to respect the floor and roof profile and to follow the seam incline automatically. Finally face alignment is turned active enabling shearer position data being shared with the roof supports controls for optimizing the conveyor position[1]).

The standard LTCC procedure used for BiDi Method works as follows (Figure 11): To begin, pull the caving shields in the same series as shields cycle according to the ASQ (automatic RS sequence).

1. The shearer passes the shield area.
2. The shield cycles passed
3. The operation of the LTCC doors behind a safety zone start. The safety zone is per parameter the defined distance between the passing shearer machine and roof supports to be operated automatically. Typically, this is about six roof supports. Up to two caving doors must open simultaneously within a group of four shields, but no overlapping movements are allowed.

The specific automation challenge is to generate and keep a simultaneous loading of the common BSL.

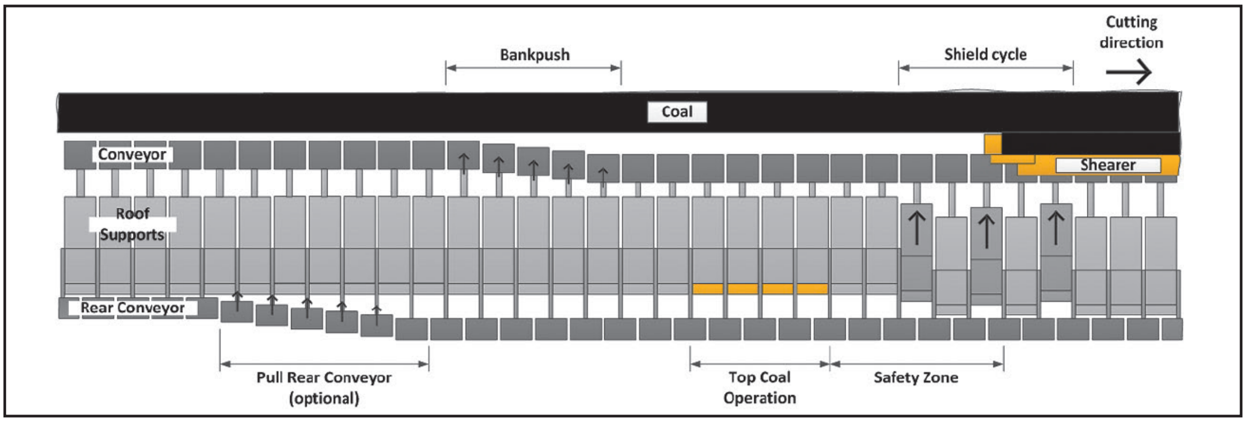


*Fig. 11. Standard LTCC procedure used for BiDi method*

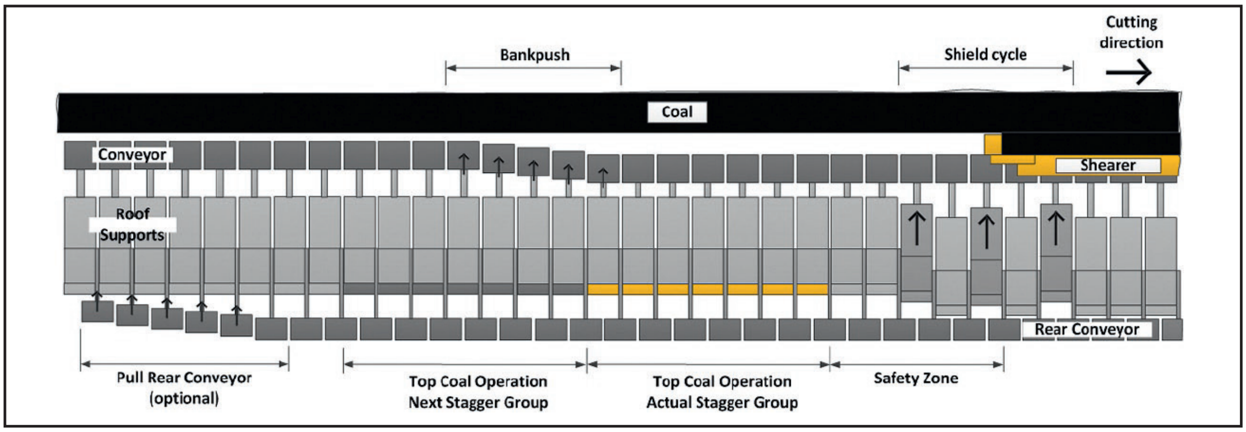


*Fig. 12. Staggered LTCC procedure used for UniDi method preferably*

The High Flow LTCC Procedure is used for UniDi Method. This method is characterized by a simultaneous control of multiple doors while no operation of direct neighbors at the same time is initiated. The operation of doors acts as a wave from the main gate (MG) to the tail gate (TG): The shearer cuts from TG to MG in UniDi mode. That follows a cleanup shear at the MG (no full "snake"), followed by an LTCC operation wave MG to TG. As a result, the shearer directly follows MG to TG in UniDi or waits awhile until the machine is operated from MG to TG. This movement is followed by a cleanup shearer at the TG end in a continuation from the start. This LTTC operation is almost independent from the actual shearer position and provides the highest production rates. An advanced control concept is needed for uniform loading of the Beam Stage Loader (BSL).

The third method, the Staggered LTCC Procedure, is preferred and is used for UniDi method. In Figure 12, a group of seven shields runs special patterns of caving door operation within its group. Then the assignment moves to another group of seven shields. Doors within this group can open overlapping as in the High Flow procedure. As mentioned earlier, maximum two caving doors are simultaneously operated. Further details are realized as in the High Flow procedure.

*[1] As at the date of creation of this document, the intellectual property rights in the LASC technology (Interconnection of Landmark Compliant Longwall Mining Equipment-Roof Support System Communication) are owned by the Commonwealth Scientific and Industrial Research Organization. LASC technology is used and distributed by Caterpillar under license*

# Top coal caving data from real applications

All automation cycles described are realized and proven in real operations. During the operation, visualization and analysis tools are frequently used – provided by the Cat MineStar capability set "Health for Longwall" (Figure 13). This toolset provides plenty of practical functions to monitor and analyze ongoing operations. In the main view status and movements are shown in detail to easily get an overview. Moreover the main view shows which caving function is currently active or has been active at a given time. The analysis of the playback features is very helpful. Due to the accelerated playback capability pattern, an analysis of shield movements is possible, as well as the real interaction between the shearer operation and the caving operation (4, 6).

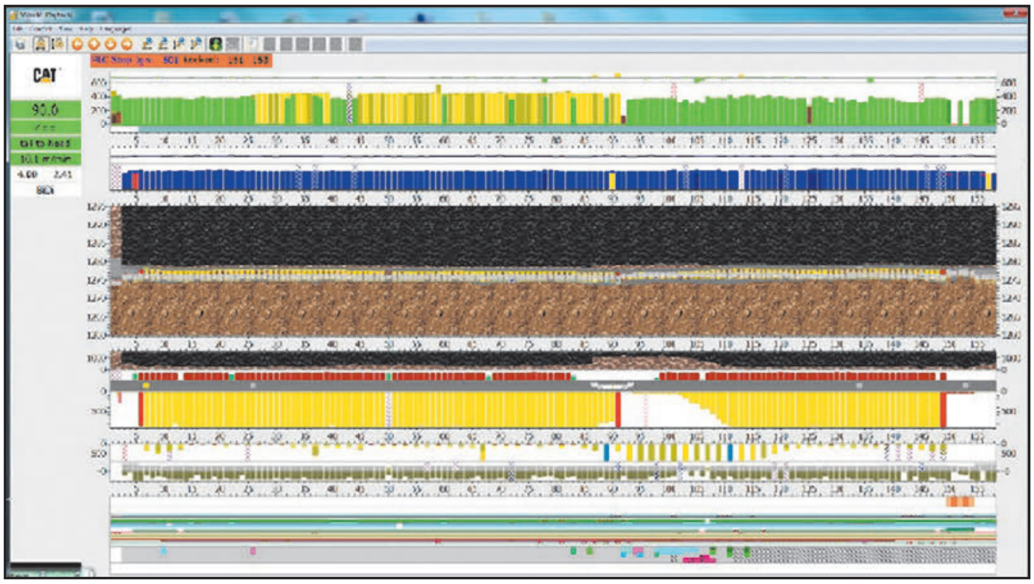

*Fig. 13. Health for Longwall – all LTCC operation information at a glance*

# Remote operated and automated longwalls

In addition to LTTC automation features, longwall automation provides full automation of the shearer and roof support equipment as part of "Command for Longwall", another capability of Cat MineStar.

Shearer automation means reduced work time for operators near the cutting machine and at the face. Today, it is possible to run a shearer with only one operator instead of two, meaning no operator has to leave the fresh air stream. Furthermore, the operator can leave the machine for defined periods of the mining cycle and wide areas of the face. As a result, operators will spend less time in dangerous areas and are exposed to less dust and noise.

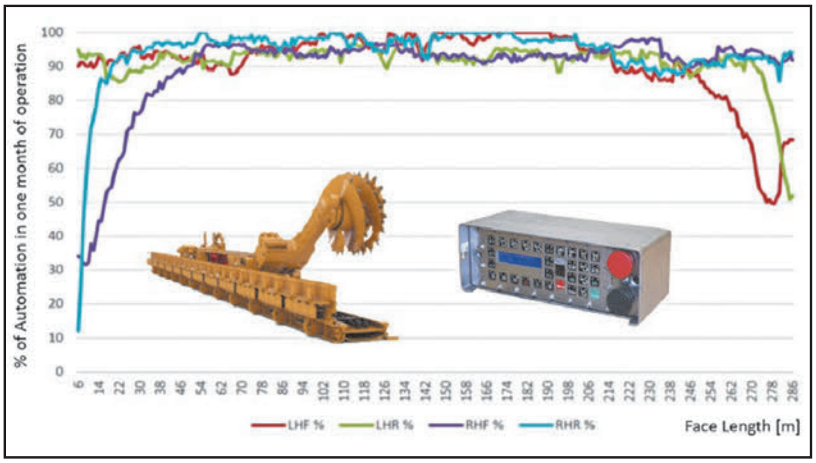


*Fig. 14. Command for Longwall – percentage of operation in automation mode in a highly automated longwall system*

This technology is provided by Caterpillar as a "Command for Longwall" feature using statebased automation and it has been shown in real operations over a period of more than one year that it is possible for complete seam heights to reach more than 95 % of operation time in automation mode (Figure 14).

While the shearer is operated in the highest level of automation mode and the roof supports follow by usage of SRB all time on their own, it is also possible to keep the face straight and the shape of the conveyor wellcontrolled. Figure 15 shows a life data based top view on the equipment in LTCC operation. The deviation from the targeted ideal conveyor line is in the dimension of 1 m at a 300 m wide face.

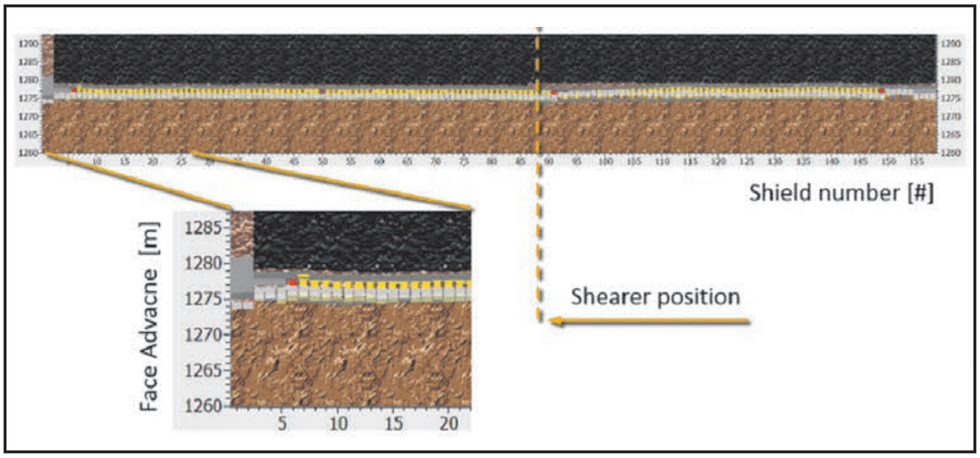


*Fig. 15. Command for Longwall – face alignment in LTCC operation*

# Discussion of LTCC application

Mines face some challenges when getting into the LTCC business, so it is necessary to adapt and optimize the LTCC procedure to individual mining conditions (processes, culture, continuous optimization, usage of Cat experience). Caterpillar offers individual adaptation of mining procedures, caving procedures and parameter settings.

Depending on the coal quality and geological specialties, autoignition in the gob can result in a possible fire hazard. This aspect needs to be handled proactively and professionally, planning the inerting with nitrogen or CO2.

While in operation, it is important to monitor shield height and to steer the roof supports accordingly – so that they are not continuously operated at the end of the nominal shield height range. Otherwise the roof supports could lose contact to the roof. This, in combination with manual hyperextension of the canopies, may lead to major destruction of the shield components, especially after roof pressure comes back (cylinders, pins, cylinder bearings). By using automation modes and reducing manual interaction, these operational mistakes can be avoided.

Too slow face advance speed could result in excessive roof pressure. This may cause loose roof and roof falls in front of the canopies or at their tip. To prevent these types of events, it is important to keep a certain advance rate. In the worst case scenario, it will reduce time for caving operation.

There are some important lessons learned when establishing high automated longwall operations. It is all about creating a cultural change and having all mine personnel striving for improvements while having the crew welltrained. The management need to get crews focused on total mine conditions instead of focusing only on machine conditions. At the same time, the frequent and right usage of healthtoolsets for continuous improvement is recommended. The operations should be reviewed regularly to achieve better efficiency and overall improvements on an ongoing basis.

# Conclusion

LTCC allows mining of seam areas that shearers typically do not reach. High resource recovery – 85 to 90 % – in high seams is possible, resulting in sustainable mining. The technology allows reduction of waste (minimal with regard to coal resources), resulting in a reduction of operating costs. By achieving the highest productivity possible, operations will stay profitable, even in difficult economic times. Finally, in comparison with high face longwall mining, the LTCC technology makes it possible to improve mine safety.

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# Notes

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