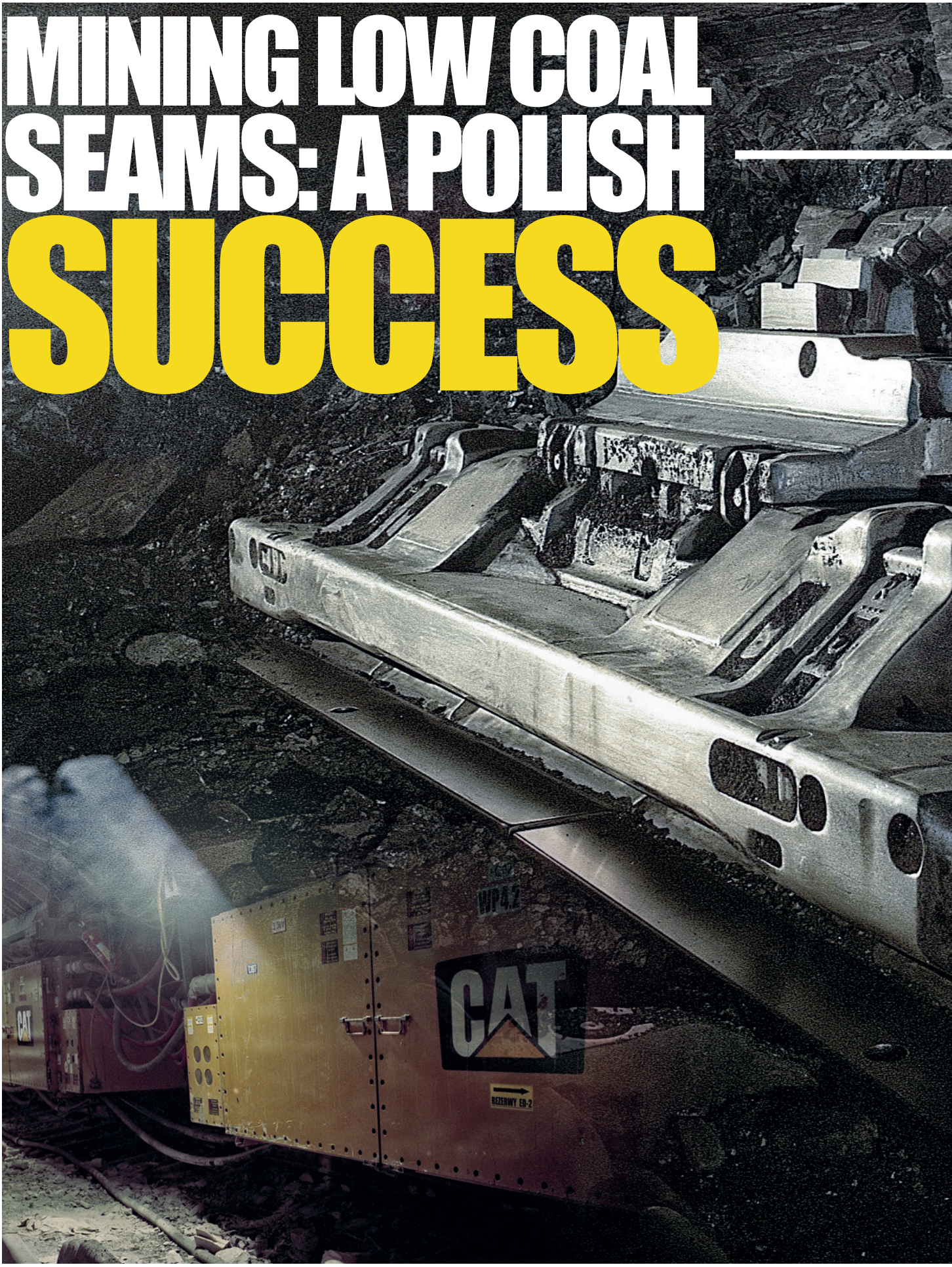
MINING LOW COAL SEAMS: A POLISH SUCCESS



Zbigniew Stopa, Lubelski Wegiel Bogdanka S.A., Poland, and Michael Myszkowski, Caterpillar Global Mining Europe GmbH, Germany, describe how plough technology has opened new horizons at one of Poland's biggest hard coal mines.

Located in eastern Poland, close to the country's borders with Ukraine and Belarus, Bogdanka is owned and operated by Lubelski Węgiel Bogdanka S.A. The mine lies in the southeastern part of the Central Coal District (CCD) in the Lubelskie (Lublin) Coal Basin (LCB), which has been evaluated in great detail. Bogdanka is the only mine producing hard coal in the LCB.

Lubelski Węgiel Bogdanka is one of Poland's leading producers of hard coal – a position achieved by the company over the past 30 years through a combination of financial restructuring and continuously improving the efficiency of its mining operations. Its output of high-volatile bituminous coal is used mainly for power generation and thermal energy, as well as for cement production.

The geological structure of this part of the coal basin consists of nearly horizontal coal seams overlain by approximately 700 m (2300 ft) of overburden. The Carboniferous-age rocks that host the seams are relatively weak and there is little significant faulting in the deposit. However, the overlying Jurassic rocks are water-bearing, with some beds subject to significant water pressure. The rock also contains a layer of unconsolidated sand.

Coal resources available to the company total 600 million t (660 million short t), of which approximately 255 million t (280 million short t) make up the current mining reserve. A total of 18 seams occur within its 77 km^2 (29.7 $mile^2$) license area at depths of 650 – 730 m

Cat GH1600 plough at Bogdanka, at face.

Cat plough longwall at Bogdanka.

(2130 – 2400 ft). Eight contain economic reserves. Mining currently takes place in two seams, 382 and 385/2.

The operation itself is split into three sections – Bogdanka, Nadrybie and Stefanów – all of which lie within a distance of a few kilometres. In total, the mine has six shafts and one coal preparation plant.

Development at Bogdanka began in 1975, with the first longwall being commissioned in 1982. Since then, Bogdanka has produced some 100 million t (110 million short t) of coal. Its output is now approximately 5.8 million tpy (6.4 million short tpy), a figure that will rise to 11.5 million tpy (12.7 million short tpy) within the next few years.

Bogdanka's mining systems

For almost 30 years, underground mining at Bogdanka centered on shearer technology, with the mine optimising its shearer operations to achieve satisfactory efficiency and reasonable economic results in seams thicker than 1.6 m (63 in.). In seams between 2.0 – 2.5 m (79 – 98 in.) thick, shearer faces have achieved ROM outputs of up to 20 000 tpd, while the mine has recorded outputs of up to 15 000 tpd in seams that are 1.6 – 2.0 m (63 – 79 in.) thick.

Nonetheless, using shearers in longwalls places some important limits on the thickness of seams that can be extracted. Significant factors here are human – the need for operators to be working on the face all the time – and technological, in relation to the physical size of the shearer and the armoured face conveyor (AFC). Taken together, these factors mean that shearer faces need to be installed in seams that are at least 1.6 – 1.8 m (63 – 70 in.) thick to be economical.

This, in turn, means that many millions of tonnes of in-situ coal cannot be mined economically, because seams are too thin to be worked cost effectively using shearer technology. At Bogdanka, this applies particularly to seam 385/2, which has been worked since 1997, as well as to the prospective 389 and 391 seams. Being able to mine effectively in seams as thin as 1.2 m (47 in.) would significantly increase the operation's mining reserves and would extend its operational life.

To achieve this, the company decided to introduce plough technology at Bogdanka. Seen as being of strategic importance for the mine, the introduction programme has been carried out consistently for several years now, with the aim of achieving a reliable mining system in seams 1.2 – 1.6 m (47 – 63 in.) thick. Using this technology should both improve the cost effectiveness of mining and significantly reduce the amount of waste rock produced in the ROM coal.

First plough panel: 1/VI/385

The first plough longwall at Bogdanka was set up in the Nadrybie section of the mine, in panel VI of the 385/2 seam. The face length was 250 m (820 ft), while the panel was 1750 m (5470 ft) long. Within the first plough panel, the seam was 1.4 – 1.7 m (55 – 67 in.) thick and dipped at a maximum of 2.5°. The coal had a compressive strength of 8 – 19 MPa (1160 – 2756 psi) and a Protodyakonov strength index of 0.75 – 1.2.

The roof in this panel contained alternating layers of siltstone, mudstone and sandstone, with the first 3 m (118 in.) of roof having a compressive strength of 24.4 – 40.7 MPa (3540 – 5900 psi). The seam floor consisted of alternating siltstone and mudstone – with some local thin layers of sandstone – and it had a compressive strength over the first 3 m depth of 12.9 – 31.8 MPa (1870 – 4610 psi).

For the first plough installation, the Cat roof support system consisted of 1.75 m wide, two-leg face shields operating between 950 and 2000 mm (37 – 79 in.), with face-end shields with a height range of 1480 – 2300 mm (58 – 91 in.) that were spaced at distances of 1700 – 2200 mm (67 – 89 in.). All the face supports were rated at 2 × 3619 kN capacity.

The Cat GH1600 plough had a body height of 980 – 2100 mm (39 – 83 in.), with a 42 × 137 mm drive chain. Two 210/630 kW (282/845 hp) motors, driving through 16:1-ratio Cat PF4 UEL gearboxes, provided ploughing speeds of between 0.98 – 2.94 m/sec. (193 – 579 ft/min.).

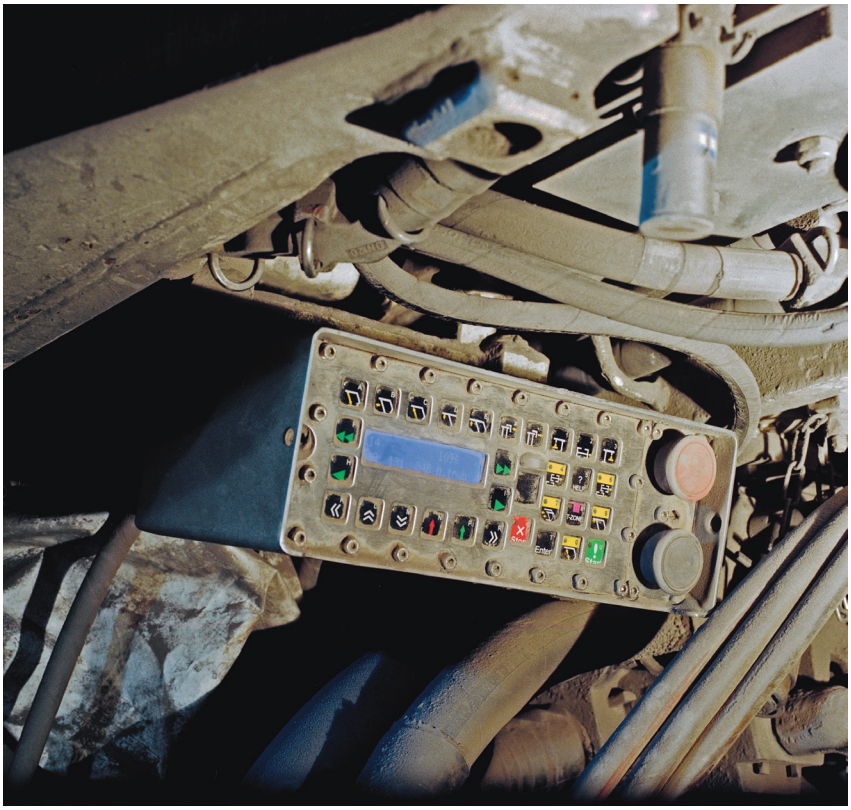
The overhead-discharge Cat AFCPF4 face conveyor was powered by two 800 kW (1073 hp) motors through 33:1 Cat CST45 gearboxes, giving a chain speed of 1.52 m/sec. (299 ft/min.). The AFC pans were 1750 mm (69 in.) long, with a two-strand 42 × 146 mm chain assembly.

Both the AFC and the beam stage loader had a capacity of 3000 tph (3300 short tph) of ROM coal. The Cat BSLPF4 beam stage loader was equipped with a SK 1111 crusher, with twin 34 × 126 mm chains driven at a speed of 2.03 m/sec (400 ft/min.) by a single 400 kW (536 hp) motor. Power to all the face equipment was supplied at 3300 V.

Learning the system

Bogdanka's first plough longwall entered production on 23 March 2010. Staff used the first few weeks of operation to gain experience in operating the automated plough system properly. With operators continuing to fine tune the system's control and automation software, and

Cat VFD system at Bogdanka.



PMC-R roof support control underground.

Surface control room.

optimise it to the existing mining conditions, it was not long before the face was producing 6000 tpd (6600 short tpd) of ROM coal.

After that, its performance increased steadily. Within three months of start-up, it reached the expected output of 10 000 tpd (11 000 short tpd). On 25 August 2010, the system achieved its peak output of 16 894 tpd (18 583 short tpd), while the first panel was completed on 20 October 2010. In its seven month life, the plough system advanced an average of 10.4 m/d (34 ft/d), and achieved an output of 8200 tpd (9020 short tpd) ROM. On a monthly basis, this equated to an average advance of 247.4 m (812 ft) and an output of 195 400 t (215 000 short t). The daily running time for the plough averaged 5 hours 23 min., with the panel producing 1.38 million t (1.52 million short t) overall.

The second panel: 7/VII/385

With the first panel complete, the plough system was moved to a new area in Bogdanka's Stefanów section. This panel (7/VII/385) was different from the first, experimental panel in some important ways. The face was widened from 250 m to 305 m (820 ft to 1000 ft) and the panel length was increased by about three times – to 5.022 km (3.12 miles). The thickness of the seam in this area ranges from 1.2 m to 1.6 m (47 – 63 in.) with an average thickness of 1.42 m (56 in.). The 7/VII/385 longwall started up at the beginning of October 2011.

In this panel, Bogdanka used a different return belt conveyor station, with a 12 m (39 ft) overlap instead of the 3 m (10 ft) used in the first panel. This allowed the face equipment to run longer before the conveyor belt had to be shortened, which achieved greater utilisation of the plough.

In addition, the mine installed a special ramp in the main gateroad that helped load any material that had been pushed out from the face by the plough body on to the AFC. This eliminated the need for a dinting machine, which was used to handle this material on the first panel.

Another important change was to relocate the plough control station from its original position in the energy train underground to a special control room in the Stefanów administration building. The surface control room was also equipped with a number of additional control systems for monitoring ventilation, energy supply, conveying, transport and other vital processes.

A control centre plays an important role in achieving high production. In order to effectively control all of the plough system components, the dispatcher must react as quickly as possible when there are unscheduled stoppages. The dispatcher must have direct access to all of the relevant monitoring systems, including the power supply, the pump stations for the high-pressure hydraulic fluid and cooling and spraying water, the conveyors, bunkers and shaft system, ventilation and methane control, as well as material transport, among others. Being able to see all this information at a glance makes it easier to respond quickly should the face equipment stop unexpectedly. For a high-performance plough face, a 1 min. break means a loss of 15 – 30 t (16.5 – 33 short t), which quantifies the importance of quick responses to unusual situations.

The plough system in the second panel reached a ROM production level of 10 000 – 15 000 tpd (11 000 – 16 500 short tpd) relatively quickly. The daily utilisation rate for the plough increased from the six hours achieved in the first panel to more than ten hours in the second. This resulted not only from the longer face, but also from experience gained on the first panel and from technical improvements.

On 16 February 2012, Bogdanka broke the world record for daily production from a plough-equipped longwall, with an output of 24 900 t (27 390 short t) of coal from the 7/VII/385 panel. During the day, the plough face advanced more than 27 m (89 ft) at a 1.63 m (64 in.) cutting height.

The second panel was finished in February 2013. The average performance reached during the 16 months of operation in this panel was 11 778 tpd (12 983 short tpd).

Bogdanka attributes this achievement to a number of factors. The first of these is that it is now one of the most advanced mines in the world and is able to make use of high-capacity, high-efficiency mining equipment.

The second key factor is that the workforce at the mine is well motivated and has a high level of technical expertise. In these conditions, it is easy to see the advantages of using plough technology. The machine utilisation is critical and is maximised when ploughing from face-end to face-end with a double web at the face ends – the system that is used at Bogdanka.

By using a system like this, a plough face can achieve at least 50% better performance than a shearer working under comparable

conditions, both overall and as a proportion of the daily running time.

Bogdanka's second plough set

During the 2H12, Bogdanka installed a second plough system, this time in its Nadrybie section. The new longwall was located close to the first panel, which was mined in 2010, but had moved in the opposite direction. The ROM coal had been transported underground to the No.2.1 shaft at Stefanów.

The new system is used on 250 m (820 ft) long faces and is based mainly on the technology used in the original face. There are, however, some important changes.

Instead of using 210/630 kW (282/845 hp) motors, the new system is equipped with asynchronous motors with 800 kW (1073 hp) of installed power. In addition, 3.3 kV variable-frequency drives (VFDs) are used for powering the plough and AFC motors, while the specially developed Cat CST45 M is be used for driving the plough instead of the P45 UEL gearboxes.

The explosion-proof medium-voltage VFDs of this type were used in a longwall in underground mining for the first time anywhere in the world. They are housed in a flame-proof enclosure and use a pulse width modulated (PWM) current source inverter (CSI) for the machine-side converter. VFDs of this type have an effective power structure, with a current-limiting DC link inductor. All four VFDs, together with a special liquid cooling station, are positioned in the energy train on the tailgate side of the plough system. The cooling station is acting on all four VFDs, using a closed circuit for the coolant.

The application of CSI VFDs brings a significant improvement for the plough and AFC operation. It implements several advantages:

- Application of standard asynchronous motors.
- Distance between motors and powering VFDs under Polish mining law up to 4 km (2.5 miles).
- Variable speed for AFC and plough in a wide range (0 – 120% of nominal speed).
- Precise torque control of the asynchronous motors.
- Full utilisation of installed power on both plough's motors through load shearing.
- Improvement of overload protection for motors and chains.
- Braking possibilities and thus returning back power to the network.
- Unlimited start-ups of the motors.
- No significant voltage drop during start-ups.
- The usage of weaker networks is possible.
- The control system for the VFDs is located on the surface.

Another important technical innovation is the very first application of a new CST gearbox. This unit is designed for operation at any rotational speed, unlike any CST drive previously in operation. The application of CST drives delivers very sensitive overload protection for the chains.

The third and fourth plough set

Bogdanka implemented its third and fourth plough systems in late 2014. Both systems are based upon GH1600 technology with Cat roof supports. Every system is equipped with CSI VFDs on the plough and AFC and with the newest generation of CST – VM gearboxes. As of early 2015, there are four high performance plough systems operational at the Bogdanka mine.

Conclusion

Bogdanka has proved beyond any doubt that plough technology can provide world-leading performance – not just one time, but day after day, month after month, year after year. At a time when Europe's hard-coal mining industry has to operate within an increasingly competitive world market, the mine relies on its plough systems to keep production costs under control and to help it reach its new production targets. Given its success to date, this should not be difficult. WC

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