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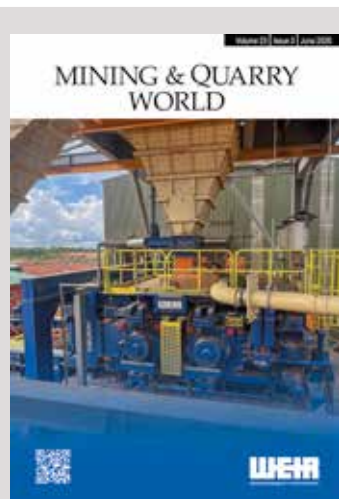
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### BHP makes its biggest-ever community investment in WA

BHP has committed \$160 million to community infrastructure projects in Port Hedland, including an \$80 million upgrade of Hedland Senior High School, a new aquatic centre and service worker accommodation.

“Strong communities like Hedland don’t happen by chance. They’re built by people and supported by partnerships that last,” BHP Australia president Geraldine Slattery said.

“This is BHP’s biggest community investment in Western Australia. It will help young people get a good education, build great local facilities and ensure more housing for the people who deliver vital services to the region.”

The largest component of the package will fund the redevelopment of Hedland

Senior High School, which caters to more than 1200 students each year. Obsolete buildings will be replaced with new science, technology and classroom facilities, with initial stages expected to be completed by early 2029.

The upgrade is expected to support student outcomes, strengthen family retention and contribute to long-term workforce development in the Pilbara.

The investment also includes \$10 million towards accommodation for essential service



workers and \$20 million for a new aquatic centre, which will replace ageing facilities and support population growth, community health and youth engagement.

BHP Western Australian Iron Ore asset president Tim Day said the projects

will deliver lasting benefits for the community.

“These projects will transform how Port Hedland locals experience education, recreation and everyday life in the town – ensuring modern facilities that support a thriving regional centre.”

### Russian Platinum plans November launch of Arctic mine

Russian Platinum plans to start production at its Arctic polymetallic project in November, the company’s owner said recently.

Currently only metals giant Nornickel produces platinum group metals (PGM) in Russia.

Russian Platinum had planned to launch the first stage of the project in 2024, but postponed it owing to difficulties

accessing equipment amid Western sanctions.

“We expect to obtain our first output in November this year,” Musa Bazhaev said at the St Petersburg Economic Forum.

The company has licences for the Chernogorskoye deposit and the southern part of the Norilsk 1 deposit, which contain copper/nickel ores with high PGM content

mainly used in emissions control catalysts and electronics.

These deposits are located near Nornickel’s core assets and the companies agreed in 2018 to create a PGM alliance, but it collapsed in 2020 due to opposition from Rusal, one of Nornickel’s biggest shareholders. After that, the parties signed five year offtake agreements

in 2021 for concentrate supplies from the Chernogorsky plant to Nornickel’s Global Palladium Fund.

Nornickel, the world’s largest palladium producer with around a 40% market share,

said in a market review late last year that Russian Platinum’s project could add about 500 000 oz of palladium and 200 000 oz of platinum to Russia’s output annually.

Capital expenditure on Russian Platinum’s project has already reached 500-billion roubles (\$6.72-billion), Interfax reported, citing Bazhaev.

Bazhaev said a second phase of the project is expected to bring on stream the southern part of Norilsk 1, with output reaching 15-million tons of ore and 55 t of PGMs annually.

That would make Russian Platinum a major global supplier, Bazhaev said, but did not give a timeframe for when the second phase would start operations.

He also said Russian Platinum could return to partnership discussions with Nornickel.



## Major miners consider unified China iron ore strategy

Major miners BHP, Rio Tinto and Fortescue are reported to have urged for closer coordination and potential government support as they respond to China's reshaping of global iron ore purchasing through China Mineral Resources Group (CMRG).

Iron ore is Australia's largest export earner at about \$115 billion annually, but China may impact this as it has centralised roughly 70 per cent of imports through CMRG, established in 2022.

The Australian Financial Review has reported Australian producers are increasingly considering whether a more unified negotiating approach could strengthen their position, despite long-standing competition rules that have traditionally prevented

coordinated pricing or volumes.

"If we can enhance our competitive ability in what is clearly a global marketplace for iron ore, then we should be doing just that," former ACCC chair Graeme Samuel told AFR.

The Federal Government has been monitoring the situation, as discussions between miners and CMRG came up again this week.

"Iron ore pricing is ultimately a matter for iron ore producers and their customers," a spokesperson for Resources Minister Madeleine King told AFR.

At company level, BHP chief financial



officer Vandita Pant said cooperation across the sector is being explored.

"You [BHP and Rio] should be thinking of any opportunities to work together," Pant said at the Australian British Chamber of Commerce, adding that any approach must preserve transparency.

"This is quite important across every commodity."

Industry executives say negotiations with CMRG have become more challenging, reinforcing interest in a coordinated industry stance as Australia's iron ore sector adapts to shifting global demand dynamics.

## Sandvik partners with Rio Tinto to advance autonomous open-pit drilling

Sandvik and Rio Tinto are partnering to jointly develop and integrate Sandvik i-series surface drill rigs with Rio Tinto's Autonomous Drilling System (Rio Tinto ADS™). The collaboration combines Rio Tinto's experience in autonomous drilling and remote operations with

Sandvik's AutoMine® automation technology to improve safety, productivity and system compatibility, starting initially on support drilling activities in open-pit mining operations.

Under the agreement, Sandvik and Rio Tinto will co-develop the interoperability and

autonomous capabilities required for remote, multi-rig and multi-site autonomous operation via Rio Tinto's Perth Operations Centre. The program will include field trials to validate performance against production targets.

The project will

begin with development and on-rig testing at the Sandvik Test Pit in Finland, followed by site-based testing at Rio Tinto operations in Western Australia.

"This joint development reflects Sandvik's commitment

to improving safety and productivity through open, interoperable automation," said Petri Virrankoski, President of Surface Drilling at Sandvik. "Building on AutoMine® and our i-series platform, we are proud to extend our long-standing relationship with Rio Tinto and support the continued development of autonomous drilling for demanding Pilbara conditions."

The joint program builds on Rio Tinto's long track record in autonomous systems, including the remote monitoring and control of drills, trucks and trains from Perth. This approach is in active use at Rio Tinto Iron Ore sites such as Gudai Darri, which combines an autonomous mobile fleet with a digital operations model.



### Epiroc wins order for LinkOA, extending its autonomous haulage system to aggregates sector

Epiroc AB, a leading productivity and sustainability partner for the mining and infrastructure industries, has won an order from Heidelberg Materials, one of the world's largest integrated manufacturers of heavy building materials and solutions, to adapt and implement autonomous solutions for driverless haul trucks at a quarry in Australia. The deployment extends Epiroc's award-winning autonomous solution LinkOA beyond mining to include the aggregates sector.

The proof-of-concept project will demonstrate how automation can be applied in mid-scale quarry operations, where design variability and more complex conditions compared to more standardized surface mining operations have traditionally limited adoption of automation.

"We are proud to partner with Heidelberg Materials to support them on their autonomous journey," says Helena Hedblom, Epiroc's President and CEO. "Our LinkOA system is already a proven mining automation technology, and with this project we look forward to bringing the same productivity and safety

benefits to the aggregates sector."

The order follows Epiroc's crucial role in creating the world's largest OEM-agnostic and fully autonomous mine, Roy Hill in Australia, using LinkOA. The parties have agreed not to disclose the order value.

Heidelberg Materials announced recently that it is "working closely with established technology partners" to ramp up the use of autonomous heavy mobile equipment globally, aiming to reach around 30 autonomous vehicles this year and more than 100 by the end of 2028. As one of Heidelberg Materials' technology partners, Epiroc will deploy LinkOA for some of the company's Komatsu HD605 haul trucks, which will also interact with loaders and auxiliary vehicles, at a quarry in Western Australia.

The project focuses on validating safe mixed-fleet operation, improved haulage efficiency, reduced operator dependency, and system performance across varying conditions. Autonomous haulage brings proven productivity and safety benefits such as 24/7 operation, removal of operators from hazardous environments, and reduction

of accidents linked to human error and fatigue.

LinkOA is Epiroc's open, OEM-agnostic autonomy platform that unifies haulage, drilling and blasting under a single intelligent control layer. Using advanced sensors, cameras and AI, LinkOA improves situational awareness, removes personnel from hazardous environments, and enables real-time, data-driven decision-making across mixed fleets.

In 2025, Hancock Iron Ore's Roy Hill mine, with support of the LinkOA system used on 78 mining trucks, became the world's largest OEM-agnostic, fully autonomous mine. More than 350 million tonnes of material have been moved autonomously at this mine.

Also last year, Epiroc, using LinkOA, partnered with Luck Stone, one of the United States' leading producers of crushed stone, to deploy a fully autonomous SmartROC D65 drill rig. This was also the first fully autonomous surface drill rig delivered to the quarry market worldwide.

LinkOA was named Engineering Product of the Year at the 2026 Digital Engineering Awards.

### USA Rare Earth to invest \$1.2bn in South Carolina facility

USA Rare Earth said recently, it will invest \$1.2-bn to build a magnet manufacturing and rare earth metals facility in South Carolina, as it expands domestic production capacity.

Shares of the company rose 5.9% to \$31.1 in morning trade.

The plant in Cherokee County is expected to produce 6 400 t/y of neodymium-iron-boron magnets and 5 000 t of rare earth metals and alloys, with commissioning targeted to begin in 2028.

USA Rare Earth said site work is expected to begin in the coming months.

The facility will complement the company's existing magnet plant in Oklahoma, as it aims to build total domestic capacity of 10 000 t/y of magnets and metals.

The company said the magnets and metals will support industries such as defence, aerospace, semiconductors, AI and energy that rely on secure rare earth supply chains.

The investment comes as the US seeks to reduce reliance on China for rare earth materials. USA Rare Earth is

backed by the US government through a \$1.6-bn debt-and-equity funding package to develop another facility in Texas.

However, the company has faced scrutiny from US lawmakers, who say the structure of the funding package could give the government "highly concerning" leverage over the company while also boosting US Commerce Secretary Howard Lutnick's family-run investment firm.



## Cornish Tin & Lithium discovers more larger-than-expected lithium resources

Cornish Tin & Lithium (CTL), formerly Cornish Tin Limited, a company focused on the discovery and development of high-grade tin and hard-rock lithium resources in Cornwall, has announced significant results from its Phase 3 exploration drilling programme at the Tregonning project, alongside the launch of its new corporate identity.

CTL's Phase 3 exploration drilling programme, which was conducted between September 2025 and January this year, was primarily designed to target lithium-enriched aplite-pegmatite sheets in the newly identified Tregonning South extension area. Drilling has also intercepted an extensive new tin system, as well as very successful lithium results.

The drilling confirmed that a newly identified lithium-bearing rock formation, called the Newall Formation, continues far beyond the area where it was first discovered at Tregonning North. Earlier drilling there found high lithium concentrations, including an interval of 0.3 m

grading 1.33% lithium oxide, with peak grade of 1.42% lithium oxide.

The Phase 3 results show that this lithium-bearing system extends for about 3.27 km from Tregonning North to Tregonning South. Drilling also found several lithium-bearing layers at different depths across the area, suggesting the project may contain a larger lithium resource than previously thought.

Phase 3 drilling also intercepted a new tin mineralisation system across Tregonning South, including ten tin lodes identified to date and an associated sheeted vein system, highlighting the project's growing potential as a significant source of both lithium and tin.

CTL encountered high-grade tin mineralisation across multiple lodes, including up to 2.69% tin in Norcross No.1 Lode, 1.26% tin in Rib North Lode and 1.68% tin in Rib South Lode.

Together, these discoveries further strengthen Cornwall's position as a strategically



important source of critical minerals essential to the UK's energy transition, industrial resilience and long-term supply chain security.

To coincide with these successful exploration results, the company also announced its new name, Cornish Tin & Lithium, to reflect its strategic evolution and expanding focus on critical minerals essential to the global energy transition. "The name change underscores the company's dual-commodity focus and its potential to be a leading domestic source of responsibly produced tin and lithium, both vital for technologies such as electric vehicles, renewable-energy

systems, and advanced electronics," says CEO and founder Sally Norcross-Webb.

"Building on the success of our previous drilling programmes at Wheal Vor and Tregonning North, the results of Phase 3 at Tregonning South are also excellent. Never before explored systematically, Tregonning South clearly has spectacular potential. As a combined mining operation, our project areas in West Cornwall could make a very significant and positive contribution to Cornwall's economy and the critical minerals resilience of the UK and Europe," she concludes.

## Weir wins major contract to supply WARMAN® pumps for high-altitude Xizang copper mine expansion in China

Weir, a mining technology company, has secured a multimillion-dollar contract in quarter two with a major Chinese non-ferrous metals company to supply WARMAN® pumps for the Phase III expansion of a Xizang copper mine.

The scope includes two WARMAN® MCR® 450 cyclone feed pumps, and nine WARMAN® AHPP 20/18 tailings transfer pumps for use in the grinding circuit and tailings facility.

The expansion will increase processing capacity from 19.9 million tonnes to 30 million tonnes per year, delivering an annual copper output of up to

200,000 tonnes. Weir's equipment will play a critical role in supporting efficient operations in one of the world's most challenging mining environments at the country's second largest copper mine.

The contract was awarded based on Weir's strong total cost of ownership, underpinned by proven performance, durability and lifecycle value. The decision was further reinforced by endorsement from the China ENFI Engineering Corporation (China Nonferrous Engineering and Research Institute, "ENFI") and the customer's prior positive experience with

WARMAN® pumps.

Configured to operate effectively at elevations of up to 5,118 metres above sea level, WARMAN® pumps incorporate advanced wear-resistant technology to maximise uptime, extend service life and reduce maintenance requirements. Weir will provide end-to-end lifecycle support spanning commissioning, start up and ongoing operations with their teams of expert engineers.

Jack Wang, Sales Director of Weir China said: "High-altitude mining environments place significant demands on equipment, particularly in extreme cold and low-oxygen conditions. Our

WARMAN pump solution is engineered to perform consistently in these conditions while helping reduce maintenance and lifecycle costs.

This contract reflects the strong confidence placed in Weir, underpinned by ENFI's endorsement and the customer's proven experience with WARMAN pumps. Together with our end-to-end lifecycle support – from design and manufacturing through to installation, commissioning and ongoing operations – we are helping ensure reliable, cost-efficient and stable performance over the life of this project."

# Breathing Life Into the Mine: Modern ventilation for safer, smarter operations

**Gordon Barratt of *Coal International* and *Mining & Quarry World* looks at the fundamentals of mining ventilation. Effective ventilation remains one of the most critical determinants of health, safety, and productivity in underground mining. Well designed systems not only dilutes and removes toxic and explosive gases but also delivers the fresh air required to sustain efficient working conditions at the face. For modern mines – whether deep hard rock operations or extensive coal workings – ventilation is not simply an engineering requirement; it is the backbone of safe production.**

**U**nderground mining has always been a battle against the invisible. Long before mechanisation or modern safety systems, miners understood that stale, foul, or explosive air could kill as surely as a roof fall. The story of ventilation is therefore the story of how underground coal mining became possible at scale.

## **AIRFLOW UNDERGROUND: THE ORIGINS OF MINE VENTILATION**

The story of how miners have understood and controlled the movement of air underground stretches back thousands of years. Long before ventilation became a science, working miners were making practical observations that shaped the foundations of modern mine airflow.

As early as 4000–1200 BC, European miners were driving tunnels into chalk to extract flint. Excavations at Grimes Graves in southern England show that these Neolithic workers used brushwood fires at the face – likely to fracture the rock. In doing so, they would have seen first-hand how fire draws air through confined spaces. That simple observation, made at the working face, became a principle rediscovered repeatedly by the Greeks, the Romans, medieval miners, and later during Britain's Industrial Revolution.

By 600 BC, the Laurium silver mines of Greece were already demonstrating a deliberate approach to ventilation. Their layouts show that Greek miners understood the need for a connected circuit, with at least two airways serving

each major working area. Evidence also suggests they used divided shafts to separate intake and return air – an early form of controlled ventilation.

Roman metal mines continued this practice. Many had twin shafts, and Pliny the Elder (AD 23–79) recorded how workers used palm fronds to push air along headings – primitive, but unmistakably a ventilation technique.

For the next 1,500 years, European metal mining left few written records, but the first comprehensive technical text arrived in 1556 with Georgius Agricola's *De Re Metallica*. Working in the mining districts of Bohemia, Agricola documented the methods of his time with remarkable detail. His illustrations show miners diverting surface winds into shafts, operating wooden centrifugal fans driven by men or horses, using bellows for auxiliary ventilation, and installing air doors to control flow. He also recognised the dangers of "blackdamp" – oxygen-depleted air – and the explosive threat of "firedamp," which he compared to a dragon's fiery breath. The English translation, completed in 1912 by Herbert and Lou Hoover, remains a cornerstone of mining literature.

From the seventeenth century onward, papers presented to the Royal Society began to examine the explosive and toxic nature of mine atmospheres. As the Industrial Revolution accelerated coal demand, conditions in many British coal mines became increasingly hazardous. Ventilation relied either on natural draught – often ineffective when surface and underground temperatures equalised – or on fire. Early ventilating furnaces were built at surface, but miners soon discovered that lowering burning coals in a wire basket down the upcast shaft produced a stronger

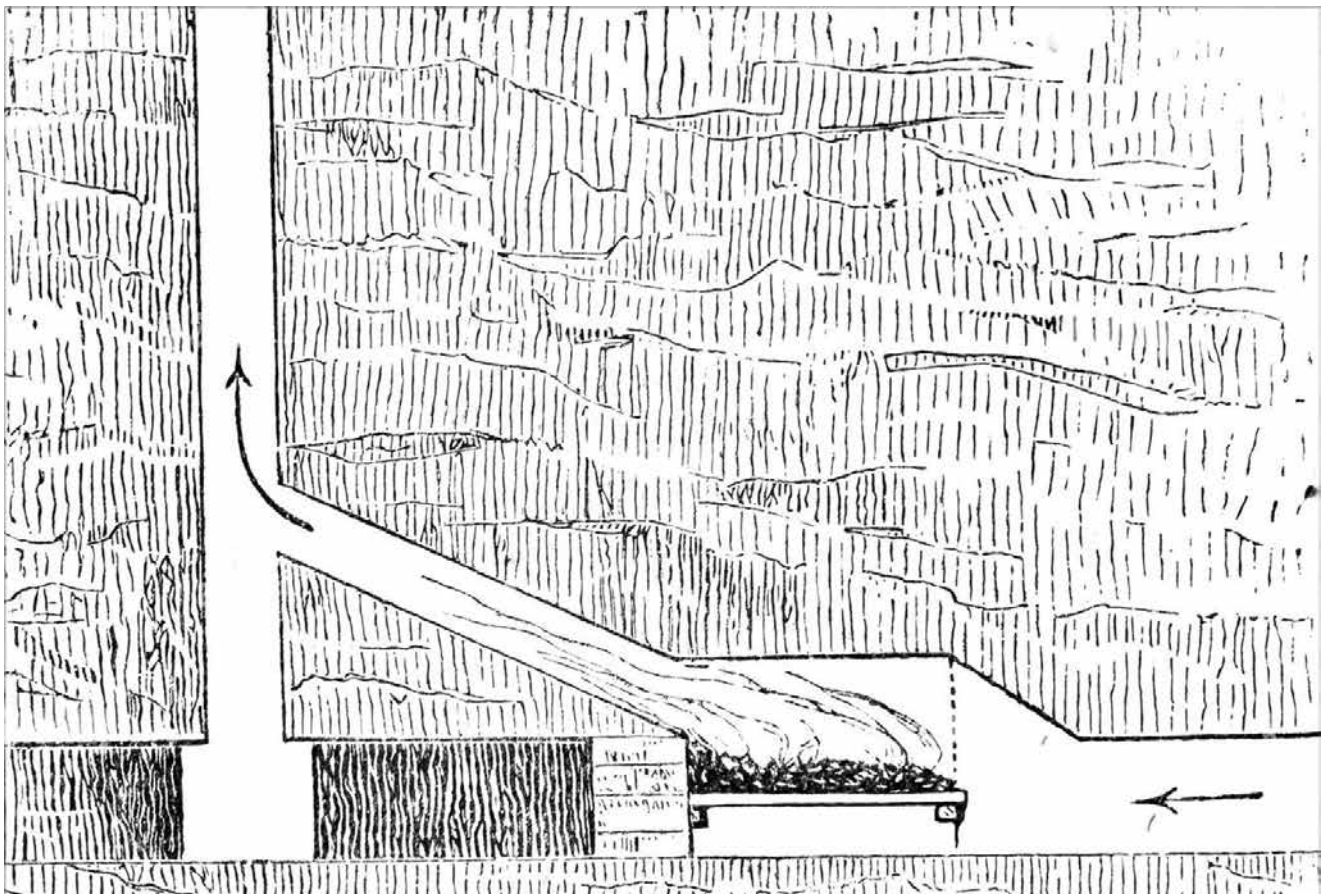
draught. This insight led directly to the development of shaft-bottom furnaces.

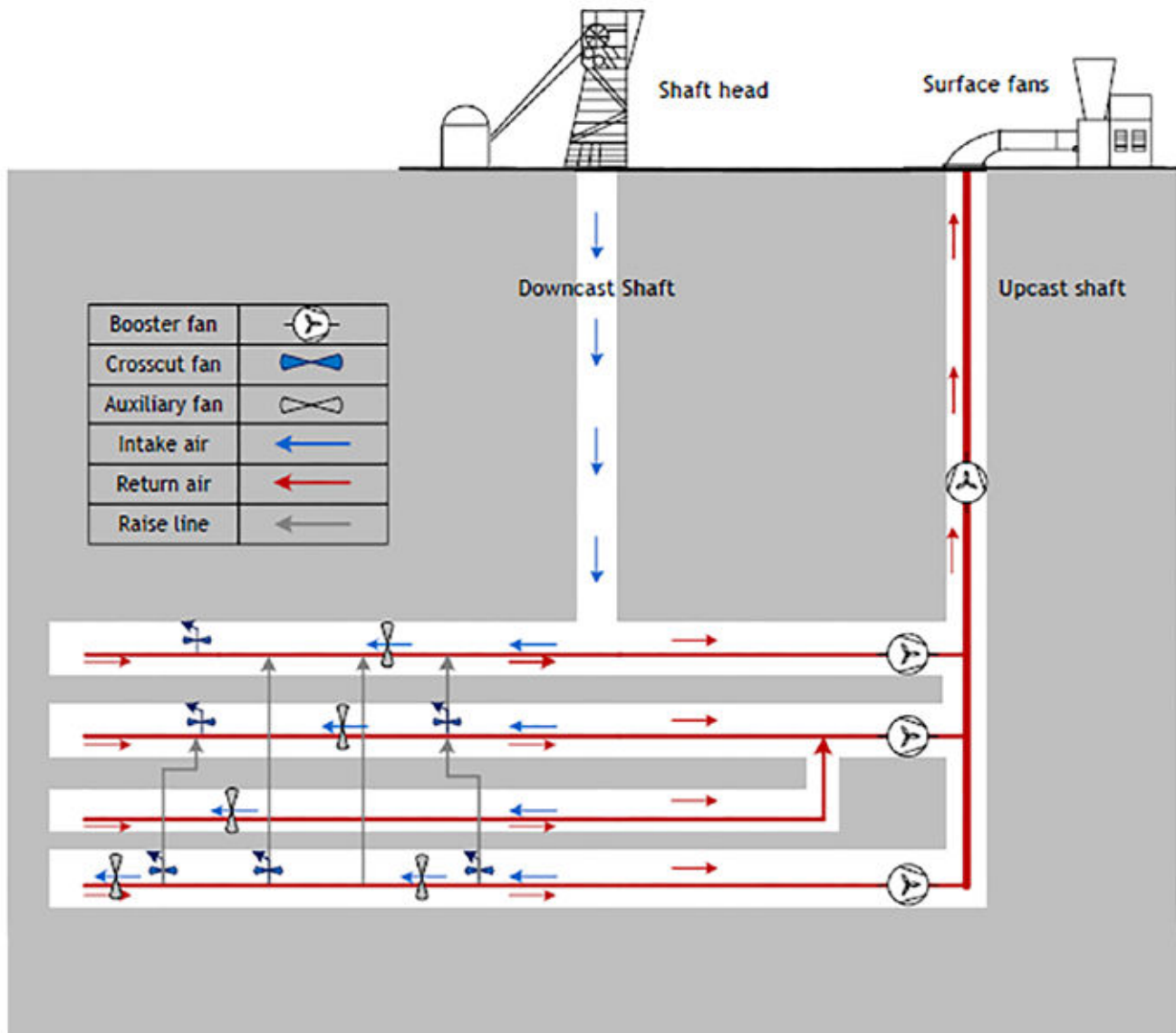
Throughout this period, the only source of underground light was the candle – an ever-present ignition risk in an atmosphere where firedamp and poor ventilation were constant threats.

The earliest coal workings in Britain and Europe were shallow bell pits and adits where air moved only because the openings were close to the surface. Ventilation was little more than a natural draught created by differences in temperature and elevation. As workings deepened in the 17th and early 18th centuries, this passive airflow became dangerously inadequate. Blackdamp (oxygen-poor air) and firedamp (methane) accumulated, and explosions became common.

By the mid 1700s, collieries began using furnace ventilation – a simple but ingenious method. A fire was lit at the bottom of a return shaft; the rising hot gases created an upcast, drawing fresh air through the mine. This allowed deeper workings and more extensive networks of roadways, but it came with obvious risks. The furnace itself could ignite methane, and the system struggled to cope with the growing scale of industrial-era mines.

The Industrial Revolution brought the first real leap forward. Steam engines were adapted to drive large fans, replacing furnaces and giving mine managers far greater control over airflow. By the late 19th century, mechanical ventilation was becoming standard in major coalfields. Mines could now be sunk deeper, with multiple districts ventilated through regulated splits, doors, stoppings, and regulators.





The late 19th and early 20th centuries saw the emergence of purpose-built mine fans – Guibal, Waddle, Sirocco, and later axial-flow designs. Ventilation engineering became a science. Airflow could be measured, predicted, and balanced. Mines introduced ventilation plans, pressure monitoring, and systematic control of leakage. This era enabled the vast deep collieries of South Wales, Yorkshire, the Ruhr, and Appalachia.

From the mid 20th century onward, ventilation evolved from simply moving air to managing a complex atmospheric environment. Flame safety lamps gave way to electronic methane detectors, fixed monitoring systems, and automatic fan controls. Regulations tightened, requiring minimum air quantities, continuous monitoring, and emergency ventilation protocols. As mechanisation increased dust levels, ventilation also became a tool for dust suppression and occupational health.

Today's underground coal mines operate with sophisticated ventilation-on-demand systems, computer modelling, and high-efficiency axial fans capable of moving hundreds of cubic metres per second. Airflow is dynamically adjusted to match production cycles, reducing energy consumption while maintaining safety. Refuge chambers, real-time gas telemetry, and emergency inertisation systems reflect a

modern understanding of mine atmospheres as dynamic, controllable systems.

At every stage, ventilation dictated what was possible underground. Mines could only deepen when airflow improved. Mechanisation only became viable when dust and gas could be controlled. And the modern safety culture – from gas monitoring to explosion prevention – is built on the foundations laid by centuries of trial, error, and innovation in moving air.

Underground environments accumulate contaminants that surface operations naturally disperse. Diesel exhaust, blasting fumes, naturally occurring gases, dust, and heat all build up unless they are actively removed. Ventilation is the only mechanism capable of maintaining a safe atmosphere underground, and its performance directly shapes the health of personnel, the reliability of equipment, and the efficiency of the entire operation.

## VENTILATION SYSTEMS IN TODAY'S MINES

Underground ventilation systems fall broadly into two categories: natural ventilation and mechanical ventilation. Natural ventilation relies on pressure and temperature differences between the surface and the workings, but as your document highlights, it is inherently unreliable because



these pressure differences can be small and fluctuate throughout the day or season. Mechanical ventilation, by contrast, uses fans and ducting to generate a controlled pressure differential and deliver air where it is needed.

Fresh air typically enters through shafts or adits, and the objectives remain constant across all mine types: dilute and remove hazardous gases, control dust, manage heat, and supply oxygen for breathing and combustion. Diesel vehicles, human respiration, drilling, blasting, and natural emissions from the rock mass all contribute to the gas load that ventilation must handle.

**BOUNDARY AND CENTRAL VENTILATION SYSTEMS**

Ventilation networks are commonly classified as boundary (unidirectional), central (bidirectional), or combined systems. The boundary system is widely regarded as the most efficient, with air flowing in a single direction from intake to return and achieving volumetric efficiencies of 70-80 percent. This configuration is especially common in metal mines working steep lodes, where intake and return shafts are positioned at opposite ends of the strike. Larger operations may use a central intake shaft with return shafts or winzes at either end, often supported by multiple exhaust fans.



Centrifugal fans



Axial Air Flow fans



The central or bidirectional system, more common in seam coal mines, places intake and return shafts near the centre of the property. Air travels in opposite directions through parallel roadways separated by stoppings. While this arrangement allows earlier production and reduces development requirements, it suffers from higher leakage and lower volumetric efficiency – typically 40–50 percent – due to the number of stoppings and air crossings required.

### AIRFLOW PATTERNS AND ENGINEERING CONSIDERATIONS

Several airflow patterns can be used within these systems. Ascensional ventilation introduces fresh air at the lower levels and allows it to rise along the working faces, sometimes generating natural ventilation pressure that assists fan performance. Descensional ventilation delivers air from the rise side downward, reducing heat accumulation and often producing cleaner, less dusty



conditions. Antitropical ventilation describes situations where air and mineral flow in opposite directions, while homotropical ventilation refers to both moving in the same direction.

Ventilation engineering involves planning, implementation, and continuous monitoring. Engineers must calculate air requirements for current and future operations, design intake and return airways, select and install fans and control devices, and ensure that the system can deliver the required airflow. Regular monitoring of temperature, dust levels, airflow, and pressure is essential, and ventilation equipment must be inspected and maintained to ensure ongoing performance.

### MECHANICAL VENTILATION AND FAN TECHNOLOGY

Mechanical ventilation relies on fans to generate airflow. Axial flow fans move air directly through the centre of a cylindrical housing using blades set at a defined pitch, while centrifugal fans draw air into a rotating impeller and discharge it radially. Large underground mines typically use high capacity axial or centrifugal fans as part of a primary exhaust based system, with the main fans located on the surface. Radial booster fans may be installed underground to overcome pressure losses in extensive workings.

Secondary ventilation systems distribute air to individual working areas using barriers, regulators, and ducting. Vent walls constructed from hessian screens coated with concrete provide a simple and cost effective method of sealing airways. Inflatable stoppings can be installed quickly to isolate areas, and doors may be incorporated

into vent walls to maintain access while preserving airflow integrity.

### VENTILATION CONTROL AND MONITORING INSTRUMENTS

Effective ventilation management requires a suite of monitoring instruments. The barometer is essential for detecting atmospheric pressure changes that may influence gas behaviour underground. Sudden drops in barometric pressure can cause gases trapped in abandoned workings to expand and migrate into active areas, increasing the risk of explosive atmospheres.

The mine water gauge, a partially filled U tube, measures the pressure generated by the fan and reflects the total resistance of the mine and shaft system. Temperature and humidity are monitored using thermometers and hygrometers, while air velocity is measured with anemometers. These instruments provide the data needed to verify airflow quantity and distribution and to ensure that ventilation systems are performing as designed.

### CONCLUSION

Ventilation remains one of the most critical engineering functions in underground mining. This article concludes that effective ventilation design and management are essential for maintaining safe working conditions, reducing losses, and ensuring that air reaches all parts of the mine in the required quantity and quality. By understanding the strengths and limitations of different ventilation systems, the behaviour of airflow, and the tools available for monitoring and control, mining professionals can ensure that their operations remain safe, efficient, and resilient.

## Maximize Throughput. Reduce CO<sub>2</sub> Emission.

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For Mining with Meaning.

# Increase efficiency improve reliability lower lifecycle costs

**As conveying systems evolve, operators are rethinking drivetrain design to meet rising demands for performance, efficiency and sustainability. Gearless drive technology offers a practical way to simplify operations, improve long-term reliability and lower total cost of ownership.**

**A**s conveying systems grow in scale and performance requirements intensify, operators are reassessing how drivetrain design impacts long-term reliability, energy consumption and overall cost. Higher throughputs, longer distances and increasingly stringent environmental targets are driving the need for more efficient and robust conveyor solutions.

In this environment, gearless drive technology offers a compelling alternative to conventional drive systems, supporting improved performance across the full conveyor lifecycle.

### A SIMPLER DRIVETRAIN FOR HIGHER AVAILABILITY

Traditional conveyor drives depend on high-speed motors and gearboxes to deliver the required torque. While widely used, these systems introduce mechanical complexity and require regular maintenance.

Gearless drive technology transfers torque directly from a low-speed synchronous motor to the drive pulley, eliminating the gearbox. This results in fewer wear components, simplified

maintenance and a reduced number of potential failure points.

For mining and quarrying operations, particularly in remote or hard-to-access locations, this simplicity can translate into improved availability and more predictable performance.



First ore on the TAKRAF Overland Conveyor with gearless drives at Chuquicamata, Chile.



Drive pulley for the Chuquicamata project in the workshop at the TAKRAF Product & Service Center in Lauchhammer, Germany.

## DRIVING EFFICIENCY AND REDUCING ENERGY LOSSES

Energy efficiency has become a key metric in conveyor system design. By removing gearbox-related losses and utilizing highly efficient synchronous motors, gearless drives improve overall system efficiency.

When combined with modern drive control systems, conveyors can operate at speeds aligned with actual material flow requirements. This approach reduces energy consumption, limits mechanical wear and supports more stable operation.

## RELIABILITY IN DEMANDING ENVIRONMENTS

Harsh operating conditions, including dust, temperature extremes and high installed power, place significant demands on conveyor drivetrains. Gearless drive systems, with reduced mechanical complexity and low-speed operation, offer advantages in these environments.

Lower vibration, reduced heat generation and fewer critical components contribute to reliable, continuous operation, particularly in high-capacity and long-distance conveying applications.

## MAXIMIZING PERFORMANCE ACROSS THE LIFECYCLE

Gearless drive solutions are particularly well suited to applications where high torque, long distances or challenging conditions are key factors. In these scenarios, lifecycle performance considerations often outweigh initial capital investment.

By improving efficiency, reducing maintenance and supporting higher system availability, gearless drive conveyor technology helps operators maximize throughput while lowering total cost of ownership and supporting emissions reduction objectives.



The entire drive arrangement, including stator, rotor, bearings and frame, arrived at the Chuquicamata site assembled and tested as a single, ready-to-install unit.



# Progress and Persistence

**R**oof support has long stood at the centre of underground coal mining safety, yet few technologies illustrate both progress and persistent challenge as clearly as the evolution of roof bolting. Since the Coal Mine Health and Safety Act of 1969 formally established bolting as the primary means of roadway support in the United States, the industry has relied on a standardised 4 × 4 ft pattern – an approach that has delivered consistency but not immunity from failure. Even today, roof falls continue to occur in bolted entries, ranging from superficial skin falls to large collapses, cutter roofs and, in the most severe cases, massive failures that threaten both production and life.

What becomes immediately apparent when comparing international practice is that the U.S. remains an outlier. Most coal producing nations employ significantly higher bolt densities – South Africa being the notable exception – reflecting differing geological conditions, regulatory philosophies and engineering traditions. The American system, rooted in suspension and friction principles, has proven itself through hundreds of millions of installed bolts, yet it still lacks a universally accepted design methodology. That absence of consensus underscores a deeper truth: roof control remains as much an evolving science as a practical craft.

*As Mining & Quarry World continues to examine the technologies shaping modern underground operations, this article by Gordon Barratt revisits the foundations of roof bolting practice, explores why failures persist, and considers how global experience may help guide the next generation of support design.*

## HISTORICAL CONTEXT

Roof bolting's story is, in many ways, the story of modern underground mining itself: a shift from timber and intuition to engineered, systematic control of the rock mass. Its development spans barely a century, yet it represents one of the most profound transformations in mine safety and productivity.

The earliest underground workings relied almost entirely on timber props, bars and chocks. These supports did little more than hold up what gravity threatened to bring down, and they offered no real interaction with the surrounding strata. As mines deepened and workings widened through the late nineteenth and early twentieth centuries, the limitations of timber became increasingly obvious. It was labour intensive, prone to decay, and incapable of providing long term stability in highly stressed ground.

Experiments with mechanical anchorage began in the 1920's and 1930's, particularly in the United States, where engineers sought a support that could reinforce the rock rather than simply prop it. Early bolts were crude by modern standards – short, rigid bars grouted or wedged into place – but they introduced a revolutionary idea: the roof could be made self supporting by binding fractured strata into a single, competent beam.

The Second World War accelerated the adoption of bolting. Timber shortages, combined with the need to maintain coal output, pushed mines to trial steel bolts on a wider scale. By the 1940's and 1950's, roof bolting was proving itself as a practical alternative to timber, reducing congestion,



Underground Mine Support & Stabilisation



Wooden Support Beams

improving ventilation, and allowing faster development rates. The technology matured rapidly, with better anchorage systems, resin cartridges, and longer, stronger bolts.

The decisive moment came in 1969, when the U.S. Coal Mine Health and Safety Act formally recognised roof bolting as the primary means of roadway support. This legislative endorsement cemented bolting as the industry standard and triggered a wave of research into bolt mechanics, load transfer, and ground control design. Other mining nations followed their own trajectories – some adopting higher bolt densities, others integrating bolting with steel arches or mesh – but the principle remained the same: reinforce the rock, don't fight it.

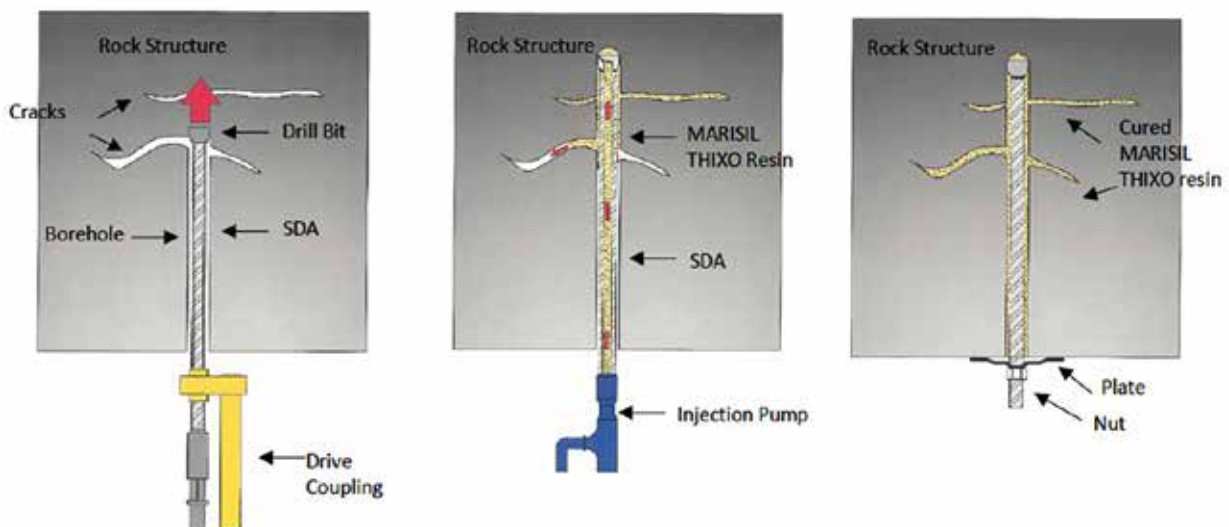
By the late twentieth century, bolting had become a sophisticated engineering discipline. Fully grouted systems, cable bolts, and yieldable designs allowed mines to manage increasingly complex geologies. Numerical modelling and monitoring technologies deepened understanding of how bolts interact with the rock mass, while mechanised bolters improved installation quality and reduced exposure for workers.

Roof bolting is so deeply embedded in the fabric of underground mining that it is easy to forget how

transformative it has been. What began as a pragmatic replacement for timber props has evolved into a sophisticated engineering discipline, shaped by advances in materials science, geomechanics and mechanised installation. Today, roof bolts are not merely supports; they are instruments of ground control, data sources, and in many cases the decisive factor between safe production and catastrophic failure. Understanding the different bolt types – and the technology behind them – is essential to understanding the modern underground mine.

### SDA BOLTING SYSTEM – WEBER-MINING

The fully grouted rebar bolt remains the most widely used support system across both coal and hard rock operations. Its principle is straightforward yet highly effective: a deformed steel bar is bonded to the surrounding rock using resin or cement, creating a continuous load transfer system along the entire bolt length. This transforms fractured or laminated strata into a reinforced beam capable of spanning weak zones. Resin technology has advanced dramatically over the past three decades, with two component cartridges capable of achieving full load capacity within minutes. Cementitious systems, while slower to cure, offer unmatched corrosion resistance and long term stability. Increasingly, these bolts are being instrumented with fibre optic strands or embedded load cells, turning them into real





time monitoring devices that reveal how the rock behaves long after the bolter has moved on.

Mechanical anchored bolts represent the earliest generation of engineered support. Their expansion shells grip the rock mechanically, providing immediate anchorage and allowing the bolt to clamp layers together through tension. They remain valuable in competent ground where rapid installation is essential, but their reliance on point anchorage limits their performance in weak, laminated or highly fractured strata. In many operations they now serve as temporary supports or are combined with resin to create hybrid systems that offer both instant and long term stability. Their longevity in the industry is a testament to their simplicity, but their limitations are equally well understood.

Friction bolts introduced a fundamentally different approach to ground control. Split Sets and Swellex type systems generate support through radial pressure and continuous friction along the borehole wall. Their ability to yield under load makes them particularly effective in burst prone or squeezing ground, where the rock mass continues to move after excavation. The hydraulic expansion technology behind Swellex bolts – where high pressure water plastically deforms the tube to create uniform contact – remains one of the most elegant innovations in strata control. These systems are fast

to install, tolerant of ground movement and capable of absorbing significant deformation without losing capacity. Their main vulnerability lies in corrosion and in ground so soft that the borehole wall cannot provide adequate confinement.

## CABLE BOLTS

Cable bolts occupy a category of their own. Designed for long reach reinforcement, they are indispensable in large excavations, longwall tailgates and deep hard rock mines. Their multi strand construction allows installation in holes far longer than any rigid bar could accommodate. Once grouted, they provide deep anchorage that bridges weak zones and stabilises extensive spans. Variants such as bulbed cables, birdcaged strands and post tensioned systems allow engineers to tailor support to highly specific geological conditions. In many operations, cable bolting is the backbone of long term stability, particularly where the roof must remain competent for years rather than months.

As mining has pushed deeper and encountered higher stresses, the industry has turned increasingly to yieldable and dynamic bolts. These systems are engineered not merely to hold the rock but to absorb energy during violent ground movements. Cone bolts, Garford bolts and specially designed yielding rebars incorporate controlled deformation mechanisms that allow them to elongate without failing. Their ability to dissipate energy makes



FRP Anchor Bolts used in Rock Bolting

them essential in seismically active mines and in coal seams prone to bursts or sudden roof dilation. In many respects, dynamic bolts represent the frontier of ground control engineering: supports that must survive not just static loads but dynamic events capable of releasing tens of kilojoules of energy in fractions of a second.

More recently, fibre reinforced polymer bolts have emerged as a solution for corrosive environments and for operations where future excavation requires the bolt to be cut through without damaging equipment. Their composite construction offers high tensile strength and complete immunity to corrosion, though their brittle failure mode demands careful engineering. They have found particular favour in evaporite mines, where steel bolts deteriorate rapidly, and in development headings where future cutting is planned.

Self drilling anchors represent another technological leap, combining drilling and bolting into a single operation. By pumping grout through a hollow bar as it advances, these systems provide immediate support in ground too weak to maintain an open borehole. Their adoption in mining is growing, particularly in development headings where poor ground conditions threaten progress. In civil tunnelling they are already well established; mining is now catching up.

## ROOF BOLTING FAILURES

Roof bolting failures persist not because the technology is flawed, but because the underground environment is far more complex, variable and dynamic than any single support system can fully control. Even with decades of research, millions of installed bolts and increasingly sophisticated design tools, the rock mass continues to behave in ways that challenge engineering assumptions. A clear understanding of why failures still occur is essential for any mine striving to improve ground control performance.

The most fundamental reason is geological variability. Roof bolts are installed into rock that is rarely uniform. Bedding planes, slickensides, clay partings, moisture sensitive shales and hidden discontinuities can all undermine the intended load transfer mechanism. A bolt designed to reinforce a competent beam may instead be anchored in weak, swelling or laminated strata that cannot hold the load. In many coal measures, the immediate roof is inherently unstable, and even small changes in moisture or stress can trigger deterioration long after bolting is complete.

Stress redistribution is another major factor. Every excavation alters the stress field, and in deep or highly stressed mines the redistribution can be severe. Bolts installed under one set of conditions may later be overloaded as the abutment pressure increases, the longwall face advances or the roof begins to sag. In burst prone ground, dynamic loads can exceed the capacity of conventional bolts in milliseconds. Even in non seismic environments, gradual roof dilation can pull bolts out of their anchorage or shear them at bedding interfaces.

Installation quality remains a persistent challenge. Roof bolting is often carried out under production pressure, in confined spaces, and in variable ground. Resin may not mix properly, holes may be under reamed or over drilled, torque may be insufficient, grout may not fully encapsulate

the bar, and plates may not seat correctly. A single poorly installed bolt can compromise the integrity of an entire pattern. Mechanised bolters have improved consistency, but human factors still play a significant role.

Design limitations also contribute. Despite decades of research, there is still no universally accepted design methodology for roof bolting. Many systems rely on empirical rules, local experience or regulatory minimums rather than rigorous geomechanically modelling. Standard patterns – such as the 4 × 4 ft pattern common in U.S. coal mines – may be inadequate for certain geological conditions but are applied uniformly for simplicity or compliance. In contrast, countries with higher bolt densities often experience fewer failures, suggesting that design conservatism plays a role.

Time dependent deterioration further complicates matters. Rock can weaken through weathering, moisture ingress, oxidation or creep. Bolts themselves can corrode, particularly in humid or chemically aggressive environments. Cement grout may crack; resin may degrade; plates may deform. A support system that was adequate at installation may no longer be sufficient months or years later, especially in roadways intended for long term use.

Finally, roof bolting is often expected to do too much. In many mines, bolts are the primary – and sometimes the only – form of support. Yet bolts alone cannot prevent skin falls without mesh, cannot control large scale deformation without cable bolting, and cannot absorb dynamic energy without specialised yielding systems. When bolts are used in isolation, or without proper integration into a broader support strategy, failures become more likely.

In essence, failures persist because underground mining is a living environment. The rock mass moves, relaxes, swells, fractures and responds to excavation in ways that are not always predictable. Roof bolting is a powerful tool, but it is not infallible. Its success depends on geology, stress, installation quality, design philosophy, maintenance and the integration of complementary support systems. As mines deepen and conditions become more challenging, the industry's task is not simply to install more bolts, but to understand more deeply how and why they work – and why, at times, they do not.

Across all these systems, one trend is unmistakable: roof bolts are becoming smarter. Instrumentation is transforming them from static supports into active monitoring tools. Fibre optic strands, embedded sensors and wireless load monitoring devices allow engineers to track bolt performance and strata movement in real time. This shift from reactive to predictive ground control marks the next major step in the evolution of roof support. Mines are beginning to treat bolts not simply as consumables but as part of an integrated digital ecosystem, feeding data into modelling software, hazard prediction algorithms and real time decision making systems.

Roof bolting has travelled a long way from its origins as a simple replacement for timber. Today it is a complex, data rich engineering discipline, central to both safety and productivity. As mines continue to deepen and geological challenges intensify, the technology behind roof bolts will remain at the forefront of innovation – quietly, but decisively, shaping the future of underground mining.

# Another fine mess? Dealing with dust at transfer points

**T**he vital connections between different sections of a processing plant are commonly a constant source of fugitive dust. That's because when raw materials drop onto a moving conveyor, belt dust emissions are inevitable, aren't they? Not necessarily, writes Jerad Heitzler of Martin Engineering.

When dry crushed materials land on a running conveyor at a transfer point, the impact causes some of the cargo to disperse, particulates become airborne, and the air turbulence from the movement forces the dust toward the nearest opening. If the environment isn't sealed, the dust-filled air creates a serious workplace health and safety hazard, a problem that's exacerbated if dust is allowed to build up.

Dust emissions don't just create a harmful environment for those working in the area. Abrasive particulates make their way into exposed machine parts and rolling components, causing them to wear quicker, seize, and require replacement sooner. Particulates also clog air intakes of nearby equipment, further raising the need for maintenance and downtime. Then as it settles, dust

builds up to cover walkways and stairs, engulfing control units, obscuring signage and, in some cases making access for in section and maintenance impossible without shutdown and clean-up.



Dust emissions around transfer points can affect the overall air quality of the entire workplace.

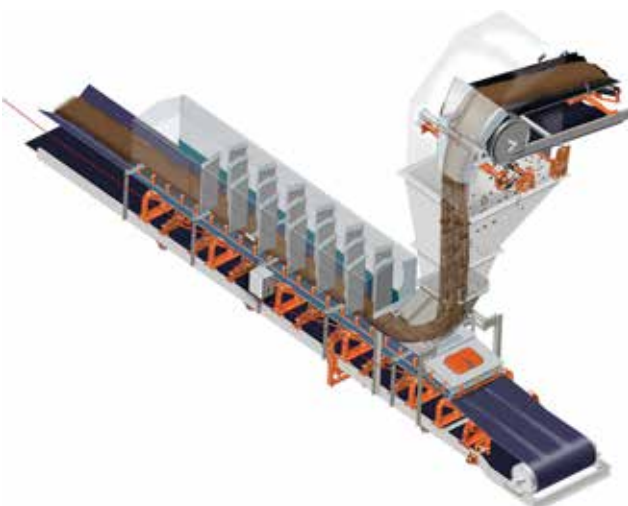


Dust quickly builds up on every surface creating safety as well as health hazards.

## UNDERSTANDING THE ROOT CAUSES

Often, the reason such problems haven't been fixed is an operator's lack of understanding of the underlying issues of dust at transfer points. Even today, many solutions focus on dust suppression and collection, but decades of field study and experience have shown that to control air quality at transfer points it is more beneficial to address the root causes by taking a holistic view of the function and design of the material transfer process. In fact, there are three main factors that cause dust within a minerals processing plant:

- a) **Material degradation** from crushing and milling, as well as transfer and movement, which creates an abundance of fine particles that become airborne.
- b) **Air Flow** through the plant is a key factor in carrying airborne particulates and this can be controlled with the right design, considering material speed, volume and fall.



A well-designed transfer point has many design features that prevent fine material from escaping.

- c) **Transfer point design** is one of the main causes of dust emissions and spillage on conveyor systems, often exacerbated due to desired increases in productivity.

## ELEMENTS OF A TRANSFER CHUTE

A transfer chute should have several key components that mitigate material spillage and dust, allow the cargo to settle on the belt's center, and facilitate the settling of dust either back into the cargo flow or into a dust collection mechanism. These components include cradles, wearliners, skirting, raised enclosures and strategically placed dust curtains.

Some manufacturers offer modular transfer chute enclosures that can be efficiently retrofitted for changes in production during scheduled downtime. Extending the transfer chute enclosure provides a better space to steady the turbulent air and allow dust to settle. Additionally, externally facing wearliners and skirting enables easy access to enclosures for significantly safer maintenance. Although the standard lock-out, tag-out, try-out procedures are still required, servicing from the outside eliminates the need for chute entry and the risks associated with confined spaces, as well as drastically reducing maintenance downtime.

## BEST PRACTICES FOR DUST CONTROL

1. Avoid belt sag with cradle support – For each transfer point, support the belt the entire length of the chute wall (also known as the 'skirtboard') so it doesn't sag away from skirting. The pressure from air turbulence is enough to push dust and fines out of these gaps, causing excessive dust and spillage.
2. Use wearliners to increase system life – Modern chute designs raise the height of the chute, providing more room for dust to settle in the stilling zone and allowing space for an external wearliner. Without it, the rubber skirting takes the force of falling materials which lowers the equipment's life and requires premature replacement.
3. Seal the environment with belt skirting – Single skirting should be cut to the belt's trough angle for a tighter seal and mounted externally for easy and safe adjustment. Self-adjusting skirting has spring-driven latches that offer slight downward pressure for reduced maintenance. Dual skirting offers a single skirt with a rubber flap that provides a second layer of sealing and protection from spillage and emissions.



Cradle support prevents the belt from becoming distorted and allowing fugitive material to escape.

## TRANSFER POINTS AND DUST EMISSIONS

4. Use dust collection only when necessary – ‘Passive dust control’ uses engineered design solutions such as controlled loading, wearliners, skirting, curtains and modular enclosures first. When there are length or space restrictions for chutes which prevent an extended settling zone, dust bags and mechanical air cleaners are still effective. They use the airflow to collect dust and, once the conveyor system stops, that dust is deposited back onto the belt. However, they can require more maintenance and monitoring, so sealing is preferred to minimise servicing costs.
5. Slow the exiting air velocity – Some flow of air is still going to be prevalent exiting the system, but the key is slowing it to under 200 fpm (1 m/s), slow enough to allow for settlement happen. Adding a tail panel and curtains is essential to this but simply adding them at the ends does not accomplish the proper stilling environment required. Understanding the air flow and then strategic placement is the key to reducing exiting air velocity.



Sealing systems are crucial in the elimination of fugitive dust at transfer points.

### AN EXCELLENT PLACE TO START

Improving workplace air quality in a major mineral processing plant seems like a daunting task but eliminating dust delivers numerous benefits, notably in health and safety, housekeeping, efficiency, productivity and cost reduction. Of course, conveyor transfer points are not the only source of dust. However, as one of the most prevalent generators of particulate emissions inside any bulk handling operation, addressing these is an excellent place to start.



Strategically positioned dust curtains are the key to reducing air velocity at transfer points.

By following best practices using modern and well-designed retrofitted components, operators can tackle dust in a methodical way. Once the major dust sources are addressed, it becomes easier to identify emissions from other parts of the operation with the ultimate goal of a clean, efficient and safe operation.

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### AUTHOR

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*Training Manager / Martin Engineering*

As program manager and lead instructor for Martin Engineering's FOUNDATIONS™ Training Workshops, Jerad Heitzler is a leader in helping the industry learn how to make the handling of bulk materials cleaner, safer, and more productive. He started with Martin Engineering as a Customer Development Representative in 2006. He soon realized his love for presentations and for teaching about conveyor systems, and so in 2010 took over management and development of the company's FOUNDATIONS™ Workshop program. Under his leadership the program has expanded to offer several levels of conveyor improvement workshops around the world.



# Could disused mines heat more than six million homes in the UK?

**T**he use of naturally heated groundwater as a thermal resource has a long and geographically diverse history, evolving from simple bathing practices into engineered district heating systems and industrial applications. The earliest recorded use dates back to ancient civilisations such as the Romans, Chinese and Japanese, who exploited hot springs for bathing, space heating and small scale craft production. These early systems relied entirely on natural artesian flow and required no mechanical pumping or heat exchange technology.

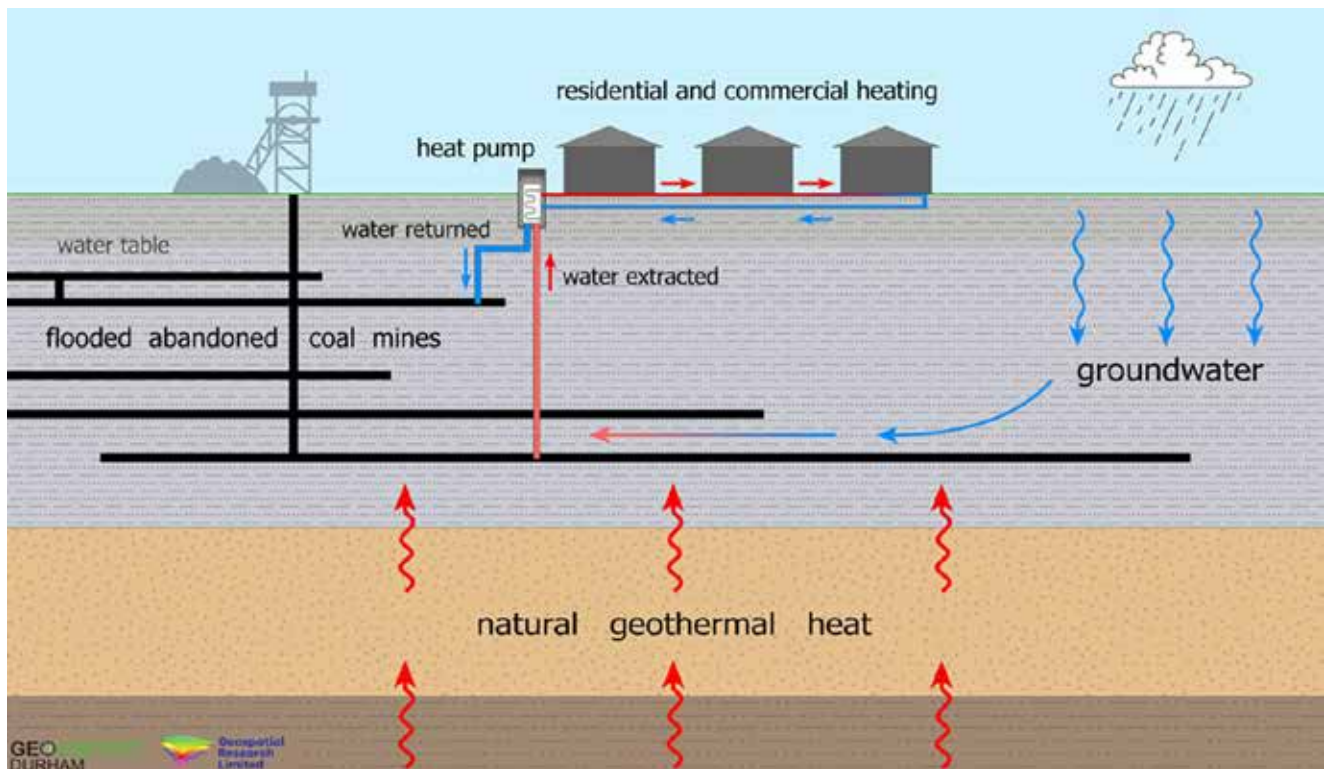
The transition from passive use to engineered geothermal heating began in the 14th century in Chaudes Aigues, France, where one of the world's first documented district heating networks channelled geothermal water through wooden pipes to heat homes – a system that operated continuously for centuries. By the late 19th and early 20th centuries, advances in drilling and hydrogeology enabled deeper access to geothermal aquifers. Towns such as Boise, Idaho (1892) and Reykjavik, Iceland (from the 1930s onward) developed large scale geothermal heating schemes, supplying municipal buildings, homes and later industrial facilities. These systems demonstrated that geothermal water could be delivered reliably, economically and at scale, particularly in regions with favourable geology.

Industrial applications expanded rapidly in the mid 20th century as heat exchange technology improved. Geothermal water began to support food processing,

greenhouses, drying operations, district heating for factories and, in some regions, combined heat and power systems. By the late 20th century, geothermal district heating had become a mature technology in countries such as Iceland, France, Hungary, Italy and New Zealand, where it remains integral to national energy strategies.

Today, geothermal heating is recognised as one of the most stable and predictable forms of renewable heat. Its historical evolution – from natural hot springs to engineered heat networks – provides a clear precedent for modern low temperature geothermal systems, including the emerging use of mine water geothermal in former coalfields. The long operational history of geothermal heating demonstrates that subsurface thermal resources, when properly characterised and managed, can supply reliable heat to homes and industry for generations.

The question of whether the UK's abandoned coal mines could heat more than six million homes is rapidly shifting from theoretical curiosity to a serious engineering proposition. Beneath the country's former coalfields lies an enormous, largely forgotten thermal resource: thousands of kilometres of interconnected roadways and shafts, now flooded and thermally stable, forming one of the largest accessible geothermal reservoirs in Europe. With mine water temperatures typically ranging between 12 and 20°C and remaining consistent throughout the year, these workings present a naturally pre warmed, high volume heat source that aligns well with modern heat pump technology.



For mining engineers, the opportunity is uniquely familiar. The same hydrogeological, geotechnical and structural behaviours that once dictated safe coal extraction now define the feasibility of large scale mine water geothermal systems. Understanding shaft condition, roadway connectivity, water chemistry, flow pathways and long term thermal drawdown is not an academic exercise; it is the foundation of whether these systems can operate reliably for decades. The UK's coalfields were never designed as thermal assets, yet their geometry, permeability and storage capacity make them unusually well suited to district scale heat extraction.

As the UK accelerates its transition away from fossil fuels, the coalfields may be poised for a second life. Instead of supplying coal, they could supply heat – potentially at a scale that rivals major gas networks. Whether this resource can realistically heat millions of homes depends on engineering decisions made now: how the workings are characterised, how water movement is managed, how surface infrastructure is designed and how these systems are integrated into existing communities. This article examines the technical feasibility, engineering challenges and system level considerations that will determine whether the UK's disused mines can once again become a national energy asset – this time delivering low carbon heat.

## 1. THE SCALE OF THE RESOURCE BENEATH THE COALFIELDS

When deep mining ceased across the UK, pumps were switched off and the workings gradually flooded. Today, most abandoned coalfields are fully inundated, with water levels stabilised by natural hydrogeological boundaries or by controlled pumping at key shafts. These flooded workings form a vast thermal reservoir. Their large volumetric capacity, stable temperatures and extensive surface area – created by the sheer length of roadways

and the surrounding strata – provide ideal conditions for heat exchange. Unlike deep geothermal systems, which are geographically constrained, mine water geothermal aligns closely with population centres. The North East, Yorkshire, the Midlands, South Wales and Central Scotland all sit atop extensive coalfields, many of them directly beneath towns and cities where heat demand is highest. This proximity to demand is one of the most compelling engineering advantages of the resource.

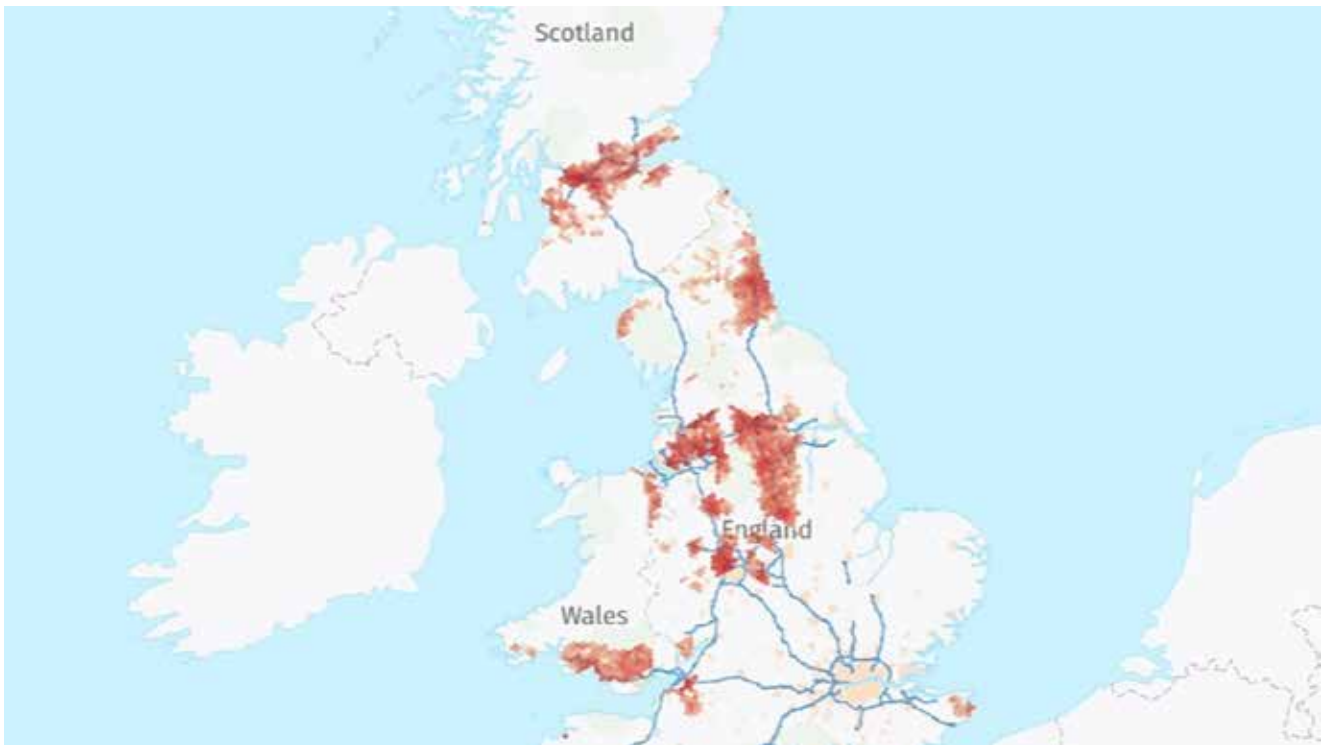
## 2. HOW MINE WATER GEOTHERMAL SYSTEMS OPERATE

A mine water geothermal system functions by abstracting warm water from the flooded workings, passing it through a heat exchanger and heat pump, and reinjecting the cooled water back underground. Only heat is transferred to buildings; the mine water itself remains within a closed subsurface loop. Heat pumps typically deliver three to five units of heat for every unit of electricity consumed, and their efficiency improves with higher source temperatures. Mine water's stable thermal profile ensures predictable performance throughout the year, avoiding the seasonal variability associated with air source systems.

The long term viability of such systems depends on the workings' ability to sustain heat extraction without excessive thermal drawdown. This requires a detailed understanding of the mine's geometry, the thermal properties of surrounding strata and the rate at which heat can be replenished through conduction and groundwater flow. For mining engineers, these considerations echo familiar challenges from the operational days of the coal industry, albeit applied to a new purpose.

## 3. HYDROGEOLOGICAL AND GEOTECHNICAL REALITIES

Not all abandoned mines are equal. Some coalfields contain highly interconnected roadway networks with predictable water flow pathways, while others are compartmentalised



An extract from the interactive map viewer showing heating demand in Britain over recorded abandoned coal mine workings – Coal Authority/OS

Mine – Water Heat – Geospatial Research

by faults, collapses or historical barriers. Connectivity determines sustainable flow rates, thermal recharge potential and the optimal placement of abstraction and reinjection wells. Shaft integrity is another critical factor. Many shafts have been capped, filled or stabilised, and their structural condition varies widely. Engineers must assess lining degradation, potential for re opening and the feasibility of drilling adjacent boreholes to access deeper workings.

Water chemistry presents additional challenges. Mine water often contains iron, manganese, sulphates and suspended solids. While heat exchangers can tolerate moderate contamination, high iron concentrations can cause fouling and reduce system efficiency. Treatment systems may therefore be required, adding complexity and cost. Thermal drawdown must also be carefully managed. If heat extraction exceeds the rate of thermal recharge, the system will gradually cool, reducing efficiency. Numerical modelling is essential to predict long term behaviour and ensure sustainable operation.

#### 4. ENGINEERING FEASIBILITY AT NATIONAL SCALE

Estimating the total heat potential of the UK's coalfields is complex, but the resource is undeniably large. The Coal Authority has suggested that mine water geothermal could theoretically supply heat to millions of homes. However, practical deployment depends on a range of engineering, economic and logistical factors. District heating infrastructure is central to the concept. Mine water geothermal is most effective when paired with heat networks capable of distributing low temperature heat to multiple buildings. The UK currently has limited district heating coverage, meaning new pipe networks, heat

centres and building level retrofits would be required. This represents a major engineering challenge, but one that is increasingly being addressed in urban regeneration projects.

Electrical demand is another consideration. Heat pumps require electricity, and large scale deployment will increase local grid loads. However, because heat pumps are far more efficient than resistive heating, the overall energy demand is significantly lower than alternative electric heating options. Smart grid solutions and thermal storage can help manage peak loads and improve system flexibility.

#### 5. LESSONS FROM EARLY PROJECTS

Several early projects provide valuable insights into the practical realities of mine water geothermal. The Seaham Garden Village development in County Durham draws heat from the Dawdon mine water treatment scheme, where temperatures of around 18 to 20°C support a large scale heat pump installation. The project demonstrates the importance of high flow rates, stable temperatures and integration with new build communities.

##### *Major Minewater Project Begins At Seaham Garden Village*

Construction has officially begun on a landmark large-scale mine water heat project, building on our ongoing efforts to harness geothermal heat from disused coal mines. By utilising water already being pumped to the surface, this project marks a crucial step forward in expanding renewable heat solutions across former coalfield areas.

## MINE WATER AND GEOTHERMAL NETWORKS



Representatives from Vital Energi joined members of the Mining Remediation Authority, Severn Trent Services, Durham County Council, Karbon Homes and Esh Group gather to celebrate the beginning of the project.

The Energy Centre being built directly next to the Mining Remediation Authority's Dawdon Mine Water Treatment Scheme in County Durham, will tap into the mine water already being treated there. The mine treatment scheme will now provide heat for a new housing development as well as protecting a vital drinking water source.

Seaham Garden Village is a new mixed-use sustainable community located to the south of Seaham. The Garden Villages comprises 1,500 homes, a new primary school, village centre and innovation hubs. The Garden Village will be built over the next 10 years.

The district heat network project has been led by Durham County Council, with the Mining Remediation Authority spearheading the development of the mine water heating initiative. Multiple organisations have been involved including Karbon Homes, which is now set to provide 750 affordable homes on the site and has led the way in adopting the mine water heat technology. Vital Energi has been appointed to design, build and operate the low-carbon system. They will run the district heat network for the next 40 years.

The project has benefited from a grant from the Government's Heat Networks Investment Project which has enabled the project to be delivered.

Seaham Garden Village will offer a thriving, sustainable new community on Durham's heritage coast and play a vital role in local growth. The state-of-the-art energy centre will capture the geothermal heat from the warm mine water, which remains at a stable underground temperature. This heat will be upgraded to domestic heating levels via a heat pump, delivering low cost and low carbon heat to new Karbon homes.

The Dawdon scheme began treating mine water in 2009 and the Mining Remediation Authority has been researching the possibility of 'bolting on' the heat feature to these treatment sites as part of their pioneering work in the geothermal arena.

This new development follows the success of the Gateshead scheme, the UK's first large-scale mine water heat network, which began providing heat to homes and businesses in March 2023, as well as another pioneering privately funded scheme nearby at Lanchester Wines warehouses. Unlike Seaham Garden Village, the Gateshead projects used boreholes, which were drilled up to 150 metres underground to tap into water in disused mines.

"With over 80 mine water treatment schemes across the UK, we see great potential to deliver dual-purpose facilities that protect water supplies and generate renewable heat," Mr. Bond added. "Whether accessing mine water heat via our treatment schemes or boreholes the Mining Remediation Authority are proud to offer innovative ways to reduce carbon emissions by repurposing the amazing UK coal-mining heritage."

In Glasgow, the Clyde Gateway project uses mine water from the city's extensive coalfields to heat commercial buildings. Drilling into old workings revealed the importance of detailed hydrogeological modelling and the challenges associated with accessing partially collapsed or poorly mapped roadways. Long term monitoring has shown how thermal behaviour evolves over time, providing valuable data for future schemes.

International examples from the Netherlands, Spain and Germany reinforce these lessons. They highlight the need



for robust water treatment, careful management of thermal drawdown and the benefits of integrating heat storage to balance supply and demand.

## 6. ENGINEERING CHALLENGES AND RISKS

Despite its promise, mine water geothermal is not without challenges. Subsurface uncertainty remains a significant issue. Historical mine plans are often incomplete or inaccurate, and unexpected collapses or unmapped connections can complicate drilling and flow modelling. Long term sustainability must also be considered. Systems that extract heat faster than it can be replenished risk cooling the workings to the point where efficiency declines. Engineers must design systems that balance abstraction and reinjection, avoid hydraulic short circuiting and monitor temperature trends over time.

Capital costs are another barrier. Mine water geothermal systems require drilling, heat centres and district heating networks, all of which involve substantial upfront investment. While operating costs are low, the initial expenditure can be difficult to justify without long term policy support or anchor customers. Regulatory and environmental considerations add further complexity. Projects must address water discharge permits, groundwater protection, subsidence risks and community engagement – all areas where mining engineers' experience is invaluable.

## 7. THE ROLE OF MINING ENGINEERS IN A NEW ENERGY LANDSCAPE

Mine water geothermal is, at its core, a mining project repurposed for energy. It demands geological interpretation, hydrogeological modelling, shaft and roadway assessment, pumping expertise and long term monitoring – all skills deeply embedded in the mining engineering profession. As the UK seeks to decarbonise its heating sector, mining engineers are uniquely positioned to lead the development of this emerging industry. Their

understanding of the subsurface, combined with practical experience in water management and geotechnical stability, makes them essential to the success of mine water geothermal at scale.

## 8. COULD THE UK REALLY HEAT SIX MILLION HOMES?

The theoretical heat capacity of the UK's coalfields is vast, and the technology required to harness it is well understood. However, achieving a national network capable of heating six million homes requires more than technical feasibility. It depends on the expansion of district heating, the availability of suitable shafts and workings, the economic viability of large scale heat pump deployment and the willingness of communities to adopt new heating systems. Not every coalfield will be suitable, and not every region will have the demand density required to justify investment. Yet, with coordinated engineering, systematic characterisation of the subsurface and sustained investment in infrastructure, the coalfields could become a major component of the UK's low carbon heat strategy.

## CONCLUSION

The UK's abandoned coal mines represent one of the country's most promising and overlooked low carbon heat resources. Their flooded workings offer stable temperatures, vast storage capacity and proximity to millions of homes. For mining engineers, this is a rare opportunity to repurpose legacy infrastructure for modern energy needs, applying familiar skills to a new challenge. Could mine water geothermal heat more than six million homes? In principle, yes. The resource is large enough, the technology is proven and the coalfields are well located. But achieving this scale requires coordinated engineering, significant investment in district heating and a systematic approach to characterising and managing the subsurface. If the UK chooses to pursue this path, the coalfields may once again become vital national assets – not for the coal they once produced, but for the heat they can now provide.

# Beyond the Belt: how modern conveyor technologies redefine efficiency

**M**echanical conveying systems are fundamental to the productivity and continuity of modern mining operations. They form the backbone of material-handling infrastructure, moving everything from run-of-mine ore to refined product with the consistency, safety, and efficiency that high-throughput sites demand. For engineers, designers, and operators across the mining sector, a clear understanding of how these systems have evolved – and how their design principles influence performance in abrasive, high-impact, and often unforgiving environments – is essential to improving reliability and reducing whole-of-life costs.

In this article, **Gordon Barratt of Coal International and Mining & Quarry World** examines the major conveyor technologies used across surface and underground operations, including belt, roller, chain, screw, and overhead systems. The discussion highlights the engineering considerations that matter most in mining: durability under heavy load, resistance to impact and wear, maintainability, energy efficiency, and integration with increasingly automated plant systems. It also explores the innovations reshaping conveyor performance, from advanced composite materials to smarter monitoring and control technologies.

By clarifying the role of conveyor systems in enhancing productivity, safety, and long-term operational resilience, this piece offers mining professionals practical insights that support better system selection, improved plant design, and stronger competitiveness in an industry where efficient material flow remains a decisive advantage.

## HISTORICAL CONTEXT

The story of conveying in mining begins long before the appearance of anything recognisable as a modern belt

system. Early civilizations relied on sledges, baskets, and simple mechanical aids to shift stone, ore, and earth, but these were intermittent and labour-intensive methods. The idea of continuous material movement – of a machine performing the work of many hands – did not truly take hold until the Industrial Revolution reshaped the technological landscape of Europe and North America. As factories adopted mechanised production in the late eighteenth century, engineers began experimenting with flat belts made from leather, canvas, or woven fabrics to move goods within workshops. These early conveyors were short, fragile, and limited in capacity, yet they introduced a principle that would eventually transform mining: the steady, uninterrupted flow of material.

Mining operations of the nineteenth century were expanding in scale and complexity, driven by deeper shafts, longer drifts, and rising global demand for coal and metals. Traditional haulage methods – hand tramping, horse-drawn tubs, and narrow-gauge rail – were increasingly inadequate. By the 1880's and 1890's, inventors and mine engineers began adapting factory belt conveyors for underground use, reinforcing frames, improving belt materials, and experimenting with tensioning systems to cope with abrasive ores and harsh conditions. These early mining conveyors were still relatively short and often used for loading, sorting, or stockpiling, but they demonstrated the potential for mechanised haulage to reduce labour, increase throughput, and improve safety.

A decisive shift occurred in the early twentieth century with the introduction of rubberised belts. Vulcanised rubber offered far greater durability, flexibility, and resistance to moisture and abrasion, enabling conveyors to extend over longer distances and operate reliably in damp, dusty,



Industrial narrow-gauge railways



and confined underground environments. By the 1920's and 1930's, troughed belt designs had become standard, using angled idlers to cradle the belt and increase carrying capacity. This period also saw the emergence of standardised components – rollers, pulleys, bearings, and belt widths – which allowed mines to install, maintain, and expand conveyor systems more efficiently.

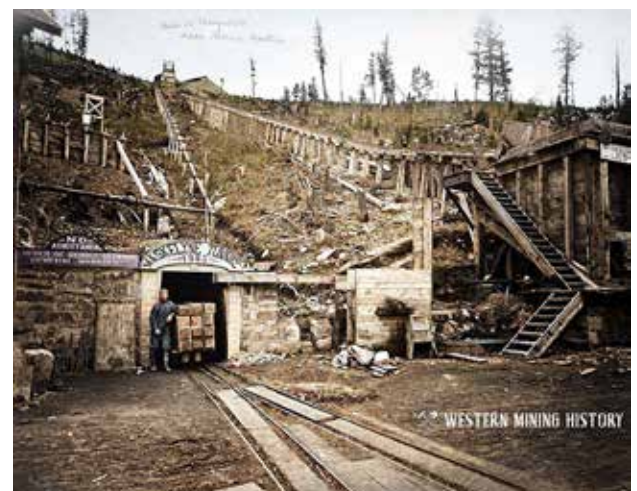
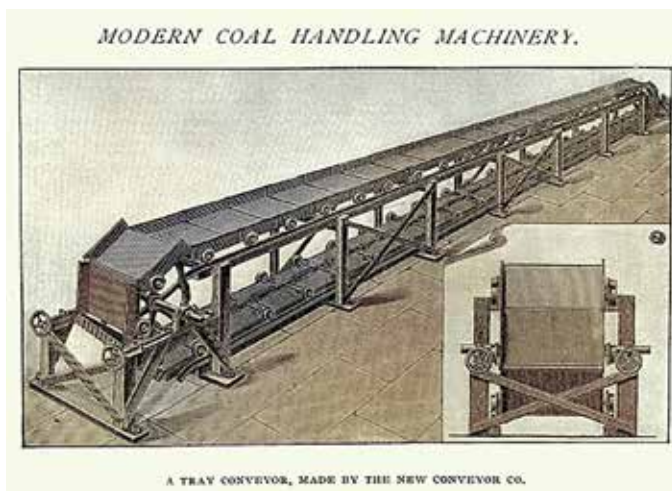
The mid-twentieth century marked the true industrialisation of conveying in mining. Electrification, improved motor technology, and advances in steel fabrication enabled conveyors to handle heavier loads and steeper gradients. Longwall coal mining, which demanded rapid and continuous removal of cut material, became a major driver of conveyor innovation. Armoured face conveyors (AFCs) were developed to operate directly at the coal face, feeding onto gate conveyors and then onto trunk belts that carried coal out of the mine. At the same time, surface operations embraced overland conveyors capable of spanning kilometres, crossing valleys, and replacing fleets of trucks. Steel-cord belts, introduced in the 1950's and 1960's, provided the tensile strength needed for these long-distance systems, while improved take-up mechanisms and braking systems allowed for controlled operation on steep terrain.

By the late twentieth century, conveying had become a backbone technology of global mining. Computerised control systems, variable-speed drives, and condition-monitoring sensors enhanced reliability and efficiency. Conveyor

networks grew into integrated haulage systems linking extraction, processing, and stockpiling, often operating with minimal human intervention. In large open-pit mines, shiftable and semi-mobile conveyors began replacing truck haulage, reducing fuel consumption and operating costs. Underground, advances in fire-resistant belts, dust suppression, and automated tensioning improved safety and performance.

In the twenty-first century, the evolution of conveying continues to accelerate. High-tension steel-cord belts now span tens of kilometres, while pipe conveyors, sandwich belts, and curved overland systems allow material to be transported along complex routes with minimal environmental impact. Automation and digitalisation have transformed conveyors into intelligent systems capable of self-diagnosis, predictive maintenance, and real-time optimisation. As mining moves toward electrification, decarbonisation, and reduced surface disturbance, conveyors are increasingly positioned as the most efficient, sustainable, and scalable method of bulk material transport.

From crude ancient methods to today's high-capacity, sensor-rich haulage networks, the development of conveying in mining reflects the broader trajectory of industrial progress: a shift from manual effort to mechanised continuity, from isolated machines to integrated systems, and from simple belts to sophisticated, long-distance arteries that sustain the modern mining industry.





Conveyor systems – Quarry Mining

Mechanical conveyor systems are indispensable across modern industry, but nowhere is their value more evident than in the mining sector – both surface and underground – where the continuous, reliable movement of bulk materials determines the pace, safety, and profitability of operations. In these environments, conveyors are not simply tools for transporting material; they are critical infrastructure that keeps extraction, processing, and distribution flowing. Whether hauling overburden across vast open-pit benches or carrying ore through confined underground drifts, conveyor systems reduce manual handling, minimise operational risk, and support the high-throughput demands that define contemporary mining.

Today's conveyor landscape reflects decades of engineering refinement, offering manufacturers a wide range of specialised systems tailored to the demanding conditions of mining. Belt conveyors dominate both surface and underground operations due to their ability to move large volumes over long distances and challenging terrain. Roller conveyors support heavy loads in processing plants and distribution hubs, while chain conveyors provide the durability required for harsh, abrasive mining environments. Screw conveyors remain vital for handling fine or granular materials in processing circuits, and overhead conveyors continue to serve niche applications where floor space is limited. Understanding the operational strengths and constraints of each system is essential for selecting the right solution, particularly in mining where reliability, maintainability, and safety are paramount.

## ROLLER CONVEYORS

Conveyor rollers form the mechanical backbone of belt-based haulage systems in mining, and their behaviour has a direct influence on the efficiency, reliability, and long-term performance of every conveyor installation. Although often overshadowed by higher-visibility components such as drives, pulleys, and belting, rollers determine how smoothly material travels, how evenly loads are distributed, and how effectively the belt maintains its geometry under dynamic conditions. In modern mines – where conveyors may run continuously for thousands of hours per year – the engineering of the roller set is inseparable from the engineering of the conveyor itself.

The primary function of the carrying rollers is to support the loaded belt and maintain a stable material profile as it moves along the conveyor line. In most mining applications, this is achieved through a troughing configuration. A typical schematic representation would show three rollers mounted on a frame: a horizontal centre roller supporting the belt's mid-section, and two wing rollers angled upward to form a shallow trough. The angles of these wing rollers – commonly 20°, 35°, or 45° – determine the depth of the trough and therefore the volume of material the belt can safely carry. Engineers select these angles based on material characteristics, belt width, and required throughput. The geometry ensures that the load remains centred, reduces the risk of spillage, and distributes stress evenly across the belt carcass.





Designing transfer points for confined spaces.

On the return side of the conveyor, return rollers support the empty belt as it travels back toward the loading point. Although the load is lighter, the engineering considerations remain significant. A schematic example would depict a single horizontal roller mounted beneath the structure, maintaining a straight, tension-controlled return path. If the return belt is allowed to sag excessively, it can oscillate, flap, or drift laterally, introducing dynamic loads that accelerate wear on both the belt and the supporting structure. Properly spaced return rollers maintain belt tension, reduce vibration, and ensure that the belt re-enters the loading zone in a stable condition.

At loading points – where material is dropped onto the belt from chutes, hoppers, or transfer points – impact rollers are used to absorb the energy of falling material. These rollers often incorporate rubber rings or thickened shells that deform under impact, dissipating energy before it reaches the belt. A schematic description would show a closely spaced series of rollers positioned directly beneath the loading chute, with rubber-ringed surfaces arranged along the roller shell. The spacing between these rollers is typically reduced compared with standard carrying rollers, creating a reinforced impact zone that protects the belt from gouging, tearing, and premature fatigue.

To maintain proper belt tracking, guide rollers are installed along the conveyor structure to prevent lateral drift. These rollers do not carry vertical load; instead, they provide corrective force when the belt begins to wander. A schematic example would show small vertical rollers mounted on either side of the belt edge, engaging only when the belt deviates from its central path. In more advanced systems, guide rollers may be part of self-aligning frames that pivot slightly to steer the belt back into position. Effective tracking is essential for preventing spillage, reducing edge wear, and avoiding contact between the belt and the conveyor structure.

In environments where moisture, clay, or fine material creates adhesion problems, rubber-coated rollers are employed to improve traction and reduce slippage. These rollers feature a bonded rubber layer – sometimes patterned or grooved – to enhance grip and shed water. A schematic representation would show a standard steel roller shell overlaid with a rubber coating, designed to deform slightly under load and maintain consistent contact with the belt. This design reduces noise, dampens vibration, and improves belt stability in wet or contaminated conditions.

The advantages of high-quality rollers extend across the entire conveyor system. Precision-machined shells, sealed-for-life bearings, and corrosion-resistant housings allow rollers to withstand abrasive ores, high loads, and continuous operation without premature failure. Reduced friction lowers power consumption and minimises heat generation, contributing to longer belt life and improved energy efficiency. Over the lifespan of a conveyor installation, these factors translate into fewer stoppages, lower maintenance costs, and significantly improved system availability – key considerations for mining engineers tasked with designing or upgrading haulage infrastructure.

In contemporary mining operations, where conveyors may stretch for kilometres and operate around the clock, the roller set is no longer a simple mechanical accessory but a critical engineered subsystem. Its performance influences everything from belt tension and power draw to material stability and structural loading. By understanding the mechanical behaviour, design principles, and application-specific requirements of each roller type, engineers can ensure that their conveying systems achieve the reliability, efficiency, and longevity demanded by modern mining.



Chain making



Cobalt chains clarifier tank

## CHAIN CONVEYORS

Mining-grade high-strength circular chain is a critical transmission component used extensively across key pieces of underground and surface mining equipment, including scraper conveyors, transfer machines, and coal-cutting systems. The reliable operation of these machines depends on the performance of the circular link chain, which serves as the primary traction element. Within scraper conveyors in particular, the connecting ring functions as a high-strength mechanical link that directly influences the efficiency, stability, and safety of the entire conveying system. Any weakness in the chain or its connectors can compromise production continuity, making the quality and integrity of these components central to mining operations.

The mining circular link chain is typically constructed from open or flat connecting rings and is designed to serve as the traction chain for large coal-mining machinery. Because it forms the mechanical backbone of scraper conveyors and related systems, the chain must undergo rigorous inspection and testing to ensure that it meets the demanding requirements of mining environments. Its performance is not merely a matter of mechanical convenience; it is fundamental to the safe and continuous operation of the equipment it supports.

Circular chains are manufactured in a range of types depending on their intended function, including transmission chains, conveyor chains, traction chains, and specialised variants designed for unique applications. Their specifications vary accordingly. In mining, high-strength circular link chains are produced in widely used sizes such as 10 × 40, 14 × 50, 18 × 64, 22 × 86, 26 × 92, and 30 × 108, each selected to match the load, speed, and environmental conditions of the equipment. These dimensions reflect the evolution of chain design as mining machinery has grown in scale and complexity.

Technical standards for circular chains differ across regions and manufacturers. Many international producers follow the American ANSI standard, while several European

manufacturers adhere to BS standards. Regardless of the standard adopted, two factors ultimately determine the quality of a mining circular chain: the processing technology and the material used. Historically, Chinese manufacturers relied on imported steels from the United States and Europe, but advances in domestic metallurgy have enabled the localisation of chain-grade materials without compromising performance.

Material grades for circular chains vary widely. Chains are classified into strength levels ranging from 30-grade to 120-grade, with higher grades used in the most demanding applications. The steels employed include Q235, 20MnSi, 20Mn2, 25MnV, and more advanced alloys such as 23MnNiMoCr54. Over time, Chinese chain materials have evolved from simple carbon-manganese steels to more sophisticated manganese-nickel-chromium-molybdenum alloys. As metallurgical technology has progressed, silicon and manganese contents have been reduced while chromium and molybdenum levels have increased, resulting in significantly improved toughness and fatigue resistance. With the growing performance demands placed on mining chains, manufacturers have begun developing new alloy systems tailored to specific operational challenges.

The production process for mining circular chains follows a precise sequence: cutting, cold bending and weaving, jointing, welding, primary calibration, heat treatment, secondary calibration through pre-tensioning, and final inspection. Among these stages, welding and heat treatment are the most critical, as they directly influence the mechanical integrity and service life of the chain. Optimised welding parameters improve yield and reduce production costs, while an appropriate heat-treatment regime ensures that the material's inherent properties are fully realised. Modern mining chains are typically heat-treated using medium-frequency induction heating with continuous quenching and tempering. This method relies on electromagnetic induction to generate heat within the steel itself. As the chain passes through the inductor, alternating current induces a corresponding

current within the metal, rapidly heating it to the required quenching temperature. This process allows precise control of heating rates and temperature uniformity, producing chains with excellent hardness, toughness, and fatigue resistance.

Understanding the compliance requirements and potential failure modes of mining circular chains is essential for engineers responsible for equipment reliability. Failures may arise from improper heat treatment, inadequate welding penetration, material defects, overloading, corrosion, or misalignment within the conveyor system. Thorough inspection, adherence to standards, and careful material selection are therefore indispensable in ensuring that circular chains meet the rigorous demands of modern mining operations.

In the complex ecosystem of modern mining, where productivity hinges on the seamless movement of vast quantities of material, heavy-duty conveyor chains continue to play a defining role. Although belt conveyors dominate long-distance haulage, chain-based systems remain indispensable in applications where extreme loads, abrasive materials, and demanding duty cycles exceed the capabilities of lighter equipment. Their mechanical resilience, metallurgical sophistication, and operational reliability make them essential components in both surface and underground mines. For engineers tasked with designing or maintaining material-handling systems, a deeper understanding of the engineering principles behind heavy-duty conveyor chains is critical to achieving long-term performance and system availability.

At the core of every heavy-duty conveyor chain lies a deceptively simple mechanical concept: a continuous loop of interlocking steel links driven by sprockets. Yet the engineering behind these links is anything but simple. Mining-grade chains are typically manufactured from high-strength alloy steels, often chromium-molybdenum blends, chosen for their ability to deliver both hardness and toughness. Heat treatment is central to their performance. Carburising and induction-hardening processes are used to create a hard, wear-resistant surface capable of resisting abrasion, while preserving a ductile core that can absorb the shock loads common in crusher-feed

systems and apron feeders. Pins and bushings are usually through-hardened to withstand cyclic loading and impact forces. The metallurgical challenge lies in achieving the correct balance: too much hardness introduces brittleness, while insufficient hardness accelerates wear. Modern heat-treatment techniques allow manufacturers to achieve surface hardness levels in the region of 55 to 62 HRC while maintaining the internal resilience required for mining environments.

Mining exposes conveyor chains to a range of wear mechanisms that must be understood and managed. Abrasive wear is one of the most prevalent, driven by fine particles such as silica, coal dust, or crushed ore infiltrating the pin-bushing interface. This type of wear is particularly aggressive in hard-rock operations where sharp fines are ever-present. Impact wear is another major factor, especially in applications where large lumps of material strike the chain with significant force. Crusher-feed conveyors, apron feeders, and loading points all impose high-energy impacts that demand robust, through-hardened components. Corrosive wear is common in salt, potash, and certain underground coal environments, where moisture and chemical exposure degrade unprotected steel. Fatigue failure, driven by cyclic loading, misalignment, or inadequate lubrication, remains a critical concern for engineers, as it can lead to sudden and costly breakdowns. Understanding these mechanisms allows engineers to specify the correct chain design, material grade, and maintenance strategy for each application.

Lubrication is one of the most influential factors affecting chain life, yet it is often underestimated. Mining environments present unique challenges for lubrication systems, including dust ingress, moisture, and temperature extremes. Depending on the application, lubrication may be delivered through drip systems, forced-feed systems, or dry-film lubricants designed for dusty conditions where oil would attract abrasive particles. In corrosive or fine-particle environments, sealed-joint chains offer significant advantages by preventing contaminants from entering the wear surfaces. Effective maintenance practices – such as monitoring chain elongation, inspecting pin and bushing wear, checking sprocket tooth profiles,



and verifying alignment – extend service life and prevent catastrophic failures. Because chains can be rebuilt link by link, maintenance interventions are often more economical than full system replacements.

The operational advantages of heavy-duty conveyor chains are well established. Their ability to handle large lump sizes, high impact loads, steep inclines, and materials that are hot, sharp, or highly abrasive makes them indispensable in many mining applications. They are particularly effective in crusher-feed systems, apron feeders, underground trunk conveyors, and mill-feed systems where reliability and robustness are paramount. Their high load capacity and mechanical resilience allow them to operate at high speeds while moving substantial volumes of material, improving production flow and reducing reliance on mobile equipment. In underground operations, where ventilation constraints and traffic congestion limit the use of diesel haulage, chain conveyors often become the backbone of the entire material-handling system.

Safety is another significant advantage. By automating material movement, chain conveyors reduce the need for workers to interact directly with heavy or unstable loads. Modern systems incorporate emergency-stop circuits, obstruction sensors, and automated shutdown protocols that respond to abnormal conditions before they escalate. This controlled and predictable mode of operation enhances worker protection, particularly in confined or hazardous areas.

The economic benefits of chain conveyors extend beyond their operational performance. Although the initial capital cost may be higher than lighter systems, their long service life, low maintenance frequency, and modular repairability contribute to favourable whole-of-life economics. Chains resist stretching, tolerate impact loading, and can be repaired incrementally, reducing downtime and maintenance expenditure. Their energy efficiency, especially when compared with diesel-powered haulage, further reduces operating costs and supports the industry's growing emphasis on emissions reduction.

Across the mining sector, heavy-duty conveyor chains are used in a wide range of applications. Coal mines rely on them in feeder breakers and underground trunk conveyors. Hard-rock operations use them in crusher-feed systems, apron feeders, and mill-feed conveyors. Salt

and potash mines benefit from corrosion-resistant chain designs tailored to their environments, while diamond mines depend on chains capable of withstanding extreme impact and abrasion. Their utility extends beyond mining into construction, agriculture, and heavy manufacturing, wherever dense, abrasive, or irregular materials must be moved reliably.

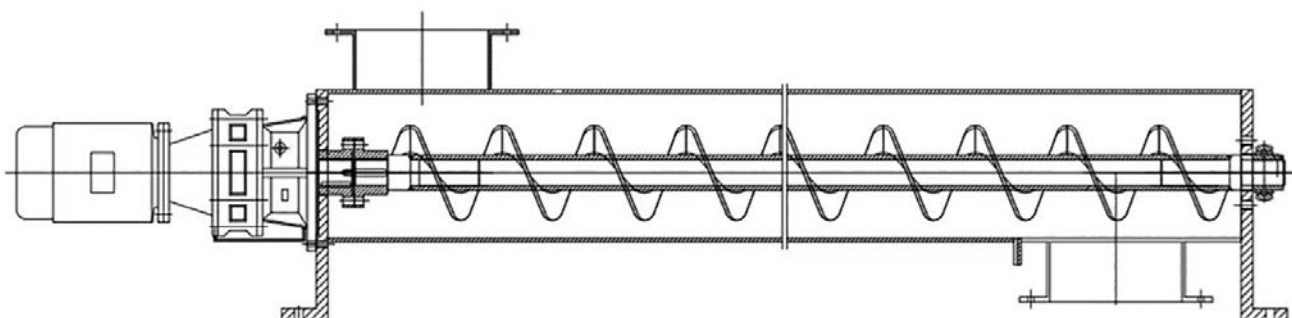
Comparative case studies illustrate the transformative impact of properly specified chain systems. In one hard-rock operation, replacing belt feeders with heavy-duty chain apron feeders reduced downtime by 40 percent due to improved resistance to impact and abrasive wear. An underground coal mine that transitioned from shuttle cars to chain-based trunk conveyors increased continuous miner utilisation by more than 20 percent, reducing congestion and improving safety. In a salt mine, the adoption of corrosion-resistant alloy chains extended service life from 18 months to more than four years, significantly reducing maintenance costs and improving system availability.

For mining engineers, the selection and specification of heavy-duty conveyor chains require careful consideration of load characteristics, environmental conditions, sprocket design, lubrication regimes, and maintenance strategies. When these factors are properly addressed, chain conveyors deliver a combination of durability, efficiency, and safety that few alternatives can match. They remain, in many respects, the quiet enablers of modern mining productivity – simple in concept, highly engineered in execution, and indispensable in practice.

## SCREW CONVEYORS

Among the many conveying technologies used in mining – from belt conveyors and apron feeders to bucket elevators and pneumatic systems – the screw conveyor occupies a distinctive niche. Its origins lie in the ancient Archimedean screw, but the modern industrial form emerged in the late nineteenth and early twentieth centuries as steel fabrication improved and continuous-processing industries demanded enclosed, controllable material movement. By the mid-1900's, screw conveyors had become standard equipment in coal preparation plants, mineral-processing circuits, and metallurgical operations.

A screw conveyor consists of a helical flight mounted on a central shaft and enclosed within a trough or tubular casing. As the screw rotates, material is advanced along the housing by a combination of rotational force, friction, and



Diagrammatic cut-away view of a Screw Conveyor

the geometry of the flights. Although mechanically simple, the design is highly adaptable, and several configurations are used in mining depending on the material and duty:

- Standard shafted screw conveyors, the most common type, used for general ore, concentrate, and reagent handling.
- Shaftless screw conveyors, ideal for sticky, viscous, or high-moisture materials such as filter cakes and dewatered tailings.
- Inclined and vertical screw conveyors, used where plant layouts require elevation changes without the footprint of a belt system.
- Live-bottom screw feeders, which regulate flow from bins and hoppers, ensuring consistent feed to downstream equipment.
- Wear-protected heavy-duty designs, incorporating abrasion-resistant flights, liners, and reinforced troughs for aggressive ores.

Installation is typically straightforward. Conveyors are mounted on structural frames or saddles, with the drive unit positioned at the discharge end to maintain tension and reduce back-driving. Troughs or tubes are sealed to control dust and prevent spillage – an important advantage in both underground and surface plants. Modular sections allow assembly in confined spaces, while surface installations may incorporate multiple inlets, steep inclines, or variable-speed drives to integrate with process flows.

Within mining operations, screw conveyors are most commonly found in processing plants rather than in primary extraction. They are used to move crushed ore, feed mills, transfer flotation concentrates, handle reagents, and convey dewatered tailings or filter cakes. Their enclosed design makes them particularly valuable where dust suppression is essential, and their ability to meter material accurately supports stable downstream performance. In coal operations, they often serve as

feeders for thermal dryers or as discharge conveyors beneath silos and hoppers; in metalliferous mining, they appear in smelters, refineries, and chemical-processing circuits where corrosive or high-temperature materials must be handled safely.

For mining operators, the advantages of screw conveyors are clear: compact footprints, excellent containment, predictable flow control, and the ability to handle difficult or abrasive materials with minimal spillage. While they do not replace belt conveyors for long-distance haulage, they remain indispensable for short-distance, enclosed, and controlled material movement – an enduring solution that has evolved alongside the industry’s increasing demands for efficiency, automation, and environmental performance.

## OVERHEAD CONVEYORS

Manual overhead conveyors continue to serve a practical role in mining and mineral-processing facilities, even as automation becomes more widespread. They are particularly useful in low- to medium-volume areas where flexibility, simplicity, and cost control are more important than high throughput. Workshops, fabrication bays, pump rebuild stations, and maintenance stores often rely on manual overhead systems to move components, tools, and assemblies between work zones. Because these conveyors operate through human effort rather than motors, they provide a reliable and low-maintenance means of transferring items without the complexity of automated drives. Their ability to handle loads approaching two tonnes makes them suitable for transporting heavy fabricated parts, pump casings, chute liners, and other equipment commonly serviced in mine maintenance operations.

These manual systems can be enhanced with switches, interlocks, and turntables, allowing operators to redirect loads through different work areas or navigate tight layouts typical of underground workshops or brownfield processing plants. This flexibility is particularly valuable when handling irregular or batch-based maintenance tasks, where the movement of components does not follow a fixed production rhythm.



Overhead mining conveyors



Monorail overhead conveyors extend this capability into more structured, continuous movement across larger sections of a mining facility. Built around a single ceiling-mounted track, monorail systems are well suited to transporting components between maintenance shops, assembly bays, reagent-handling areas, and thermal-processing zones. In mineral-processing plants, they are often used to move wear parts, filter plates, furnace components, or chemical-handling vessels through drying, curing, or coating processes. Powered monorail systems use enclosed conductor lines to ensure reliable operation in dusty, corrosive, or high-temperature environments typical of concentrators, smelters, and hydrometallurgical plants. Their ability to incorporate elevation changes, drop sections, and controlled transfer points allows engineers to design efficient routes through congested plant layouts where floor space is at a premium.

Power-and-free overhead conveyors represent a more advanced solution for mining operations that require staged, sequenced, or highly controlled material flow. These systems use a powered chain in an upper track and free-moving trolleys in a lower track, enabling loads to accumulate, stop, or advance independently. In mining, this capability is valuable in component-preparation lines, rebuild workshops, metallurgical processing areas, and any environment where equipment must be queued for inspection, coating, assembly, or heat treatment. Power-and-free systems support dynamic accumulation and line balancing, making them suitable for operations that require variable takt times or staged workflows, such as preparing crusher components, assembling pump modules, or sequencing furnace parts for metallurgical processing. Their robust construction allows them to move heavy, awkward, or heat-treated components safely through multiple workstations.

Enclosed-track overhead conveyors provide an additional level of environmental protection and reliability, making them particularly well suited to the harsh conditions found in mining. Their fully enclosed steel or aluminium track shields chains and trolleys from dust, overspray, corrosive vapours, and abrasive particles – conditions commonly encountered in concentrators, smelters, and chemical-processing plants. This protective design reduces maintenance requirements, extends component life, and ensures consistent performance even in areas with high particulate loads or aggressive chemical exposure. The enclosed track also reduces noise and vibration, which is advantageous in inspection areas, control rooms, and metallurgical laboratories where noise exposure must be managed. These systems are often used in reagent-handling zones, coating lines, furnace-feed preparation areas, and any process where contamination control or environmental isolation is essential.

Across all variants – manual, monorail, power-and-free, and enclosed-track – overhead conveyors offer mining operations a means of moving materials and components through constrained, hazardous, or environmentally sensitive areas while preserving valuable floor space and maintaining predictable, controlled flow. Their adaptability and compatibility with both manual and automated workflows make them a strategic complement to the belt, chain, and screw conveyors that dominate bulk-material handling in the mining sector, filling a specialised but essential role in the broader material-movement ecosystem.

Recent advancements in engineering, materials science, and automation have further elevated the role of conveyors in mining. Intelligent systems equipped with sensors and real-time monitoring can detect belt misalignment, blockages, or mechanical wear before they escalate into costly downtime. High-strength, lightweight materials – such as advanced polymer belts and corrosion-resistant components – have improved durability in abrasive, moisture-laden, and high-impact environments typical of both underground and surface operations. The integration of robotics, automated sampling systems, and autonomous haulage technologies has created highly efficient, interconnected material-handling networks that support continuous mining and processing.

These innovations have had a profound impact on mining operations. Modern conveyors deliver higher throughput with greater accuracy, reducing reliance on truck haulage and lowering fuel consumption, emissions, and maintenance costs. Energy-efficient motors and smart control systems support sustainability goals, while the use of recyclable and environmentally responsible materials aligns with the mining industry's increasing focus on environmental stewardship. By reducing manual handling and exposure to hazardous conditions, advanced conveyor systems also enhance worker safety – an especially critical factor in underground mines where confined spaces and complex geology heighten operational risks.

Within the mining and bulk-materials industries, conveyor manufacturers play a central role in enabling efficient, high-volume material movement across some of the most demanding operational environments. In coal mining – both surface and underground – conveyor systems are indispensable for maintaining continuous production. Companies such as Komatsu, through its Joy product line, have become synonymous with underground coal haulage, supplying armoured face conveyors, stage loaders, and chain-based systems that form the backbone of longwall operations. Sandvik Mining and Rock Solutions similarly provides heavy-duty conveyor systems and chain-driven haulage equipment designed to withstand the abrasive, high-load conditions typical of deep coal seams. Complementing these system manufacturers are leading belting specialists such as Fenner Dunlop and Continental, whose flame-resistant, high-tension belts meet the stringent safety and performance requirements of underground coal environments. FLSmidth also contributes significantly to coal-handling infrastructure, supplying belt conveyors, feeders, and integrated systems for both underground mines and surface preparation plants.

In hard-rock mining, where operations must contend with sharp, abrasive ore and long transport distances, conveyor manufacturers focus on durability, capacity, and terrain adaptability. Metso is a major supplier of overland conveyors, belt feeders, and in-pit crushing and conveying (IPCC) systems used extensively in large copper, iron ore, and gold mines. Thyssenkrupp Industrial Solutions has established itself as a leader in curved overland conveyors and high-angle systems, technologies that reduce reliance on truck haulage in massive open-pit operations. Beumer Group also plays a prominent role in this sector, providing long-distance and pipe conveyor systems capable of transporting ore across rugged landscapes while minimising environmental

impact. Supporting these system integrators are component manufacturers such as Rexnord, whose engineered chain, gear drives, and critical conveyor elements are widely used in heavy-duty hard-rock applications. FLSmidth again appears as a key supplier, offering robust material-handling solutions that integrate seamlessly with crushing and grinding circuits in large-scale mines.

Bulk-port handling represents another major domain where conveyor manufacturers exert significant influence. High-capacity export terminals for coal, iron ore, grain, and aggregates rely on continuous-duty conveyor systems capable of loading, unloading, stacking, and reclaiming vast quantities of material. Bruks-Siwertell is a global leader in this space, supplying ship unloaders, ship loaders, and port-side conveyor systems designed for high throughput and environmental efficiency. Beumer Group extends its expertise to port operations as well, providing belt conveyors, pipe conveyors, and stacker-reclaimers used in major terminals worldwide. Thyssenkrupp Industrial Solutions contributes large-scale ship loaders, bucket-wheel reclaimers, and long-distance port conveyors, particularly for iron ore and coal export facilities. FAM, known for its specialised port-side handling equipment, offers stackers, reclaimers, and ship loaders tailored to high-volume bulk operations. Metso also supports bulk-port infrastructure with conveyor systems and screening stations designed to integrate with large-scale loading and unloading processes.

Across coal mining, hard-rock mining, and bulk-port handling, these manufacturers collectively shape the global material-handling landscape. Their technologies enable safer, more efficient, and more sustainable operations, ensuring that vast quantities of raw materials move reliably from extraction to processing to export.

Across mining and bulk-materials handling, the most advanced conveyor manufacturers are driving the industry

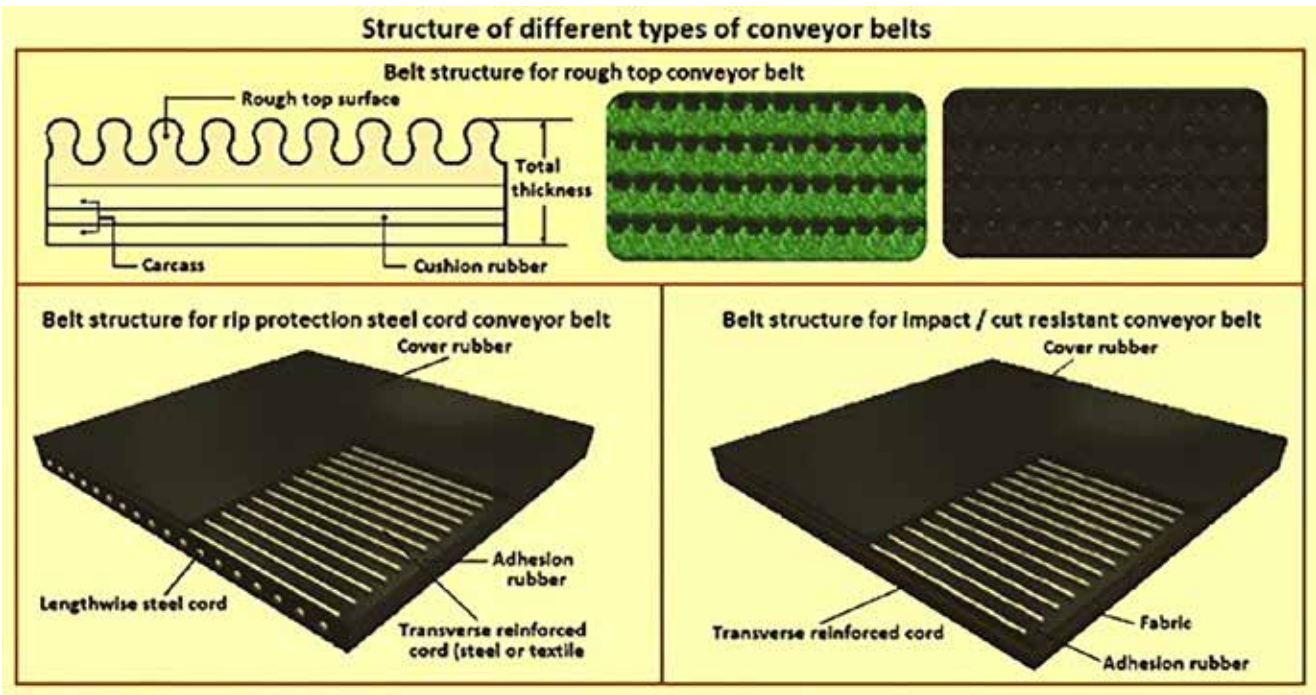
forward through a combination of intelligent automation, high-performance materials, and large-scale engineering innovations. One of the most transformative developments is the rise of intelligent conveyor monitoring systems, now widely deployed by companies such as Sandvik, Komatsu, Metso, and Beumer. These systems use distributed sensors, condition-monitoring units, and real-time analytics to track belt alignment, chain tension, idler health, and drive performance. In underground coal operations, for example, Komatsu's longwall conveyors rely on continuous monitoring to detect chain wear or AFC loading anomalies before they escalate into production-stopping failures. Similarly, in hard-rock mines, Metso and Thyssenkrupp integrate advanced diagnostics into overland conveyors to manage the stresses of long-distance, high-tonnage transport.

Another major area of innovation lies in high-strength, specialised conveyor materials. Manufacturers such as Continental and Fenner Dunlop have developed steel-cord and aramid-reinforced belts capable of withstanding extreme tension, abrasion, and impact – conditions common in iron ore, copper, and coal operations. Fire-resistant and anti-static compounds are essential for underground coal mines, while heat-resistant and cut-resistant belts support hard-rock crushing circuits. These material advances have significantly extended belt life, reduced maintenance downtime, and improved safety across all mining sectors.

In conveyor belt construction, aramid refers to a class of high-strength synthetic fibres – most notably materials such as Kevlar – that are used to reinforce the belt carcass. Aramid fibres are aromatic polyamides engineered to deliver exceptional tensile strength while remaining remarkably lightweight. When incorporated into a conveyor belt, they provide a combination of strength, stability, and durability that rivals steel cords but without the associated weight or susceptibility to corrosion.



Fenner Dunlop aramid-reinforced conveyor belt



Conveyor belt construction

In practical terms, aramid reinforcement allows a conveyor belt to operate under high tension with minimal stretch, which is particularly valuable in long-distance or high-load applications. Because aramid fibres resist abrasion, impact, and heat, they perform well in demanding environments such as hard-rock mining, underground coal operations, and bulk-port handling. Their flame-resistant and non-conductive properties also make them suitable for underground coal mines, where safety requirements are stringent.

The use of aramid significantly reduces belt weight, which in turn lowers energy consumption and decreases the load on drive systems. This lighter construction enables longer conveyor routes, steeper inclines, and improved handling of sharp or abrasive materials. Aramid belts also require less maintenance, as they experience less elongation and maintain their structural integrity over extended service periods.

In essence, aramid in conveyor belt construction denotes a shift toward advanced, high-performance materials that enhance strength, safety, efficiency, and longevity across a wide range of mining and bulk-handling applications.

In large surface mines, the integration of in-pit crushing and conveying (IPCC) technology has become a defining trend. Companies like Metso and Thyssenkrupp are at the forefront of designing systems that replace or reduce truck haulage by linking mobile crushers directly to long-distance conveyors. This approach lowers fuel consumption, reduces emissions, and enables continuous material flow from the pit to the processing plant. Beumer's long-distance and pipe conveyors complement these systems by transporting ore across rugged terrain with minimal environmental disturbance, often replacing haul roads entirely.

Automation is also reshaping conveyor applications in both mining and port environments. Automated loading, stacking, and reclaiming systems, supplied by Beumer, FAM, and Thyssenkrupp, allow bulk-port terminals to

handle enormous volumes of coal, iron ore, and grain with precision and minimal human intervention. These systems use programmable logic control, laser-guided positioning, and advanced drive technology to optimise stockpile formation and reclaiming efficiency. In ports where environmental regulations are strict, enclosed pipe conveyors and dust-suppression technologies help reduce particulate emissions during loading and unloading.

The integration of conveyors with robotics and autonomous equipment is another frontier. In hard-rock mines, conveyors increasingly interface with autonomous haul trucks, automated sampling stations, and robotic inspection tools. Underground coal operations use automated shearers and plough systems that synchronise with armored face conveyors, ensuring continuous, high-volume extraction. These technologies reduce human exposure to hazardous environments while improving consistency and throughput.

Finally, energy efficiency has become a central focus across all sectors. Manufacturers now employ variable-frequency drives (VFDs), regenerative braking systems, and low-rolling-resistance idlers to reduce power consumption. In long overland conveyors, regenerative drives can feed excess energy back into the grid, turning downhill haulage into a source of power rather than a cost. These innovations support both operational savings and broader sustainability goals.

Together, these technologies – intelligent monitoring, advanced materials, IPCC systems, automation, robotics integration, and energy-efficient drive solutions – represent the cutting edge of conveyor engineering. They enable mining and port operators to move greater volumes with higher reliability, lower environmental impact, and significantly improved safety, reinforcing the conveyor's role as a critical asset in modern material-handling infrastructure.

# Conveyor Belts – The Invisible Destroyer

When you consider the millions, indeed billions, that mines and quarries spend on conveyor belts each year, I find it absolutely amazing how the vast majority of manufacturers and suppliers are selling belts that effectively have an inbuilt weakness that seriously restricts performance and the length of working life.

## **P**ERISH THE THOUGHT

The weakness I refer to is the almost non-existent resistance to ground level ozone (O<sub>3</sub>) ultraviolet light (UV). Exposure to light and air begins from the moment the rubber is vulcanised during the production process and not, as some wrongly believe, occurs slowly over the years. The damage it causes is considerable. The early signs are small cracks appearing in the rubber surface, in some cases within weeks of first being fitted with much worse to come as the rubber becomes increasingly brittle and inflexible. This is sometimes referred to as 'dry rotting'. Further attacks occur inside the newly exposed cracks, which grow steadily until they complete a 'circuit' and the rubber fails.

It is not a new phenomenon; in fact, the problem has been scientifically recognised since the late 19th and early 20th centuries. In the past, the phrase 'perished' was used when referring to rubber that was disintegrating but this term has mostly been replaced by 'degradation' and oxidation. Whichever term you prefer to use, ozone and UV exposure is the prime cause, resulting in premature, excessive wear damage and a major decline in the performance and functional lifetime of rubber conveyor belts. The short-term and long-term effects are something that all conveyor operators need to understand but most usually do not and

consequently do not incorporate in the specification when buying belts.

## ENTIRELY PREVENTABLE

The most annoying and frustrating part is that the damage is entirely preventable thanks to the use of a range of special antioxidants such as 2,2,4-Trimethyl-1,2-dihydroquinoline polymer (MQ), anti-degradants, antifatigue agents and antiozonants, which when included in sufficient quantities during the creation of the rubber compound. Despite this, surveys of the results of EN/ISO 1431 international testing standards continue to show that more than 80%



Disintegrated – the effects of ozone and ultraviolet exposure



Prevention is achieved by including antioxidants and anti-degradants when making the rubber compound

of rubber conveyor belts sold in Europe, Africa and the Middle East have no protection.

Somewhat reassuringly, this is definitely not a failing you would find in vehicle tires, simply because they would otherwise be highly prone to catastrophic failure. So, why is most of the rubber used to make industrial conveyor belts not similarly protected? The answer boils down to two words – price competition.

## AN AVOIDABLE COST

Rubber makes up some 50% of the production cost of a conveyor belt and some 70% of its mass. In today's highly competitive conveyor belt market, it is therefore the number one target for cost-cutting. Good quality antioxidants and antiozonants generally cost between €2.50/kg and €3.50/kg. A standard 400/3 4+2 abrasion belt of 200 meters and 1000 mm width typically consists of around 1700 kg of rubber compound. Not using antioxidants/antiozonants, anti-degradants and anti-fatigue agents generally gives a 3% or more reduction in compound cost.

This may sound like a marginal saving, but it is actually very significant to those competing at the *'pile it high, sell it cheap'* end of the market. In addition to the cost saving is the more sinister aspect of not using protective agents because anything that prolongs the working life of belts is not good for business. The more frequently belts need to be replaced, especially for the service companies trading and fitting them, the better. Distasteful as it may be, the two factors added together provide a very strong case for the widespread absence of protection.

**TOP TIP:** Always insist on written confirmation that the belt you are being offered is fully resistant to the effects of ozone (O<sub>3</sub>) in accordance with the EN ISO 1431 test method and ultraviolet light (UV). Without this essential protection your belts will be more problematic and need to be replaced far sooner than they should be.

## WHAT TO LOOK FOR

Ground-level ozone (O<sub>3</sub>), also known as tropospheric ozone, is a trace gas in the troposphere (the lowest level of the Earth's atmosphere) created by the photolysis of nitrogen dioxide (NO<sub>2</sub>) from sources such as automobile exhaust and industrial discharges. The scientific name is ozonolysis. To the naked eye, rubber that has been degraded by ozone looks like there is a "cloudy" silver-grey film on the surface of the rubber, commonly referred to as "frosting". This film is often mistaken for "bloom". However,

a chemical that blooms to the surface, producing a cloudy film, can be washed or rubbed off whereas surface degradation due to attack from either ozone or ultraviolet cannot.

As mentioned earlier, the first signs are cracks appearing in the surface of the rubber. Ozone exposure is unavoidable because even tiny traces of ozone in the air will attack the molecular structure of rubber. It increases the acidity of carbon black surfaces with polybutadiene, styrene-butadiene rubber, nitrile rubber and natural rubber being the most sensitive to degradation.

Ozone cracks form in rubber that is under tension. It is important to bear in mind that the amount of tension (critical strain) needed is extremely small. Even a belt in storage has a certain amount of intrinsic tension. The cracks are always oriented at right angles to the strain axis. The dynamic stress that a conveyor belt undergoes while in operation is considerable. Ozone attack occurs at the points where the strain is greatest.

## ULTRAVIOLET DAMAGE

Ultraviolet light from sunlight and artificial (fluorescent) lighting also has a seriously detrimental effect on rubber. Ultraviolet accelerates rubber deterioration because it produces photochemical reactions that promote the oxidation of the rubber surface resulting in a loss in mechanical strength, known as 'UV degradation'.



Ozone cracks are always oriented at right angles to the strain axis.



The 'longer term' effects of ozone & UV can occur within a few months

## EN/ISO 1431 TESTING

Ozone resistance is measured in accordance with the EN/ISO 1431 test method in which samples of rubber are placed under tension (20% strain) inside an ozone testing cabinet and exposed to highly concentrated levels of ozone for a period of up to 96 hours (@ 40°C, 50 ppm).

Samples are examined for evidence of cracking at two-hourly intervals and the results carefully measured and recorded. Experience has determined that in order for the rubber to be regarded as adequately resistant, the pass criteria needs to be that the rubber sample does not show any signs of cracking within the 96-hour period. The vast majority of samples tested, however, crack within less than 8 hours, which experience shows can equate to be as short as three working months in real time.



80% of samples tested typically fail within 8 hours



Cracks deepen under the repeated stress of passing over the pulleys and drums.

## HIDDEN EFFECTS

The repeated action of the mechanical stress of the conveyor belt and the frictional process from the idlers trigger an oxidative chain reaction that forms a chemical process that breaks the molecular chain and activates the oxidation process. This in turn magnifies a whole range of problems. Over a surprisingly short time, (literally months or even weeks without built-in protection), the rubber becomes increasingly brittle and less able to stretch and contort as it should; wear resistance diminishes while transversal cracks steadily deepen and grow under the stress of passing over the pulleys and drums until catastrophic failure occurs.

Cracks present other potential risks such as scrapers catching on them and tearing off parts of the cover. Re-splicing also becomes increasingly difficult as the adhesion properties of the rubber diminish. Environmentally, dust enters the cracks and is then shaken out on the return (underside) run causing a polluted working environment.

## CONCLUSION

Rubber degradation and decomposition caused by exposure to ozone and ultraviolet light is far more damaging and costly than most manufacturers would have you believe. In fact, it is very rare to see any manufacturer or supplier/service company even mention the subject because they do not want you asking awkward questions. Please do not make the mistake of ignoring the subject yourself because in this case, ignorance is definitely not bliss!

## AUTHOR

Bob Nelson



# Payload, Powertrains, and Performance: The New Generation of Underground Mining Trucks

**G**ordon Barratt of *Mining & Quarry World* and *Coal International* takes a detailed look at the increasing intelligence now embedded into underground mining trucks, machines that have evolved far beyond their traditional reputation for brute force. Payload, powertrains, and performance have converged in a new generation of equipment where digital capability is becoming as critical as mechanical strength. In today's hard rock operations, load-haul-dump units remain the essential bridge between the production face and the wider material handling network, yet their role has expanded significantly as mines extend to greater depths, ventilation pressures intensify, and the need for precision becomes paramount. Modern LHDs are compact, high strength workhorses engineered to operate in the tightest headings while delivering the productivity levels that underpin an entire mine's output. Their development mirrors a wider transformation in underground mining: a shift from purely mechanical haulage to integrated, data driven systems that elevate safety, efficiency, and environmental performance.

The latest generation of underground trucks blends heavy duty structural design with advanced automation, real time data acquisition, and markedly enhanced operator protection. These machines are now purpose built to move more tonnes with greater accuracy, reduced emissions, and far deeper insight into machine health and operational behaviour. For engineers and mine managers, the ability to interpret and optimise these interconnected systems has become central to achieving meaningful efficiency gains underground. As digitalisation accelerates across

the sector, the haulage fleet is emerging not only as the muscle of the mine but as one of its most valuable sources of operational intelligence, providing the data foundation for smarter, safer, and more predictable underground production.

Underground mining has always depended on the continuous, safe, and efficient movement of broken rock. Over more than a century of technological change, the machines responsible for this task – haul trucks and LHDs – have undergone a transformation that mirrors the changing nature of underground mining itself. Early operations were defined by shallow workings, simple geometries, and modest production rates. As mines expanded deeper and ore bodies became more complex, the demands placed on haulage equipment intensified. The result has been a steady progression from rigid rail based systems to the highly specialised, low profile, digitally connected fleets that define modern underground mining.

For much of the early twentieth century, underground haulage was dominated by rail systems. Ore cars and locomotives offered durability and predictable operation, but they imposed rigid constraints on mine design. Fixed rail infrastructure could not adapt easily to changing headings or irregular ground conditions, and as mines deepened, the limitations of track bound haulage became increasingly apparent. The industry needed mobility – machines capable of navigating uneven ground, adjusting to evolving layouts, and operating without the constraints of permanent track.



Eimco Front Loader Rocker Shovel



Trident 12B Rocker Shovel

The breakthrough arrived in the 1950s and 1960s with the introduction of compact, articulated, rubber tyred vehicles. Adapted initially from surface equipment, these early underground trucks were modified for low profile operation and tight turning radii. Their articulation joints and low slung frames allowed them to manoeuvre through narrow drifts, marking the beginning of true mobile underground haulage. This shift liberated mine design, enabling more flexible development and more efficient extraction.

The widespread adoption of diesel engines in the 1960s and 1970s further transformed underground haulage. Diesel power delivered the torque, reliability, and endurance required for deeper mines and longer haul routes. As operations expanded, haulage ramps grew steeper and ventilation demands increased. Diesel trucks became the backbone of underground mining, but they also introduced new challenges: heat, particulate emissions, and the escalating cost of ventilation systems required to maintain safe working conditions. These pressures drove manufacturers to develop increasingly sophisticated cooling systems, exhaust treatments, and engine management technologies.

By the 1980s and 1990s, the industry had entered the era of purpose built underground trucks. Manufacturers began designing machines specifically for the unique demands of underground environments. Reinforced frames, advanced cooling packages, hydraulic braking systems, and low

profile configurations became standard features. Payload capacities rose steadily, with modern units now exceeding sixty tonnes in some applications. These machines were engineered not only for strength but for survivability in abrasive, confined, and thermally challenging conditions.

A MAN GHH load-haul-dump machine of the 1980s stood as a physical expression of the engineering priorities that defined the early era of trackless underground mining. These were years when mines were transitioning away from rail bound haulage and urgently needed mobile equipment that could survive relentless gradients, abrasive strata, tight headings, and the punishing duty cycles of expanding hard rock and coal operations. MAN GHH's loaders answered that demand with a philosophy rooted in durability above all else. Their frames were massively built, their mechanical layouts deliberately uncomplicated, and their powertrains selected for longevity rather than finesse. In an age before widespread onboard electronics, the value of a machine was measured by how long it could run between failures, and MAN GHH's LHDs earned their reputation by doing exactly that.

The German manufacturer was not alone in shaping the emerging LHD landscape. In North America, Wagner Mining Equipment – later absorbed into Atlas Copco and eventually forming part of today's Epiroc portfolio – was producing its popular ST series loaders, machines that became ubiquitous in mines from Canada to Australia. In



Early rail cars and Eimco Rocker shovel Loader



## UNDERGROUND MINING TRUCKS



Finland, Tamrock (also later integrated into Sandvik) was developing compact, agile loaders that helped define the Scandinavian approach to underground mechanisation. Sweden's Volvo BM contributed early articulated designs that influenced later generations of utility and loading equipment. By the early 1990's, Caterpillar had entered the field decisively with its R series loaders, bringing the company's global parts network and diesel engine expertise into the underground sector. Each manufacturer interpreted the same challenge – how to build a reliable, manoeuvrable, high capacity loader for confined spaces – through its own engineering culture.

Today, the evolution continues at an accelerated pace. Electrification, autonomous operation, and real time data analytics are reshaping expectations for what underground haulage equipment can achieve. Battery electric LHDs are reducing heat loads and cutting ventilation costs. Autonomous haul trucks are operating in zones previously considered too hazardous for personnel. Integrated health monitoring systems are predicting failures before they

occur, enabling mines to shift from reactive maintenance to predictive strategies that maximise uptime.

The modern underground haul truck is no longer just a carrier of rock; it is a node in a wider digital ecosystem. Its sensors, control systems, and communication networks feed into mine wide platforms that optimise traffic flow, manage energy consumption, and enhance safety. As mines continue to deepen and the pressure to improve environmental performance intensifies, these intelligent machines will play an increasingly central role in shaping the future of underground operations.

This new wave of underground mining trucks represents more than incremental improvement. It marks a fundamental shift in how capability, reliability, and intelligence are defined in the subterranean environment. The machines that once simply moved the mine are now helping to manage it, offering a level of insight and control that would have been unimaginable only a generation ago. In exploring their evolution, it becomes clear that the future of



McDowell Equipment- Wagner ST 3.5 lhd Underground Scooptram Loader



Wagner ST 5 E LHD Wheeled Loader



Wagner Scooptram ST-2B LHD

underground mining will be shaped not only by the tonnes these machines carry, but by the data, efficiency, and innovation they deliver.

## PAYLOADS

Underground mining trucks are defined as much by their payload capacity as by the geometry of the workings they serve. In the confined, highly engineered environment of an underground mine, payload is never an abstract number on a specification sheet; it is a direct expression of what the mine can physically accommodate, how far material must travel, and how efficiently the loading-hauling cycle can be sustained. As a result, payload classes have

evolved into distinct tiers, each shaped by the realities of tunnel dimensions, ramp gradients, haul distances, and the capabilities of the loaders that feed them.

At the smallest end of the spectrum are the compact 15 to 20 tonne trucks designed for narrow vein and small profile operations. Machines in this class, such as the 15 tonne units produced by manufacturers like DALL, are engineered for agility above all else. With turning radii in the region of three and a half metres and bucket volumes around 7.5 m<sup>3</sup>, they are able to navigate drifts that would be inaccessible to larger equipment. Their value lies in their ability to maintain cycle times in restricted headings where every centimetre of clearance matters. These trucks are typically paired with smaller LHDs, creating a balanced loading-hauling system that avoids the inefficiencies of under or over sized equipment.

As mines increase in scale, the industry shifts toward the medium capacity class, generally ranging from 20 to 30 tonnes. This is the domain of trucks such as Epiroc's MT22 and MT431B or Komatsu's HX30, machines built for operations with moderate tunnel widths and higher production targets. Their payloads allow for longer, more efficient hauls without the ventilation and infrastructure demands associated with the largest trucks. In this class, manufacturers focus on optimising the relationship between payload, powertrain performance, and structural durability, ensuring that the truck can sustain repeated



McDowell Equipment- Wagner ST 3.5 lhd Underground Scooptram Loader

# UNDERGROUND MINING TRUCKS



Epiroc MT22

full load climbs on steep ramps without excessive heat generation or component fatigue.

At the upper end of underground haulage are the large capacity trucks, typically carrying between 30 and 66 tonnes. Models such as the Epiroc MT436B or MT33 represent the engineering ambitions of high output mines with wide tunnels, robust ground support, and loading bays capable of accommodating large LHDs. These trucks are designed to move significant tonnage per cycle, reducing the number of trips required on long haul routes and improving overall fleet efficiency. Their frames, drivetrains, and braking systems must withstand immense stresses, particularly in deep mines where ramp gradients and ambient temperatures push mechanical systems to their limits.

Selecting the appropriate payload class is a technical decision that extends far beyond the truck itself. Tunnel size dictates the maximum permissible machine envelope and turning radius, often determining the upper limit of what can be deployed. Haul distance influences whether a mine benefits more from frequent cycles with smaller trucks or fewer, heavier cycles with larger ones. Loader capacity must be matched carefully to truck payload to avoid bottlenecks at the loading point. Mine output targets shape the scale of the fleet, ensuring that haulage capacity aligns with production without wasting capital on oversized equipment. Even cost per tonne becomes a payload dependent variable: overloading accelerates tyre wear, increases fuel consumption, and shortens component life, while underloading wastes the potential of the machine and inflates operating costs.

In practice, the most efficient underground haulage systems are those in which payload, powertrain, and mine design are treated as interdependent elements rather than isolated choices. The evolution of payload classes – from compact 15 tonne trucks to the 60 tonne giants of modern high capacity mines – reflects the industry's ongoing effort to balance mechanical capability with geological and infrastructural constraints. It is a balance that continues to shift as mines go deeper, equipment becomes more sophisticated, and the economics of underground production demand ever greater precision in matching machine to environment.

## POWERTRAINS

Powertrain engineering in underground mining trucks has undergone a profound transformation over the past three decades, driven by the competing demands of productivity, ventilation efficiency, safety, and long term sustainability. In the

unique environment of an underground mine – where heat, emissions, and noise are not merely operational concerns but engineering constraints – powertrain choice determines far more than tractive effort or cycle time. It shapes the mine's ventilation strategy, its energy consumption, and the overall economics of material movement. Today's underground haulage fleets draw on three principal powertrain philosophies: advanced low emission diesel systems, fully electric battery powered drivetrains, and emerging hybrid solutions that bridge the two.

Diesel powertrains remain the backbone of many underground operations, but the technology bears little resemblance to the engines that dominated the sector in the 1980's and 1990's. Modern underground diesels are engineered to meet stringent U.S. EPA Tier 4 Final standards, a regulatory threshold that has forced manufacturers to dramatically reduce particulate matter and nitrogen dioxide emissions. Achieving these reductions requires sophisticated after treatment systems – diesel oxidation catalysts, particulate filters, and selective catalytic reduction units with ammonia slip catalysts – working in concert to clean the exhaust stream before it enters the mine atmosphere. The result is a generation of engines that produce far less soot and NO<sub>2</sub>, reducing the burden on mine ventilation systems and improving air quality for workers.

These engines are also designed for fuel flexibility and operational efficiency. Manufacturers such as Scania have developed mining grade diesels capable of running on hydrotreated vegetable oil or FAME biodiesel blends, cutting lifecycle CO<sub>2</sub> emissions by as much as ninety percent without sacrificing torque or reliability. Their powertrains deliver high torque at low rpm, paired with heavy duty transmissions engineered for steep ramp haulage and continuous tramming. The emphasis is on durability and uptime: modular components, simplified service access, and robust cooling systems ensure that the engine can withstand the thermal and mechanical stresses of deep level mining.

Alongside these advances, a parallel revolution has taken place in the form of battery electric powertrains. Electric underground trucks eliminate diesel combustion entirely, removing tailpipe emissions and dramatically reducing heat output – an advantage that directly lowers ventilation requirements, which are among the most expensive operational costs in any mine. Electric drivetrains are inherently energy efficient, consuming roughly seventy

percent less energy than their diesel counterparts while producing far less noise and vibration. Their performance characteristics – instant torque, regenerative braking, and smooth power delivery – are well suited to the stop start nature of underground haulage. Payload capacities now range from compact ten tonne units to forty plus tonne machines, with trolley assist systems emerging for long, steep ramp haulage.

Battery safety has become a central engineering focus. Certified battery systems incorporate thermal management, fire suppression, and continuous monitoring to ensure safe operation in confined spaces. Regenerative braking not only improves energy efficiency but reduces wear on mechanical braking systems, extending component life and lowering maintenance demands.

Between these two poles lies a growing interest in hybrid and transitional electrification solutions. Some mines are adopting partial electrification – such as battery assisted drivetrains or electric loaders paired with diesel trucks – to reduce emissions without overhauling their entire infrastructure. Manufacturers like Epiroc now offer comprehensive electrification ecosystems, including charging infrastructure, battery swap systems, and fleet wide energy management services, enabling operators to transition progressively toward fully electric fleets.

Across all powertrain types, certain design principles remain constant. Underground trucks must be manoeuvrable, with low profile frames, tight turning radii, and sufficient ground clearance to navigate uneven drifts. Their chassis and suspension systems must withstand continuous shock loading, abrasive conditions, and steep gradients. Serviceability is equally critical: modular layouts, accessible components, and simplified maintenance procedures ensure that downtime is kept to a minimum in environments where equipment availability directly influences production.

Ultimately, the choice of powertrain reflects a mine's physical layout, ventilation capacity, production targets, and long term sustainability goals. Diesel powertrains continue to offer unmatched range and refuelling speed, making them indispensable in many deep or remote operations. Electric systems, however, are rapidly gaining ground as mines seek to reduce heat, emissions, and operating costs. Hybrid and transitional solutions provide a bridge between these worlds, allowing operators to modernise their fleets without committing to a single technological pathway.

What emerges is a sector in transition: diesel remains dominant, but the trajectory is unmistakably toward electrification. The powertrain of the future underground mining truck will be defined not only by mechanical performance but by its contribution to a safer, cleaner, and more energy efficient mine.

## HOW TODAY'S UNDERGROUND MINING TRUCKS TURN SPEED AND STABILITY INTO PRODUCTIVITY

Tramming performance remains one of the clearest indicators of how effectively an underground mining truck can support production. In the confined geometry of a mine – where gradients are steep, haul roads uneven, and ventilation capacity limited – the ability of a truck to move quickly, smoothly, and reliably between loading and

dumping points directly shapes overall output. Modern manufacturers compete on this metric by refining the interplay between torque delivery, traction control, cooling efficiency, and chassis stability.

Caterpillar's underground trucks illustrate how integrated powertrain management enhances tramming behaviour. Electronically controlled engines and transmissions optimise gear selection and torque distribution on inclines, while high capacity cooling systems maintain performance during long, loaded climbs. The result is consistent tramming speeds and reduced cycle times, even in deep or thermally demanding operations.

Epiroc's MT series trucks focus on maintaining high speeds on both loaded and empty runs. Their drivetrains deliver strong low rpm torque for smooth acceleration, while robust axles, advanced suspension systems, and carefully balanced articulation geometry support stability on uneven ground. These design choices reduce tyre wear and help operators maintain control on steep declines.

Komatsu's HX series trucks emphasise traction and drivetrain durability, particularly in mines with variable or challenging floor conditions. Smooth torque delivery and controlled wheel slip allow the truck to maintain momentum without excessive tyre spin or drivetrain shock loading, making them well suited to operations where ground conditions change along the haul route.

Battery electric trucks add a new dimension to tramming performance. With instant torque, no gear changes, and regenerative braking, electric drivetrains deliver rapid acceleration and strong incline performance. Manufacturers such as Epiroc and Sandvik have demonstrated that electric trucks can outperform diesel units on steep ramps while generating far less heat – an advantage that indirectly improves tramming efficiency by easing ventilation demands.

Across all platforms, the best tramming performance comes from trucks that combine power, traction, cooling, and structural stability into a predictable, repeatable operating profile. Whether diesel or electric, the leading machines are those that sustain high tramming speeds under full load while keeping maintenance and ventilation burdens to a minimum.

## SANDVIK LARGE TRUCKS: HISTORY IN THE MAKING

Sandvik Mining's development of its large truck line has always been anchored in the realities of underground production, and the story of the Toro® TH663i and TH551i begins almost fifteen years ago in Australia. It was there that the foundations of today's high capacity, high performance trucks were laid, shaped by the day to day challenges mines faced on long ramps, in tight headings and under rising pressure to move more tonnes with fewer delays.

Those early engineering efforts concentrated on the fundamentals of underground haulage – payload, reliability, serviceability and operator protection – and the resulting prototypes were tested hard in real operations. The lessons learned set the trajectory for a new generation of trucks built to lift productivity, sharpen efficiency and raise safety standards across demanding mining environments.



The turning point came in 2013 with the launch of the TH663 and TH551. Nearly eight tonnes lighter than the models they replaced, they immediately set a new benchmark for payload in their class while delivering a clear step change in efficiency. Safety and performance were embedded from the outset, with more than sixty integrated safety functions and an onboard weighing system that allowed operators to load accurately and consistently, ensuring every cycle delivered maximum value. The introduction of front axle suspension transformed ride quality and reduced stress on both operators and components, while a suite of engine options enabled lower emissions without sacrificing the power required for fast, confident ramp speeds. When paired with Sandvik's large loaders, the trucks formed a tightly optimised loading and haulage system that shortened cycle times and lifted overall productivity.

Field trials in Western Australia provided compelling proof of what the new platform could achieve. Over a single month, a TH663 moved 24,000 tonnes – almost half of the site's total haulage – while maintaining availability above 85 percent after commissioning, roughly ten percent higher than other trucks operating at the same mine. Fuel burn told a similar story. Across a three month period, the TH663 averaged 50 litres per hour, compared with more than 70 litres per hour for older Sandvik units and over 100 litres per hour for competitor trucks in the same class. These results demonstrated not only the performance potential of the new generation, but also its ability to materially reduce operating costs and improve fleet wide efficiency.

Alongside these gains, Sandvik introduced a series of innovations aimed squarely at reducing downtime and improving the operator and maintenance experience. One of the most striking was the optional onboard jacking system, developed to address a scenario every underground operation dreads: a fully loaded truck immobilised on a ramp with a flat tyre. By enabling rapid, safe tyre changes underground, the system removed a major bottleneck that previously caused extended delays. Operator comfort also received serious attention. Improved cabin sealing reduced dust and noise, while suspension seating cut vibration exposure and fatigue. Reliability was strengthened through targeted component upgrades, and the introduction of the Intelligent Control System brought real time monitoring of critical parameters

such as tyre pressure and hydraulic performance. The system required operator acknowledgement of alerts and could initiate controlled shutdowns to prevent damage, giving maintenance teams clearer diagnostics and better planning capability.

This culture of continuous improvement led directly to the launch of the Toro® TH663i and TH551i in 2017. The “i” signalled the shift to Sandvik's intelligence driven platform, bringing more powerful and fuel efficient Volvo Penta engines, a redesigned driveline and full readiness for automation. Integration with Sandvik's digital ecosystem, including Knowledge Box™, enabled data driven decision making and more precise control over fleet performance. Gear shifting refinements improved drivability and reduced mechanical stress, while safety remained the defining principle of the platform. By the time the i series was introduced, the trucks incorporated more than one hundred safety enhancing functions, reinforcing Sandvik's long standing commitment to protecting underground personnel.

Today, the Toro® large truck platform has become a global success story, recognised for its consistency, reliability and ability to deliver high volume haulage in the most demanding conditions. It is also the foundation for the next phase of underground mining automation. Sandvik's first 63 tonne autonomous trucks operating with AutoMine® have already demonstrated how automation can transform haulage by improving consistency, reducing variability and enabling continuous operation. The evolution that began in Australia nearly fifteen years ago is now shaping the future of underground trucking, proving that intelligent design, rigorous field validation and a relentless focus on safety can redefine what is possible in hard rock haulage.

### THE HAUL TRUCK MARKET

The global underground haul truck market continues to expand at a steady and strategically significant pace. Latest industry analysis places the market at USD 3.1 billion in 2024, with growth projected to accelerate at a compound annual rate of 6.2 percent through to 2033. If current trends hold, the sector is expected to reach USD 5.34 billion by the end of that period. This trajectory reflects a convergence of forces: rising demand for efficient material movement in both mining and tunnelling, rapid advances in automation and electrification, and sustained investment in technologies



that improve safety, productivity, and environmental performance. Together, these factors are reshaping competitive dynamics and redefining what operators expect from modern underground haulage fleets.

At the heart of this expansion is the global appetite for minerals and metals, driven by industrialisation, urban growth, and the accelerating shift toward energy transition technologies. As ore bodies become deeper and more complex, mining companies are turning to purpose built underground haul trucks to maintain productivity and reduce downtime. The need to operate in increasingly challenging geologies has pushed manufacturers to deliver higher payload capacities, improved manoeuvrability, and greater structural resilience. This demand is stimulating a new wave of engineering innovation, with OEMs refining designs to withstand abrasive conditions, tight headings, and the thermal stresses associated with deep mining.

Technological progress is also playing a decisive role. The adoption of electric and hybrid powertrains is transforming the underground haulage landscape by reducing emissions, lowering operating costs, and improving energy efficiency. Battery electric trucks, in particular, are gaining traction as mines seek to comply with stringent environmental standards and reduce the ventilation burden associated with diesel fleets. At the same time, automation, telematics, and remote operation systems are becoming integral to fleet management strategies. These technologies enhance safety, optimise haul cycles, and improve asset utilisation, giving operators a measurable competitive advantage while supporting long term sustainability goals. The result is a clear shift away from traditional diesel only platforms toward more advanced, digitally enabled, low emission alternatives.

The underground construction and tunnelling sectors are also emerging as important contributors to market growth. Expanding urban infrastructure – ranging from metro systems and utility corridors to underground road networks – is driving demand for haul trucks capable of operating efficiently in confined, highly engineered environments. Contractors are increasingly relying on these machines to accelerate material movement, shorten project timelines, and maintain consistent productivity in complex underground works. This diversification is broadening the market's application base and creating new opportunities for manufacturers and rental providers alike.

The market's opportunity landscape is widening further as electrification, digitalisation, and automation mature. The rapid uptake of electric and hybrid haul trucks is opening substantial growth potential, particularly as operators seek to meet tightening environmental regulations and reduce long term operating costs. Advances in battery chemistry, charging infrastructure, and vehicle architecture are enabling the development of high performance, zero emission trucks capable of working in the most demanding underground conditions. At the same time, the integration of automation, telematics, and predictive maintenance is reshaping fleet management. These technologies are improving safety, enhancing equipment availability, and creating new service based revenue streams for OEMs and technology providers, while helping end users achieve both sustainability and productivity targets.

Emerging markets add another powerful dimension to the sector's growth prospects. Countries across Asia Pacific, Latin America, and the Middle East & Africa are investing heavily in mining and infrastructure development, generating strong demand for advanced underground haulage equipment. Rising commodity prices, supportive government policies, and the untapped potential of these regions are attracting significant interest from both domestic and international players. Strategic collaborations, joint ventures, and mergers and acquisitions are becoming increasingly common as companies seek to strengthen their global footprint and capture new market share. The growing popularity of rental and leasing models is also expanding the addressable market, enabling operators to access the latest technologies without the burden of large upfront capital expenditure.

Yet the market is not without its constraints. High initial capital costs – particularly for electric and hybrid platforms – remain a barrier for many operators, especially in developing regions. Limitations in charging infrastructure, concerns over battery range, and questions about long term reliability in harsh underground environments continue to temper adoption rates. The cyclical nature of mining and construction, combined with fluctuating commodity prices and broader economic uncertainty, can also influence investment decisions and delay project timelines. Overcoming these challenges will require sustained innovation, cost reduction strategies, and flexible financing solutions that align with the evolving needs of end users.

The competitive landscape of the underground haul truck market is evolving rapidly, shaped by a combination of technological ambition, strategic consolidation, and intensifying pressure to deliver safer, cleaner, and more efficient haulage solutions. Global and regional manufacturers are competing vigorously for market share, driving a cycle of continuous innovation in powertrains, automation, digital connectivity, and service delivery. As electrification accelerates and operators demand lower total cost of ownership, OEMs are expanding their portfolios, refining their support networks, and forming strategic alliances to meet the shifting expectations of mines and tunnelling contractors.

Partnerships and joint ventures have become central to competitive strategy, enabling companies to pool expertise, accelerate product development, and enter new geographic markets with greater speed and confidence. Mergers and acquisitions are further reshaping the sector, as leading players seek to consolidate their positions, broaden their technological capabilities, and secure access to emerging markets. At the same time, the growing importance of digital transformation is prompting OEMs to invest heavily in telematics, fleet management platforms, and predictive maintenance technologies. These tools are becoming key differentiators, allowing manufacturers to offer integrated solutions that enhance uptime, optimise haul cycles, and support data driven decision making across entire fleets.

## HOW OEMS ARE RESHAPING THE FUTURE OF HAUL TRUCK COMPETITION

The competitive field is anchored by several global leaders whose influence extends across mining regions worldwide. Caterpillar continues to set benchmarks in high capacity, automated, and increasingly electrified haulage systems, supported by a vast service network and deep expertise in underground applications. Sandvik and Epiroc remain at the forefront of electrification and digital integration, leveraging their long-standing specialisation in underground equipment to deliver advanced, connected haul trucks with strong safety and performance credentials. Komatsu and Volvo Group are also making notable progress, advancing electric and hybrid platforms backed by substantial R&D investment and a clear commitment to sustainability.

Alongside these multinational OEMs, the market benefits from a dynamic ecosystem of regional manufacturers, technology developers, and service providers. These companies play a vital role in addressing local operating conditions, tailoring solutions to specific geological, regulatory, and economic environments, and driving innovation from the ground up. Rental providers, aftermarket specialists, and emerging technology firms add further depth to the competitive environment, contributing to a market that is both resilient and highly adaptive.

As the underground haul truck market continues to evolve, competitive advantage will increasingly hinge on the ability to innovate collaboratively, respond to the demands of energy transition, and deliver customer centric solutions that balance performance, sustainability, and cost efficiency. The companies that succeed will be those capable of aligning technological progress with the practical realities of underground operations, while navigating the shifting global landscape of mining and infrastructure development.

In sum, the underground haul truck market is entering one of the most transformative periods in its history. Rising demand for minerals, deeper and more complex ore bodies, and the accelerating push toward low emission mining are reshaping expectations of what modern haulage equipment must deliver. Electrification, automation, and digital integration are no longer peripheral trends but central forces driving product development, investment strategies, and operational planning across the sector. At the same time, emerging markets are broadening the industry's geographic footprint, creating new opportunities for OEMs, technology providers, and service companies willing to adapt to diverse regulatory, geological, and economic conditions.

Yet the path forward is not without challenges. High capital costs, infrastructure limitations, and the cyclical nature of mining continue to influence adoption rates and investment decisions. Success will depend on the industry's ability to innovate continuously, reduce ownership costs, and provide flexible solutions that align with the evolving needs of operators in both mature and developing regions. As competition intensifies and the energy transition accelerates, the companies that thrive will be those capable of combining technological leadership with customer centric strategies, delivering equipment that is not only more efficient and sustainable but also more reliable and adaptable to the realities of underground work.

What emerges is a market defined by momentum and reinvention – one where collaboration, ingenuity, and long term vision will determine who leads the next generation of underground haulage.

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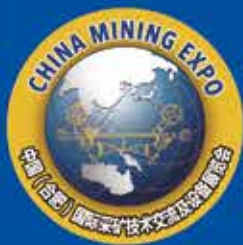


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