

# Operational Experiences with Automated Plow Systems at Pinnacle Mine in the US

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# Abstract

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Coal has been mined at the Pinnacle Mine (former U.S. Steel #50) in West Virginia using plow systems since 1977. Over the decades scores of panels were mined in the Pocahontas coal seam using plow longwalls. In the 1990s the world's first automated plow system was implemented at this coal mine and achieved the world production record of 22,700 tonnes. Pinnacle is currently operating a new modern GH1600 plow system from Caterpillar.

## KEYWORDS

Plow systems in the USA, Pinnacle Mine in West Virginia, low seam extraction, longwall, plow technology

# 1. Introduction

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Longwall mining has been in use in the U.S. since the 1950s. In the early years, many plow systems were used there for mining thin seams. At that time, however, plow systems were far inferior to today's technology, with much lower installed power and efficiency and with no comparable level of automation. Since then, thicker seams have been mined and some early improvements to shearers made them the system of choice of miners throughout the country.

In spite of the decreasing number of plow systems in the U.S., the predecessors of Caterpillar's plow product group (Westfalia Lünen, DBT and Bucyrus) have supplied a number of plow systems to the Pinnacle Mine near Pineville, West Virginia over the last 22 years. These plow systems have performed remarkably, even setting a world record.

## 2. Pinnacle Mine

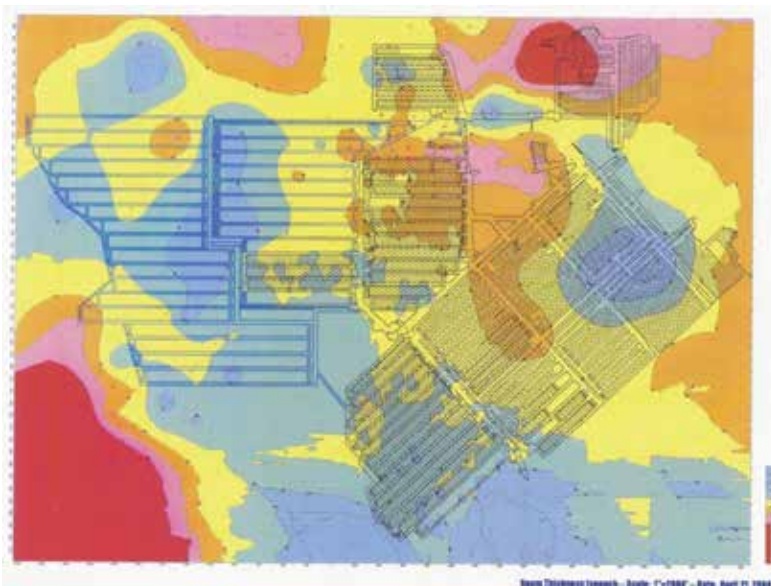
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The Pinnacle coal mine lies in southwestern West Virginia, near the city of Pineville. All exploitation of black coal at this mine is carried out in the Pocahontas #3 seam. This seam lies at a depth between 300 and 500 m and has a thickness of 1.1 to 1.4 m (1.25 m on average). All mine activities are in horizontal deposits, with an inclination of less than 5 degrees. The coal in the Pocahontas seam is classified as 'easily plowable'.

Since 1977, the mine has used roof-fall exploitation with plows and roof supports. All faces were extracted using the retreat mining system. Initially, four parallel entries were prepared on each side of the face, resulting in very high heading costs. The number of entries was later reduced to three to enable timely preparation of the entries for the next panel, an issue because of the high mining speeds of the plow system. For this reason, transport and conveyance were located in a common entry. The entries at Pinnacle have a height of approximately 1.4 to 1.5 m. Only the main transport and conveyance entries have a height of 2 m. Generally, all entries are anchored.

While the face length was fixed to a maximum of 250 m, the panel length was limited to 2200 m for firedamp prevention reasons. To ensure efficient CH<sub>4</sub> control, gas drainage drillings were carried out from the surface, as well as from the entries. Because of strong dust development, greater-than-average water spraying is called for. Initially, coal was transported to the surface by rail carriages, but a central belt conveyor was later installed.

Up until 1989, U.S. Steel Mining Company (USM) #50 mine had two longwall systems with a PF 2 600 VS AFC and a type 7-26 plow. The mine used Hemscheidt roof supports with the Hetronik electric-hydraulic control system. When both these face systems approached the end of their lifespan, it was decided to purchase a new automated plow system. U.S. Steel Mining Company prepared a tender for what was then a revolutionary technology in close collaboration with German mining engineers from the Westerholt mine. One element of that tender was a modern and highly comprehensive plow system with incremental advance of the AFC at high pressure and automatic plowing with automatic reversal of the plow at the face ends.



**FIGURE 1. Map of U.S. Steel #50 Mine (now Pinnacle Mine) (date April 21, 2000)**

This mine map of U. S. Steel #50 shows the sealed area of former mining activities, as well as the location of future panels. #50 mine has five shafts, one of which is the inclined main shaft (coal and material transportation). Three Continuous Miners are being used for roadway development.

### 3. First Plow System from 1989

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The Pinnacle mine has been successfully extracting coal with plow systems since 1977. Bucking the trend toward shearers at the end of the 1980s, USM decided to purchase what was then a state-of-the-art plow system.

In 1989, US Steel's Pinnacle mine became the world's first automated longwall face, eliminating the need for an operator at the face. The mine used a complete Gleithobel plow system with full automation built by Westfalia Lünen (now a part of Caterpillar). The two plow longwall systems delivered to U.S. Steel #50 Mine in 1989 and 1990 by Westfalia Lünen were the world's first fully automated plows, representing the state of the art at the time.

The world's first fully automated longwall system met these specifications:

- Face length: 250 m
- 2-leg roof supports with PM 3 controls, 1.75 m centers
- Installed plow power: 2 x 270 kW
- Plow guide: 9-34 ve
- Plow chain: 30 mm (later 34 mm)
- Plow speed: 1.54 m/s
- AFC width: 900 mm
- Installed AFC power: 2 x 270 kW

In 1991, a new plow guide was implemented, allowing the use of 38x137 mm chain and installation of up to 2 x 400 kW power. In 1994, five years after the start of the system, a new AFC drive system called CST (Controlled Start Transmission) became operational. CST ensured:

- No-load motor start
- Synchronized heavy-load start-up
- Accurate load sharing
- Excellent overload protection

The initially defective electronic controls were later (in 1996 and 1997) replaced by the reliable PM 4 system built by DBT (now part of Caterpillar). In 1995, a new 5.7 plow body with all parts exchangeable underground was introduced. In 1999, a new UEL plow planetary gearbox with overload protection came into use, allowing application of up to 500 kW power.



**FIGURE 2. First plow system from Westfalia Lünen used at U.S. Steel #50**

Average production has been in excess of 10,889 clean tonnes per day. The peak production record achieved is 18,145 clean tonnes per day.

## 4. Second Plow System from 1999

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In 1999 DBT delivered a second fully automated plow system. The technical specifications of that plow were:

- Face length: 319 m
- Installed plow power: 2 x 400 kW with HK 30-2 plow box
- Plow guide: 9-38 ve
- Plow chain: 38 mm
- Plow speed: 1.98 m/s
- Plow body: triple 2.7
- AFC: PF4/1032 mm with cross-frame
- Installed AFC power: 2 x 600 kW
- AFC speed: 1.86 m/s



**FIGURE 3. Plow system delivered for U.S. Steel #50 mine in 1999**

The plow at the U.S. Steel #50 Mine operates with a large cutting depth of up to 250 mm. This large web results in large loading streams of extracted coal. Experience shows that a single plow body has difficulty loading such a large amount of coal. For this reason, a new triple plow body was developed with bottom bits located near the center of the plow allowing loading of extracted coal at two different points simultaneously. As with the previous plow body, all wear parts were exchangeable underground.

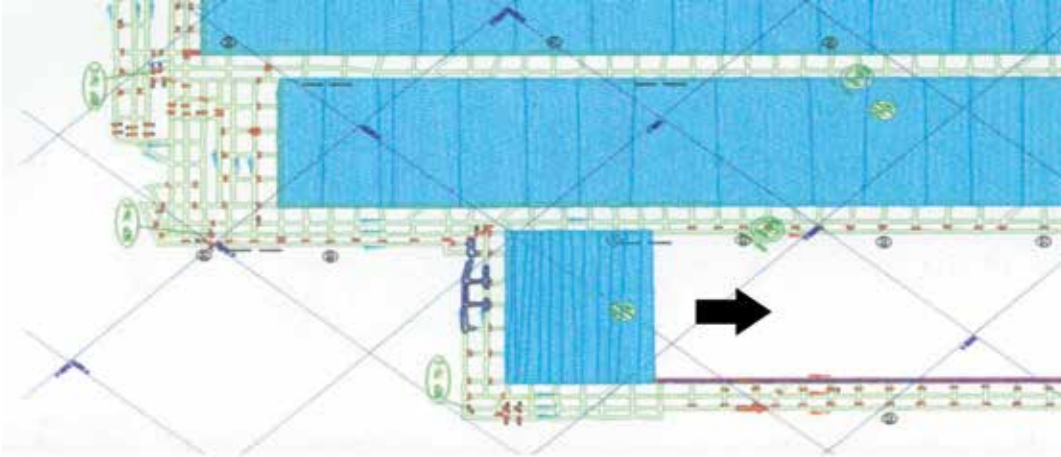


**FIGURE 4. The type 2.7 triple plow body used at the U.S. Steel Mine since 1999**

## 4. Second Plow System from 1999

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Fig. 5 (*below*) shows panel 7 O in detail, including its three-entry system. The face length was 290 m, and the panel length was 2,800 m. The seam thickness was 1.4 m. Underground installation took place between February and March 2000, with the panel starting production at the end of March.



**FIGURE 5. Panel 7 O at USM #50**

This plow system reached cutting depths of 240 mm uphill and 220 mm downhill at a seam height of 1.4 m. The plow system achieved production rates of up to 1,400 t/h. Based upon a daily plow run time of 14–16 hours (regularly achieved at #50 mine), daily production of 14,000 to 17,000 t/d of clean coal was achieved. The peak production achieved from that face was 22,700 t/d clean coal, a world record for a plow face.



## 5. Third Plow System from 2010

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After ten years of very intense mining activity, the Pinnacle Mine decided to purchase a new longwall system for extraction of the Pocahontas seam. A comprehensive study of available technologies was undertaken to select the most reliable and efficient system and ensure the lowest possible production costs. After a very detailed analysis, Pinnacle Mine—which at that time belonged to Cleveland Cliffs, Inc.—decided in favor of a plow system. After comprehensive discussions, the company decided to purchase an automated plow system from Bucyrus (now part of Caterpillar).

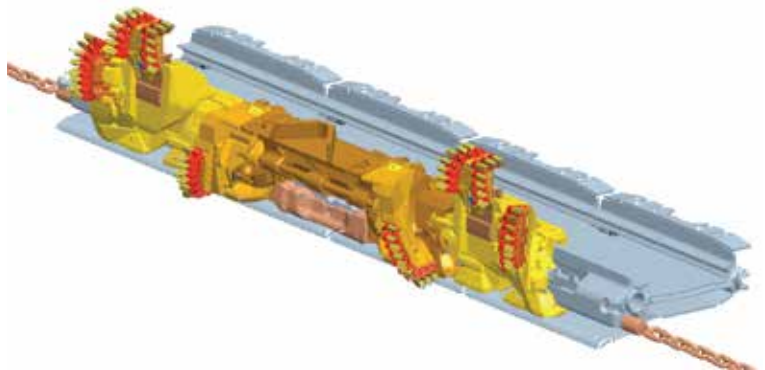
This plow met the following specifications:

- Face length: 300 m
- Roof support: Bucyrus 850/1930 2x3181
- Machine frame: MR35-1100/1500
- Installed plow power: 2 x 600 kW / 4,160 V, 60 Hz
- Plow box: HK 40-2
- Plow chain: 42 mm
- Plow speed: 1.98 m/s
- Plow body: GH1600 Pinnacle type (triple body)
- AFC: PF4/1132 mm with cross-frame
- AFC chain assembly: 2 x 34x126 mm, spacing 6
- AFC gearbox: KP30 CST
- Installed AFC power: 2 x 600 kW / 4,160 V, 60 Hz
- AFC speed: 2.13 m/s



**FIGURE 6. The new plow system delivered to the Pinnacle Mine in 2010**

The newest plow system for the Pinnacle mine was assembled and extensively tested during the compatibility test, which took place in July 2010 in Houston, Pennsylvania. A 50-meter-long plow longwall system, together with roof supports, energy supply and control units, was set up, tuned and screened over a period of two weeks. This was necessary, as the system incorporated several new technical solutions being implemented for the first time.



**FIGURE 7. Plow body of the 2010 plow system for the Pinnacle mine**

## 5. Third Plow System from 2010

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The GH 1600-2 plow body for the new Pinnacle plow face had a similar configuration to the previous one. The plow body consists of two external parts and one intermediate part, with the drive chain attached to the plow body via the pulling sledge. The plow body is designed in this way because heavy coal streams would be difficult to load onto the AFC with a single body. The bottom bits are located near to the middle of the lateral axis to improve the behavior of the plow body when crossing undulations.

The plow system consists of two types of roof supports: face and gate. Face roof supports support the roof where coal is being mined while gate roof supports protect the gate ends of the plow system.

The face roof supports have a retracted height of 0.88 m and an extended height of 1.97 m. A hydraulic cylinder with a diameter of 300 mm delivers a yield strength of 715 tons. The transport length, which is critical for a roof support around the mine, is 5.64 m, and the roof support weights 16.3 tonnes.

The gate roof supports have a yield strength of 945 tonnes, a retracted height of 1.14 m and an extended height of 3.05 m. The collapsed and extended height ranges are slightly higher to accommodate and protect the equipment in the gate entry. The length and weight increase substantially to 8.18 m inches and 26.1 tonnes, respectively.

These roof supports have been designed and validated through rigorous testing. Their life expectancy will enhance overall performance and the ultimate return on investment.



**FIGURE 8. A face roof support for the newest Pinnacle plow system**

The plow system commenced service at the Pinnacle mine at the end of 2009 in a relatively short panel. After the move to a new panel, the plow system started again in the spring of 2011. In mid-2011, the Mining Safety and Health Administration (MSHA) closed the Pinnacle mine for several months because of a CO occurrence and required countermeasures.

Currently, the Pinnacle Mine and its plow system face have been operational again for some two months and achieving daily production rates of over 10,000 tonnes. The current production restrictions are caused by CH<sub>4</sub> occurrence. The performance of the Pinnacle mine is expected to increase significantly after overcoming these restrictions.

## 6. Summary

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Based on a performance perception dating back to the 1970s, when plow systems were not automated and did not have the cutting and conveying power of today's systems, the US has been reluctant to embrace plow technology.

Nevertheless, the Pinnacle Mine (former U.S. Steel #50 Mine) in West Virginia has been using plow systems since 1977. In 1989, U.S. Steel #50 Mine purchased world's first automated plow system from the German company Westfalia Lünen. This system operated for ten years and achieved excellent production: Almost 11,000 t/d clean coal in Pocahontas #3 with an average seam thickness of 1.25 m.

Ten years later, the next plow system—this time purchased from DBT—was implemented in U.S. Steel Mine #50, operating successfully for the next 11 years and setting the plow face world record of 22,700 tonnes of clean coal in a day.

In 2010, following exhaustive research into the most efficient mining method for low-seam coal, Cliffs Natural Resources decided to use an automated Cat plow longwall as the safest, most cost-effective and most environmentally friendly way to extract coal from low and medium seams—seams with thickness of less than 1.8 m.

# Operational Experiences with Automated Plow Systems at the Pinnacle Mine in the US

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