# Plow Technology — History and the State of the Industry

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# Abstract

Plowing is a coal mining method invented in the early 1940s. Many different plow models were designed and tested underground, until—in the mid-1990s—only two models remained: the Reisshakenhobel®, or base plate plow, and the Gleithobel®, or gliding plow. Horsepower and plow speed have increased steadily over time, but it wasn't until 1989 that the biggest weakness of plow systems was overcome: automated plowing using electro-hydraulic controls with defined cutting depths finally allowed plowing to become the most productive mining method for seams below 1.8 m thick. This technology step—like most inventions in plowing—came from Caterpillar predecessor Westfalia Luenen. Another milestone was yet another invention by Westfalia. The PM4 was the world's first and only mine-worthy and rugged control system, and it was introduced in 1993. Today, Caterpillar offers three standard plows, along with tailor-made plow shields and the most advanced electronic shield control system available, the PMC®-R. Cat plows offer installed cutting power of up to 2 x 800 kW, coupled with a blazing plow speed of up to 3.6 m/s and world-leading automation capabilities, all of which lead to an integrated longwall mining system for medium and thin seams that produces more clean coal at a lower cost than any shearer.

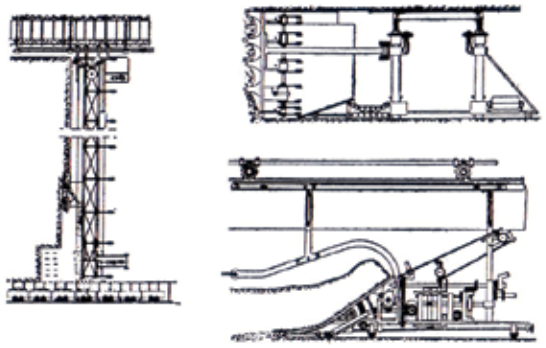
**KEYWORDS**

Plow longwall history, automated plowing with defined cutting depths, installed horsepower, plow speed

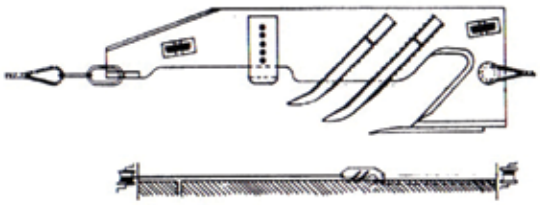
# 1. Plowing History

The longwall underground mining method was established in the early 20th century. True mechanization of the coal mining process wasn't established until the early 1940s, but the first patents for the "slicing cutting" of coal were granted as early as 1912. The following list shows the patents granted and some examples of these inventions.

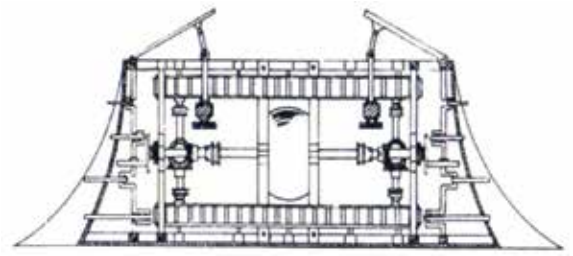
- 1912—Wissmann *(Germany)*
- 1917—Hirst *(UK)*
- 1922—Diancourt *(Netherlands)*
- 1927—Ducoer *(France)*
- 1929—Morgen *(USA)*
- 1930—Wilhelm Löbbe receives the patent for the coal plow
- 1935—Hammel *(Germany)*
- 1941—Ibbenbüren mine builds the first coal plow *(Inventor: Konrad Grebe)*



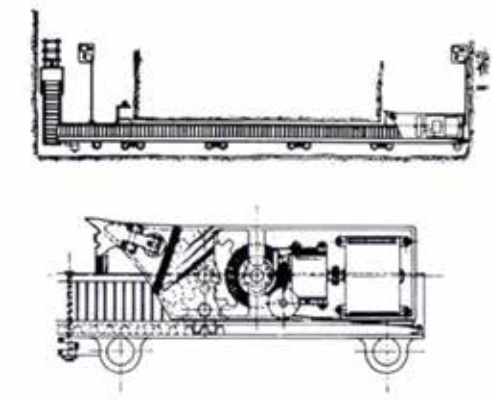
***Invention of Wissmann (1912)***



***Invention of Ducoer (1927)***



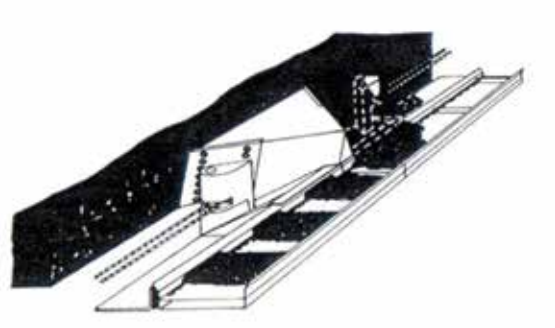
***Invention of Diancourt (1922)***



***Invention of Morgan (1929)***

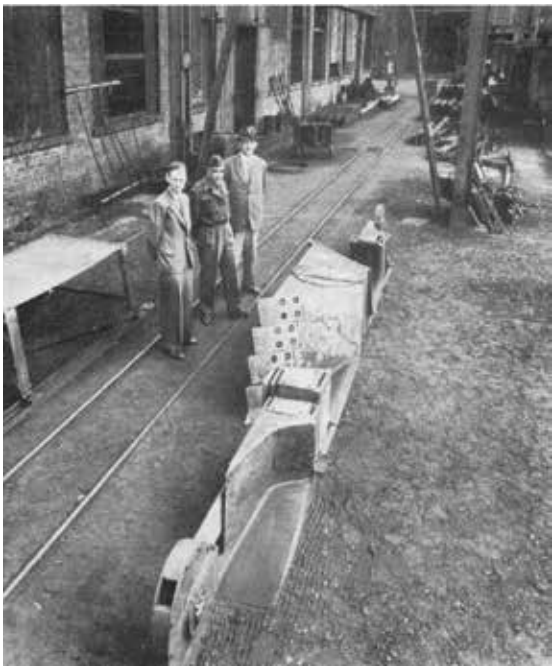
# 1. Plowing History

Konrad Grebe was the inventor of the first built plow, installed at Germany's Ibbenbüren Mine in 1941. The plow cutting principle was already established, but the plow body was pulled by a rope then. The installed power was 2 x 40 kW; the cutting speed was 0.3 m/s.



***Invention of Grebe (1941)***

***Konrad Grebe (middle), the inventor of the first plow used at Ibbenbüren Mine in 1941***

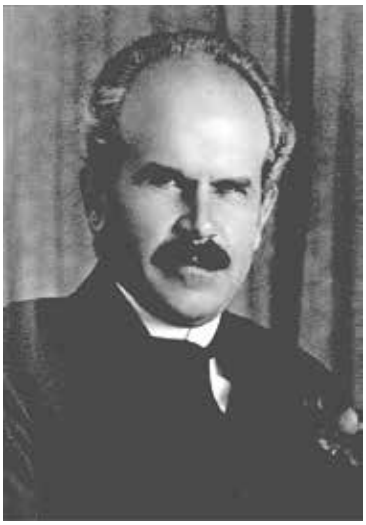


***First Ibbenbüren plow in 1941***

# 1. Plowing History

The plow was invented and refined by Wilhelm Löbbe, chief engineer at Westfalia Luenen (a predecessor company of Caterpillar) back in 1947 in an attempt to modernize and mechanize underground coal mining. Löbbe also invented the PANZER-Förderer® or armored face conveyor, which was successfully installed underground for the first time in Poland in 1942. Löbbe improved plow performance by reducing the cutting depth and increasing the cutting speed. The 'fast plow' was first installed in 1949 at Friedrich-Heinrich mine in Germany. With an installed power of only 2 x 40 kW, it achieved a daily output of more than 1,000 tonnes for the first time in 1950.

In fact, this first truly successful plow was so popular that the German government decided to publish a special stamp for it.



***Wilhelm Löbbe (1890–1950) was chief engineer at Westfalia Luenen, predecessor of DBT, Bucyrus and now Caterpillar***


***Löbbe plow stamp (translation: "The Löbbe plow — helper of the miner. The miner — helper of the human race.")***

***Löbbe Plow System 1950***

# 1. Plowing History

From this point on, plow development picked up speed. In 1956, Westfalia Luenen and later the Beien Company built the first plow systems with a gob-side plow guide (prototype of the Reisshakenhobel® base plate plow). In 1960, Westfalia Luenen installed a plow without a base plate that was instead guided on gliding ramps at the NV Nederlandse Staatsmijnen in Heerlen, Netherlands (prototype of the Gleithobel® plow). 1963 saw the first underground installation of the first real Gleithobel plow, type I/26, at the Prosper III/IV, Graf Bismark and Wester-holt mines in Germany. Between 1960 and 2003, there were 14 more plow models just for the Gleithobel alone.

The following plow models were pulled by a rope:

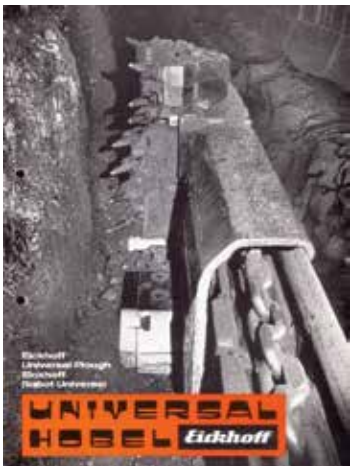
- **Ibbenbüren mine:** Einheitshobel
- **Demag Company:** Stufenhobel
- **Brüninghaus Company:** Schnellhobel
- **Westfalia Lünen:** Schnellhauer "Hannibal-Hauer".

After 1947, all plows were pulled by chains. The following is a list of all these plows:

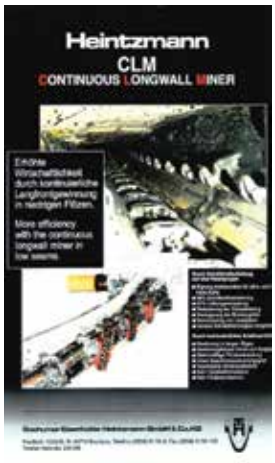
- **Westfalia Lünen:** Löbbe-Hobel, Reisshakenhobel, Gleithobel, Gleitschwerthobel® (furthermore Anbauhobel, Prismenhobel, Tandemhobel, Vibrationshobel, Drehhobel, Pottshobel, Pulthobel, Tischhobel, Hydrohobel, Steilhobel)
- **Brand:** Kettenstufenhobel
- **Eickhoff:** Universalhobel
- **Beien:** Megahobel, Rampenhobel, Schlaghobel, Raupenhobel, Gelenkhobel
- **Klöckner Becorit:** Universalhobel, Schlagkopfhobel
- **GHH:** Hydrohobel Jet-Miner
- **Halbach&Braun:** Kompakthobel, Kompaktrollenhobel, Schwertrollenhobel
- **Heintzmann:** CLM

The following pictures show some of these plows[1].


***Westfalia Anbauhobel***




***Eickhoff Universalhobel***




***Heintzmann CLM plow system***


***Klöckner-Becorit plows***

***Westfalia Gleitschwerthobel®, combining the Gleithobel® and the Reisshakenhobel® principles***

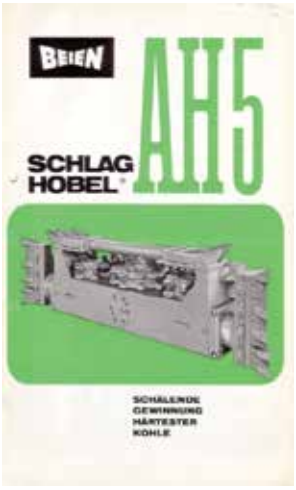
# 1. Plowing History

In addition to these German companies, others from Japan, Russia, the Czech Republic and Poland developed plows—always based on one or more of the above mentioned models. Until 1956, Westfalia Luenen alone delivered 248 Löbbe plow systems. As per an investigation in 1965, the German coal industry already used 531 plow systems from various suppliers; the vast majority of which came from Westfalia Luenen. Ever since the introduction of the Löbbe plow, Caterpillar and its predecessors Bucyrus, DBT, Westfalia Becorit and Westfalia Luenen have installed well more than 2,000 plow systems in many countries around the world. They were and are used for the following minerals: hard coal, lignite coal, phosphate and bauxite.

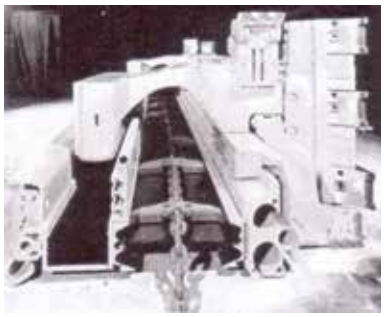
In addition to the conventional cutting type plows, there were also several attempts to activate plows through an activated cutting process. The images to the right show two of these models.

The activated plows were investigated and partly developed into trial machines because the older plow systems had low horsepower and no automation, so cutting hard coal or rock was basically impossible. However, all of the trials did not result in a machine that provided satisfactory production figures. In addition, those machines showed much less availability, and maintenance was complicated. As incremental plowing with defined cutting depths was invented by Westfalia Luenen in 1989, coupled with more and more available horsepower, these developments were finally abandoned in the early 1990s.

By the mid-1980s, installed power had drastically increased to 2 x 250 kW. To match this power, the plow chain size increased to a 34 mm diameter, which allowed plow speeds of 1.8 m/s to be achieved. By the 1990s, installed cutting power had increased again, first to 2 x 315 kW using a plow chain diameter of 38 mm; and later in that decade it increased to 2 x 400 kW with maximum plow speed finally reaching 3 m/s.




***Activated plow from the Beien company (activation of bits through chain detour through the plow body)***




***Activated plow from the GHH company (high-pressure water jets pre-cut the coal behind the mechanical bits)***

***Schlagkopfhobel of Bergbau-Forschung GmbH (activated through hydraulic pick hammers on both sides of the machine, which was pulled by a plow chain)***

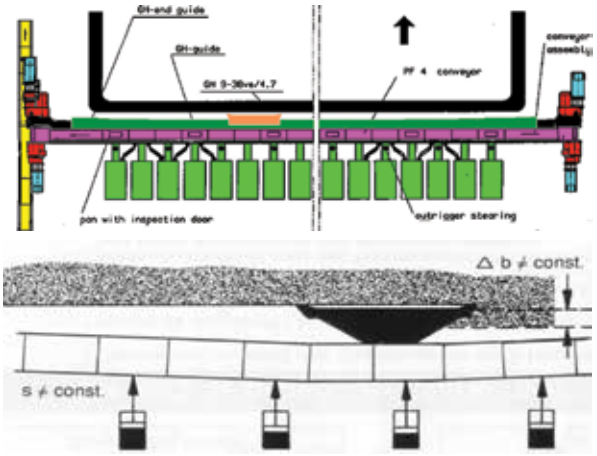
# 1. Plowing History

### WORKING PRINCIPLE AND EARLY ACHIEVEMENT OF CUTTING DEPTH

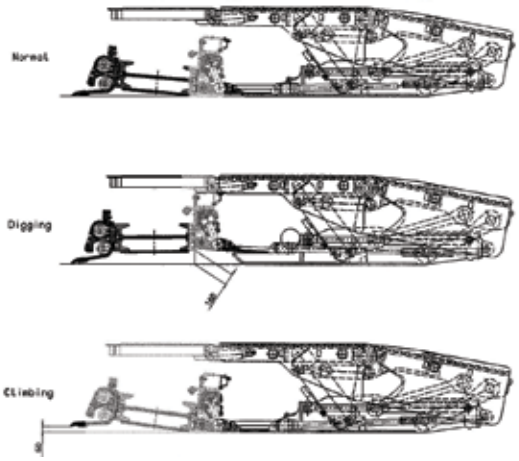
The working principle of plows has not really changed since its invention: the plow guide is attached to the face conveyor, and the plow body is pulled (first by ropes, later by an endless chain) in both directions from the face end drives. The conveyor drives are also located at the face ends. The plow body "slices" off the coal from the seam and loads it into the face conveyor through its shape.

After the plow has passed by the face conveyor and the attached plow guides are pushed forward, which was done until the late 1980s/early 1990s by constant low pressure push from standalone push beams and later from roof supports of different kinds, or from shield supports beginning in the 1970s. This led to inconstant cutting depths and an undulated face, which had to be corrected very frequently. In addition, production was limited as the average cutting depth was lower than the one intended to be cut per plow pass.

Further to the face end drives, plow systems are characterized by a horizon control system called "outrigger steering," allowing the operator to adjust the plow cutting to go straight forward, uphill or downhill by changing the angle of the face conveyor pan. For many years, plows also used a "block anchorage" system for two purposes: they keep the AFC from creeping and at the same time keep enough mechanical play between the individual line pans to allow them to be pushed over easily.




***Plow system setup and constant low-pressure push principle***




***Outrigger steering plow horizon control system***

***Modern Cat block anchorage system***

# 1. Plowing History

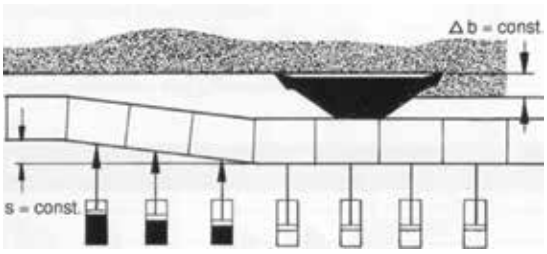
### REMAINING PLOW SYSTEMS AFTER 1995

Many of the previously mentioned plow models disappeared over the years due to their disadvantages and technical inefficiencies as the companies designing and manufacturing them went into bankruptcy or merged with other companies. The last of these mergers was the one between Westfalia Becorit, Hemscheidt and Halbach&Braun in December of 1994, forming DBT Deutsche Bergbau-Technik under the ownership of RAG AG. Based on an in-depth look at the advantages and disadvantages of the existing four plow models, they decided just to use Westfalia's Reisshakenhobel plow system S4N and Westfalia's Gleithobel plow system 9-38 ve[2].

***Standard plow systems at DBT Deutsche Bergbau-Technik in 1995: Reisshakenhobel® S 4N (above) and Gleithobel® 9-38 ve 5.7 (below)***

### AUTOMATED PLOWING WITH DEFINED CUTTING DEPTHS

The breakthrough invention (outside of ever more horsepower) was the introduction of automated plowing with defined cutting depths. The use of electromagnetic valves and reed rod stroke measurement sensors inside the ram cylinders—coupled with electronic control units in every shield—finally allowed plows to overcome the biggest weakness of previous systems. Now, the AFC with the attached plow guide could be pushed over with high pressure after the plow body had passed by a predefined stroke equivalent to the next cutting depth.




***Automated plowing with defined cutting depth and high-pressure push***

This method was successfully applied for the very first time in the USA, when Westfalia Luenen delivered two automated plow systems to U.S. Steel's Pinnacle mine in West Virginia, USA in the late 1980s. While the automation algorithms installed by Westfalia into their third-party sourced electronics worked very successfully, the reliability of these electronics was very poor. It took until 1996, when Pinnacle installed the company's self-developed PM4 electronics to finally make the last step toward reliable automation. This, the world's first automated plow system, was upgraded with regards mainly to installed horsepower (eventually reaching 2 x 400 kW) several times until, in 2010, the then-new owner Cleveland Cliffs ordered a complete new automated plow system from Bucyrus.

Today, the main requirements for any high-performance plowing are remote control and a precisely adjustable cutting depth, which produces a straight face line. These are easily achieved by incremental plowing, a feature typical to Cat plows.

# 1. Plowing History

Cat incremental plowing, which is precisely controlled electronically, ensures that the plow cuts to an exactly defined depth—regardless of coal hardness, seam structure and presence of rock intrusions. This results in balanced loads on conveyors and steady advance through the seam. The AFC/plow system and shield supports can be positioned exactly where they are needed (snakes, faults etc.). The system is self-correcting for over- or underpush, maintaining a straight face regardless of conditions. In fact, as a result of automation, Cat plow systems now cut as straight a face as shearers do. Today, the electrohydraulic system of choice is the Cat PMC®-R system, which was developed as the successor of the longtime pacesetter in the industry, the PM4, in 2004.

***Cat PMC®-R electrohydraulic shield control system***

## PLOW SYSTEM DEVELOPMENTS SINCE 2000

Caterpillar's predecessor DBT continued to develop these plow systems in various steps after 2000, adjusting to the demand of increased horsepower for cutting and increased productivity. Caterpillar now offers two types of plows with three different models: The Reisshakenhobel RHH800 and the Gleithobel in two different models; the GH800 and the top-of-the-line GH1600.

At the entry level, the RHH800 cuts seams from 0.8–1.6 m in soft to hard coal and has installed power of 2 x 400 kW, a maximum plow speed of 2.5 m/s and a maximum cutting depth in softer coal of 150 mm with a face length of up to 300 m. A 38 mm or 42 mm chain may be used.

The GH800 is designed for slightly thicker seams of 0.9–2.1 m. With the same installed power as the RHH800, it achieves a higher maximum plow speed of 3.0 m/s and a greater cutting depth of 180 mm. The GH800 also cuts soft to hard coal with a face length of up to 400 m. This system uses a plow chain with a diameter of 38 mm. Development of an updated version of this successful model is now available after successful underground trials at the German Ibbenbueren mine in 2014.

***Underground longwall control cabin with face visualization***

***Cat RHH800 plow system***

# 1. Plowing History

The top of the line is the Gliding Plow GH1600. Designed to mine medium to extremely hard coal in seams of 1.1–2.3 m, the GH1600 has a maximum installed power of 2 x 800 kW, allowing it to achieve a maximum plow speed of 3.6 m/s with a maximum cutting depth in softer coal of 250 mm and a face length of up to 400 m, limited only by the maximum installable AFC power. This plows system uses a plow chain with a diameter of 42 mm. In Germany, this next-generation plow system—first installed in 2003—achieved a productivity of more than twice the amount of coal ever mined from a 400 m face on a 1.5 m seam of extremely hard coal with up to 3,500 t/h.

The height of all Cat plow bodies (turret head) is easily and infinitely adjustable within a certain range using a worm gear. The plow body height can also be adjusted in larger increments by simply installing or removing auxiliary bit blocks. This allows for quick and easy adjustment to varying seam thicknesses, minimizing both the cutting of adjacent rock and the associated preparation costs.

Overload protection prevents damage resulting from shock loads to drive components, minimizes chain failures, extends component life and allows for a quick restart. The Cat planetary overload protection system contains an integrated multi-disc clutch set to slip at well below the breaking force of the chain. If the chain stalls, the system decreases gearbox torque and shuts down the plow drives before a dangerous peak chain force is reached. This is achieved through yet another electrohydraulic control system. Finally, modern Cat plow shields are made out of high-strength steel for long life to make for a truly integrated plow system.

***Cat GH800 plow system underground***


***Cat GH1600 plow system for maximum productivity***

# 2. Reference Projects

### 2.1 PINNACLE MINE

In 1989, U.S. Steel's Pinnacle mine became the world's first longwall operation to eliminate the need for an operator at the face. After conducting an extensive evaluation of the most efficient mining method for low seam coal, Cliffs Natural Resources, Inc. opted for an automated plow system, concluding that it was the safest, most cost-effective and most environmentally friendly way to extract coal from the low seam (Pocahontas No. 3) at the Pinnacle mine.

The 2010 installation has 2 x 600 kW plow drives, large P-45 UEL, a 42 x 137 mm plow chain, a plow body rated at 1.6 MW, the Cat 2003 heavy-duty bit system, heavy-duty plow guides, robotically welded plow guides, PMC®-D plow control system and more plow steering cylinders. The AFC installed power is increased to 2 x 600 kW, with a higher AFC speed of 127 m/min. For Cliffs, the unveiling marks the start of a new era in low-seam productivity and safety. For Caterpillar, it marks the kick-off of a nationwide promotion of this highly advanced and efficient technology, which is ready to assume a very important role in North American mining going forward. With its new mining system, Cleveland Cliffs wanted to break the world record for low seam longwall mining, set at the same Pinnacle mine in the late 1990s with nearly 23,000 clean metric tons of coal in one day. This has been achieved twice, increasing this record to more than 32,000 clean tonnes on April 1, 2014 in a seam only 1,42 m thick.

***Surface compatibility test for the Cleveland Cliffs plow system in 2010 in the USA***

# 2. Reference Projects

### 2.2 BOGDANKA

In March 2010, Polish mine operator Lubelski Węgiel Bogdanka S.A. commissioned the automated GH1600 plow—designed for high productivity in very hard coal and the system of choice for seams up to 2.3 m—at its Bogdanka mine. The system features 2 x 210/630 kW (two-speed motors) for the plow system and 2 x 800 kW for the AFC system.

Within months of delivery, the new longwall had far exceeded the production target of 10,000 tonnes per day specified in the invitation to tender—and even set a new European record for plow faces, as well as a new world production record for plow longwalls in mines using arches to support their entries. On August 25, 2010, the longwall achieved a daily output record of 16,894 metric tonnes. During just 10.5 hours of operation, the plow made over 300 passes along the 250-meter panel, traveling a total distance of 76 kilometers at an average of 120 m/min. The plow face advanced a total of 21.6 m with a cutting height of only 1.5 m—an achievement impossible for any shearer in such seam heights. This is the result of huge advances in plow automation and technology, especially over the past 10 years.

The plow installed at Bogdanka is working in automatic mode, allowing a significant reduction of staff required at the face during operation. Incremental plowing is used, cutting to an exactly defined depth regardless of coal hardness, seam structure and faults. Horizon control allows exact control of the plow angle, ensuring that the plow does not dig or climb unless required by the seam's geology.

The Polish mining industry had abandoned plow technology in the mid-1990s because of its low productivity, which was caused by low horsepower and the lack of automation. But the success of Caterpillar's latest plow systems is causing a renaissance. JWR's Zofiowka mine was the first to buy a Cat plow system (it now has two sets in operation), and Bogdanka has already purchased three more plow longwall systems delivered between 2012 and 2014. And at Bogdanka alone, Cat plow technology will increase recoverable reserves by some 100 million tonnes.

***Bogdanka plow GH1600 underground***

# 3. Summary

Automated plowing is the most productive longwall mining method for seams below 1.8 m cutting height. High installed cutting power and plow speed allow a maximum capacity of 3,500 t/h. Cat plow systems allow clean extraction of low and medium coal seams with minimum mining of adjacent rock, which reduces costs associated with preparation and refuse disposal. Incremental plowing with defined cutting depths and full automation without any operator being required at the face, combined with cutting power of up to 2 x 800 kW, ensures high productivity even when extracting hard coal. With the ability to operate in seams as low as 0.8 m, plows can therefore mine seams previously thought to be inaccessible. And from this minimum seam height up to 1.8 m, the Cat plow system easily outperforms any shearer.

Safety is enhanced by lower methane concentrations (due both to the larger size of the cut product and greater distribution across the face created by the higher plow transit speed) and the fact that—in contrast to the shearer—the plow can operate completely unattended.

And finally, Cat plows are engineered and manufactured by the world leader in plow technology—with continuing research and development of all components to ensure maximum productivity, service life and return on investment.

# Literature

[1] Archives of Hans Dreher.

[2] Heinz-Werner Voß/Manfred Bittner: "Status of longwall mining of medium and thin seams in Germany". Publication in Glückauf Mining Reporter 1-2003; pages 20-27.

# Plow Technology — History and the State of the Industry

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