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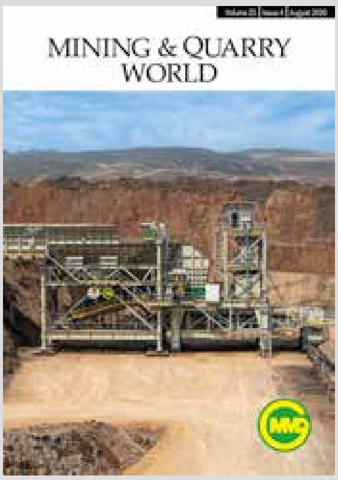

This month's cover features one of MMD Group's latest in-pit sizing and conveying solutions – combining proven Sizer and Apron Feeder technologies into an integrated mining system. Designed for modern operations, MMD solutions reduce truck haulage, lower emissions, improve safety, and deliver greater operational efficiency across mine sites.

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Global database boosts critical minerals research

A new global mineral chemistry database is set to help researchers, governments and industry better understand how critical minerals occur, supporting exploration, resource assessment and future supply.

The Critical Minerals in Ores – Mineral Chemistry database, known as CMiO-MIN, has been developed through the Critical Minerals Mapping Initiative (CMMI), an international partnership between Geoscience Australia, the United States Geological Survey (USGS) and the Geological Survey of Canada.

The database adds approximately 13,000 data points from ore-related mineral samples collected from deposits around the world. The data is publicly available in a standardised format through the CMMI portal, bringing together compositional data from mineralised core intervals, surface samples and mine waste materials.

Geoscience Australia's chief of the mineral, energy and groundwater division, Dr Andrew Heap, said the release demonstrated the value of international collaboration in making high-quality geoscience data more accessible.

"Critical minerals are a global priority, and improving access to consistent, trusted data is an important part of supporting future discovery and supply," Heap said.

CMiO-MIN builds on the existing Critical Minerals in Ores database by linking chemistry data with sample characteristics and deposit classifications.

The database is intended to help users investigate the geological processes associated with critical mineral processing, as well as strengthen research, analysis and mineral potential modelling.

USGS associate director for geology, energy and minerals, Dr Sarah Ryker, said the database built on the knowledge shared through the partner agencies.

"The geological surveys' science has even greater impact when we pool and share our knowledge with the world," Ryker said.

"The original CMiO global database already helps users better understand critical mineral potential in over 60 countries. CMiO-MIN will take that foundation farther, sharpening research insights and accelerating evaluation of the world's future resource options."

Organisations can contribute additional mineral chemistry data through the submission template available via the CMMI portal and Geoscience Australia's Data and Publications Catalogue.

Critical minerals mining in US poised to benefit from $250bn Bank of America initiative

Critical minerals mining in the US is poised to benefit from a new $250-billion finance initiative announced by Bank of America recently.

Bank of America announced an 18-month critical infrastructure finance initiative in honour of America's 250th anniversary.

The initiative aims to drive transformative infrastructure investment across the US, with the investments targeted for the development of digital, energy, power and core infrastructure that enhances national competitiveness.

The bank says surging demand for computing power, energy, manufacturing capacity, modern transportation systems and diversified supply chains is propelling a new wave of infrastructure investment across the US, to which it desires to help clients through the bank's global capital markets platform, advisory expertise and strong balance sheet support.

Primary market lending, investing, and capital markets, banking and advisory solutions will span three broad infrastructure categories: digital infrastructure such as data centres and computing infrastructure, including hardware and chips; energy and power infrastructure such as conventional and renewable power generation and energy storage; and core infrastructure such as transportation, energy transmission, grid optimisation, water systems and critical minerals and mining.

"Meeting America's growing infrastructure needs requires mobilising capital at scale across increasingly interconnected sectors. Delivering these projects requires integrated financing solutions spanning corporate and project-level capital in both public and private markets.

"By bringing together capital providers, developers, corporations and investors, we are focused on helping accelerate investment in infrastructure that drives economic growth and creates lasting value for communities," says Bank of America infrastructure and sustainable finance head Karen Fang.

Sandvik to supply underground mining fleet, financing to Lucara's Karowe project

Multinational engineering company Sandvik has received orders from Lucara Botswana, a subsidiary of TSX-listed Lucara Diamond Corp, to supply a 15-unit fleet of underground drills and loaders, parts, rock tools and related services for the Karowe mine, in Botswana.

The order includes five Sandvik DD321 development drills, four Toro LH517i loaders, two Toro LH621i loaders, two Sandvik DD422i development drills, one Sandvik DS422i cable bolter and one Sandvik DU311 longhole drill.

Aftermarket support has also been included with this order, with Sandvik noting that this maximises equipment availability and productivity throughout the fleet's operating life.

The order was booked in the second quarter and deliveries are ongoing and will continue through to the fourth quarter of this year.

"As we continue developing the Karowe underground mine, we were looking for a partner that could support us throughout the project lifecycle.

"Sandvik's combination of leading underground equipment, aftermarket support and financing capability made it a compelling solution for our operation. This investment supports our strategy of building a safe and productive underground mine," says Lucara corporate finance director Benjamin Wang.

Regarding aftermarket sales, Sandvik states that it will support Lucara with aftermarket services, rock tools and digital solutions, including the My Sandvik and Remote Monitoring Service, which uses cloud technology, AI and telematics to track equipment health, optimise performance and transition mines to proactive maintenance.

"This order demonstrates the breadth of our offering and our ability to support customers in Botswana with an integrated solution that extends beyond the equipment.

"By bringing together expertise from across Sandvik, we can support Lucara throughout the equipment lifecycle while contributing to the long-term success of its underground operation," says Sandvik Mining Botswana territory manager Floors Foord.

The fleet investment is being financed through Sandvik group subsidiary Sandvik Financial Services (SFS), with the financing backed by an export credit guarantee from government authority The Swedish Export Credit Agency (EKN).

"By combining Sandvik's mining expertise with our financial services capabilities and EKN's export credit support, we were able to structure a competitive financing solution around Lucara's investment requirements.

"It demonstrates how financing can complement our equipment and aftermarket offering and help customers advance significant long-term mining investments," says SFS Europe, Middle East and Africa manager Tony Clark.

Karowe is currently transitioning from openpit to underground mining through the Karowe project, which aims to extend the mine life beyond 2038. The mine continues to attract global attention for its strong track record of recovering large, stand-out diamonds, including its tenth diamond weighing more than 1 000 ct, announced earlier this year.

Mining production decreased by 4% y/y in June

Statistics South Africa (Stats SA) reports that mining production decreased by 4% year-on-year in June, with the largest negative contributor being platinum group metals (PGMs), which recorded a decline of 8.4% year-on-year, contributing -2.4 percentage points.

Coal production decreased by 6.6% and contributed -1.7 percentage points, while iron-ore production declined by 10.2% and contributed -1.5 percentage points.

Seasonally adjusted mining production increased by 0.3% in June compared with May. This followed month-on-month changes of -5.2% in May and 3% in April.

Seasonally adjusted mining production decreased by 2.7% in the second quarter of this year compared with the first quarter.

The largest negative contributor was PGMs, which declined by 6.4% and contributed -1.8 percentage points.

Manganese ore production declined by 5.3% quarter-on-quarter and contributed -0.4 of a percentage point, while gold declined by 3.2% and contributed -0.3 of a percentage point.

Additionally, seasonally adjusted iron-ore production declined by 2% quarter-on-quarter and contributed -0.3 of a percentage point.

Meanwhile, mineral sales at current prices increased by 27.2% year-on-year in June.

The largest positive contributors were gold, which increased by 125.7% and contributed 17.1 percentage points; PGMs, which increased by 27% and contributed 7.3 percentage points; and chromium ore, which increased by 49% and contributed 3.7 percentage points.

Iron-ore, however, declined by 16.1% and contributed -1.7 percentage points and 'other' non-metallic minerals declined by 35.5% and contributed -1.3 percentage points. These were the only negative contributors.

Stats SA adds that seasonally adjusted mineral sales at current prices increased by 2.7% in June compared with May. This followed month-on-month changes of -4.4% in May and 3.1% in April.

Seasonally adjusted mineral sales at current prices decreased by 1.6% in the second quarter of this year compared with the first quarter.

Vale and ABB sign partnership to accelerate digital transformation in iron ore operations in Brazil

Vale and ABB have signed a strategic alliance with the aim of expanding the use of automation and artificial intelligence (AI) technologies to increase safety, productivity and sustainability in mineral production in Brazil. It follows the inauguration of one of the most advanced iron ore processing plants in the industry, Vale's Conceição II Model Plant in Itabira, Minas Gerais.

The model will serve as a reference for the technological evolution of other Vale units, with the mining company planning to expand the application of automation, artificial intelligence and digitalisation. The initiative is the result of the expansion of the partnership between Vale and ABB and will gradually replicate the technological solutions implemented at

the Itabira plant in other iron ore processing plants. Vale's aim is to increase the safety of operations, improve operational performance and raise the quality of production.

Inaugurated in June this year, the Conceição II Model Plant represents one of the main projects of Vale's Mining of the Future strategy. ABB acted as consultant, systems integrator and technology provider in the partnership, cooperating on the development, validation, interoperability and scalability of advanced industrial automation, digitalisation and integrated IT/OT technology solutions, aiming at the optimisation, security and sustainability of operations.

More than 100 monitoring cameras were installed across the 11.2 Mt per year complex, along with the automation of more than 7,000 instruments, including new advanced measurement devices and sensors. Data intelligence is also used to control, manage and optimise more than 400 variables across all stages of the ore processing workflow. Operating flows were also reviewed to anticipate failures and avoid unplanned shutdowns.

The results from Conceição II demonstrated the potential of digital transformation in mining. Since its implementation in 2024, the plant has recorded a 25% increase in productivity, a 40% growth in the production of premium ore for direct reduction, and a 26% reduction in iron losses in the tailings. The new configuration also reduced the need for manual interventions in the field, contributing to a safer operation for employees.

Now, with the unit serving as a blueprint for expanding the model to other company operations, Vale and ABB have signed a strategic alliance to bring forward their shared vision of driving productivity, safety, energy efficiency, digitalisation and sustainability across operations.

"The Model Plant Project has shown that new technologies, such as artificial intelligence, improve employee safety and increase productivity, operational efficiency and quality in mining," said Carlos Medeiros, Vale's Vice President of Operations. "Now, we are going to take this learning to other Vale operations, increasing the predictability of processes, improving the use of mineral resources and reducing people's exposure to risky activities. The initiative reinforces our new way of operating, which is increasingly safe, sustainable and data-driven, strengthening our competitiveness and preparing us for the challenges of the future."

"This new agreement with Vale represents an important milestone in our partnership," said Joachim Braun, President of ABB's Process Industries Division. "Building on the success achieved in Conceição II, we are creating a framework to deploy a consistent approach to automation, electrification and digitalisation across multiple operations."

Empire Metals' upgraded MRE confirms Pitfield project as world's largest titanium resource

Empire Metals has confirmed the Pitfield tungsten project, in Western Australia, as the world's largest titanium resource in an updated mineral resource estimate (MRE).

The upgraded MRE states 8.16-billion tonnes grading 4.3% titanium dioxide at Pitfield, for 349-million tonnes of contained titanium dioxide across the Thomas and Cosgrove deposits.

On a measured basis, Pitfield has 374-million tonnes of resources grading 5.8% titanium dioxide, for 21.6-million contained tonnes; on an indicated basis it has 3.65-billion tonnes grading 4.3% titanium dioxide for 154-million contained tonnes; and on an inferred basis the project has 4.2-billion tonnes of resources grading 4.1% titanium dioxide, for 173-million contained tonnes.

The upgraded MRE contains the project's first measured resource declaration, which strengthens confidence to progress mine planning and economic studies, Empire Metals says.

At Thomas, the upgraded MRE now has 43% of the resource reporting to the measured and indicated categories and the remainder reporting to the inferred category. At Cosgrove, 51% of the resource reports to the indicated category and the remainder reports to the inferred category.

Empire Metals envisions Pitfield to have a conventional process to produce high-purity titanium dioxide, including in pigment and metal feedstock forms, to global markets. The project has existing rail links to ports serving Asia, the US, Europe and Saudi Arabia.

"The upgraded MRE, which underlines the sheer scale of this discovery, comes just weeks after we demonstrated an integrated flowsheet based on conventional processing steps to produce 99% pure titanium dioxide. The high-grade weathered zone sits at surface and lends itself to simple, efficient mining methods.

"We now have both halves of the equation: a titanium resource of exceptional scale and an integrated processing route designed to produce high-value products," says Empire Metals MD Shaun Bunn.

Thiess excavator sets 12-month world record in the Hunter

A single Liebherr excavator has shifted 17 million bank cubic metres at a coal mine in the New South Wales Hunter Valley over 12 months, the most any R 9600 has moved in a year, according to Thiess.

The 600-tonne machine ran for 6,840 operating hours at MACH Energy's Mount Pleasant Operation, near Muswellbrook in the Upper Hunter, working out to roughly 2,485 bank cubic metres for every hour it dug. Mining services contractor Thiess has held the contract at the site since 2017.

"The result reflects the capability and collaboration of teams across operations, maintenance, technical services and planning," Thiess group executive Australia East Rae O'Brien said.

"Achieving a world record of this scale requires consistent execution over time."

The R 9600 went to work in July 2025 and set a monthly production record at the site before the year was out. Holding that rate across the full 12 months came down to availability, with maintenance crews chasing reliability, technical services planning the dig paths and operations tuning haulage to keep trucks under the bucket.

The crew also passed 745 days without a lost time injury over the same stretch.

"The achievement was built on disciplined execution. We challenged ourselves to have a 'be better' mindset every day, looking for ways to work smarter, safer and more efficiently," Thiess Mount Pleasant Operation project manager Ryan Fox said.

"The team's ability to move this volume shows how seriously we take our motto: manage the minutes, because minutes matter and seconds count.

"We strive for optimal performance every shift, and this result shows what our people and machines can achieve together."

Lithium Ionic sells Salinas group of lithium property in Brazil

Lithium Ionic and two of its subsidiaries have entered into a definitive agreement to sell the Salinas group of lithium properties, which includes the Baixa Grande lithium resources in Brazil's Lithium Valley, in Minas Gerais.

The acquiring party, PLS Brazil Mineração, a subsidiary of ASX-listed PLS Group, has agreed to a purchase price of $37.5-million in cash.

Lithium Ionic will, however, through its wholly-owned subsidiary Neolit, retain a 2% royalty on future spodumene sales from Baixa Grande.

PLS aims to integrate the Baixa Grande project into its adjacent Colina project in the country.

Lithium Ionic CEO Blake Hylands says Salinas demonstrates the value the Lithium Ionic team has created through disciplined exploration.

"We entered the district in early 2023 and, in under two years, advanced it from first drill holes to a spodumene mineral resource. This transaction crystallises that value for shareholders without dilution, at a constructive point in the lithium cycle, and the royalty keeps shareholders exposed to Baixa Grande's potential future development under PLS, one of the largest hard-rock lithium operators in the world."

Hylands adds that PLS is a natural fit as the acquirer of Baixa Grande given its neighbouring Colina project.

"We are pleased to see it pass to a leading lithium producer rapidly growing its presence in the Lithium Valley, and with a strengthened balance sheet, we are squarely focused on advancing Bandeira toward a construction decision and becoming a near-term, low-cost lithium producer," he concludes.

Coal India plans Singapore trading hub in hunt for critical mineral assets, sources say

The world's largest coal producer, Coal India, is setting up its first overseas trading office in Singapore, aiming to diversify into trading iron-ore and critical and strategic minerals, two sources said.

The move comes as Indian State-run companies step up efforts to secure overseas supplies of critical minerals such as lithium and bauxite in order to reduce dependence on China, though such efforts have so far borne little fruit.

Coal India has applied with Singapore authorities to register the office, which will also support efforts to acquire mineral assets overseas, said the sources involved in the discussions, who sought anonymity as the talks are not public.

The Singapore office will help Coal India expand its critical mineralsbusiness, pursue overseas asset acquisitions and support its iron-ore business, one source said.

Coal India did not immediately respond..

Coal India is evaluating opportunities in several mineral-rich regions, including bauxiteassets in Ghana and other parts of Africa, the source said, adding that the miner was also looking at rare earth minerals.

For lithium, the miner is focusing on Chile while also evaluating opportunities in Canada and Australia for other critical mineral assets, though opportunities are at a preliminary stage, the second source said.

The company has already begun diversifying into other mineral sectors. This month it won an iron-ore block in the eastern state of Odisha through a competitive auction, marking its entry into iron-ore mining.

Last week, Reuters reported that Coal India was considering acquiring a unit of Canada's Wealth Minerals with lithium mining assets in Chile, providing potential access to a key battery metal used in electric vehicles and energy storage systems.

Despite a push to acquire strategic mineral resources abroad to support its clean energy ambitions and manufacturing growth, Indiahas had limited success.

So far, it has signed only one overseas lithium exploration and mining pact, covering five blocks in Argentina, in 2024.

MGX puts $412m foundation behind Central Tanami

MGX Resources has made the Central Tanami gold project the centrepiece of its post-iron ore future, using a $412.1 million cash and investment chest to accelerate drilling, infrastructure upgrades and preparations for underground development in the Northern Territory.

The company's 50%-owned Central Tanami Project Joint Venture (CTPJV) is preparing to begin the Groundrush exploration decline in the September quarter.

Resource definition drilling is also underway at the Jims deposit, alongside camp and utilities upgrades, recruitment, permitting and metallurgical work.

MGX said the decline will provide underground drilling access and advance future mine development.

MGX chief executive officer (CEO) Peter Kerr said the company's iron ore exit had protected the balance sheet needed to push the gold project forward.

"Together with the recently announced agreement to divest Koolan Island to logistics proponent Crestlink, this helped MGX preserve its strong debt-free balance sheet, which will enable the business to focus on accelerating the high-grade Central Tanami Gold Project towards a development decision," he said.

"MGX is well positioned to utilise its hard-earned iron ore cash reserves to realise substantial shareholder value as it seeks to create a new high-quality Australian gold production business."

The pivot follows MGX's February completion of the $50 million acquisition of Northern Star Resources' 50% CTPJV stake; the other half is held by Tanami Gold

An updated project resource totals 31 million tonnes at 2.8 grams per tonne gold for 2.8 million ounces, including 1.2 million ounces at 3.3g/t at Groundrush.

Central Tanami also brings more than 2,100sqkm of joint venture tenure and established infrastructure, including a mothballed 1.2-million-tonne-per-annum processing plant, accommodation camp, haul roads and airstrip.

More than two million ounces of gold have previously been produced from the wider project area.

MGX Central Tanami project

MGX's financial results show the scale of the funding buffer behind that work. Cash and investments stood at $412.1 million at June 30 after the Central Tanami acquisition and subsequent joint venture spending, with no bank borrowings.

Profit before tax and impairments rose to $29.1 million from $20.2 million, although a $58.9 million non-cash Koolan Island impairment contributed to a $30.2 million statutory loss.

Koolan Island nevertheless generated $1 million in positive cash flow for the year after rehabilitation and ramp-down costs, as low-grade stockpile sales outperformed expectations.

MGX has agreed to sell the operation to Crestlink for at least $20.2 million in staged cash payments, a potential further $5 million revenue share, and the transfer of rehabilitation obligations estimated at about $30 million.

Rubidium's critical moment

Everest Metals' Mt Edon project is shaping to be a world-class critical mineral project.

Rubidium's time as a critical mineral may finally have arrived.

The alkali metal plays an essential role in technologies that underpin modern economies, including atomic clocks used for global positioning systems (GPS), telecommunications network synchronisation and research applications across the aerospace, defence and medical sectors.

Among its most specialised applications are the four United States Naval Observatory (USNO), which help maintain the US military frequency standard using a network of 48 weighted atomic clocks.

Much of the digital and automation technology that mining companies have come to rely upon contain rubidium somewhere in the value chain.

The advanced GPS technology that enables autonomous heavy machinery, precise geological surveying, and real-time fleet management, with rubidium atomic clocks supplying the precision heartbeat for stable satellite functioning.

While rubidium has long been recognised as a scientifically important commodity, its significance has grown as governments seek to diversify critical mineral supply chains away from China.

The United States added rubidium to its inaugural critical minerals list in 2018, and it remains on the country's expanded list of 60 critical minerals.

It is also recognised as a critical mineral by Japan, India and New Zealand.

Australia, however, has yet to follow suit and do the same.

Western Australian explorer Everest Metals believes that could change.

The company has formally written to the Federal Resources Minister and the Critical Minerals Office requesting that rubidium be added to Australia's Critical Minerals List, arguing the mineral has become increasingly important to global technology and defence supply chains.

The submission follows continued progress at Everest's flagship Mt Edon project in Western Australia, where the company recently upgraded the Mineral Resource Estimate to 4.3 million tonnes grading 0.23% Rb_2O, with 63% now classified as Indicated Resources.

The update reinforces Mt Edon's position as Australia's most advanced rubidium project and one of the world's highest-grade primary rubidium deposits.

Everest Metals executive chair and chief executive officer Mark Caruso believes shifting geopolitics has transformed rubidium from an obscure speciality metal into a strategically important commodity.

"As with most critical minerals, it's really about supply and the dominance that China has on global supply of almost whichever mineral you want to mention, including rubidium," Caruso told Australian Mining. "The world has woken up to that, particularly the US, and it's made a conscious effort to diversify supply."

Looking to the US

While Everest's application focuses on Australian recognition, Caruso said the company's primary commercial opportunity lies in the United States.

"The real supply chain usage is from America," he said.

Rubidium oscillators are highly sought after for critical applications such as satellite receivers. Image: Philipp Berezhnoy/stock.adobe.com

"The Australian inclusion gives it validation and probably gives us some access to federal funding and other funding schemes that are available."

The timing coincides with closer critical minerals cooperation between Australia and the US, including the US–Australia Critical Minerals Framework, which has created new pathways for Australian miners to access US investment, partnerships and downstream markets.

Caruso said those relationships are already beginning to bear fruit.

"There's been cross-pollination of US support for Australian mining companies to provide that supply chain."

Australia reviews its critical minerals and strategic materials lists at least every three years to reflect changing strategic, technological and economic priorities. With the most recent review completed in February 2024, rubidium could be considered during the next update, expected as early as next year.

Building a complete supply chain

Unlike many known rubidium occurrences globally, where the metal is recovered only as a by-

product of lithium production, Mt Edon is being developed specifically as a primary rubidium project.

That distinction gives Everest greater flexibility because production is not tied to lithium prices or the economics of another commodity.

The challenge is processing.

There is currently no commercial rubidium production in Australia because extracting the metal has historically been technically difficult.

To overcome that hurdle, Everest has partnered with Edith Cowan University (ECU) on a research program supported by funding from the Minerals Research Institute of Western Australia (MRIWA).

The collaboration forms a key part of Everest's ambition to become an integrated producer, mining ore at Mt Edon before processing it into refined rubidium products in Western Australia.

"We're trying to make a direct rubidium extraction route versus rubidium extracted from a lithium process as a by-product, and I think that's significant," Caruso said.

The partnership has already delivered encouraging results.

Metallurgical test work has demonstrated rubidium recoveries of up to 97%, while researchers have developed an environmentally sustainable extraction process capable of producing commercially viable rubidium chloride.

The multi-stage process combines extraction with iterative purification techniques that progressively increase product purity.

It is currently being refined at bench scale and is supported by provisional patent applications covering Everest's proprietary extraction technology.

The next objective is to transition from laboratory testing to pilot-scale production.

"Clearly, we've got one of the highest-grade primary rubidium deposits in the world," Caruso said. "The next marker for the company is to build a pilot plant rubidium processing facility.

Rubidium compounds are added to pyrotechnic mixtures to produce a distinct purple-to-violet-red colour in fireworks. Image: Victor Sanchez/stock.adobe.com

"We've fundamentally got that process pinned down with ECU. The next step is validating it through a pilot plant before moving to commercial production."

A niche market with growing demand

Rubidium remains one of the least transparent mineral markets in the world.

"The market is quite opaque because production is so limited," Caruso said.

Limited production and highly specialised applications mean pricing information is scarce, but Everest estimates rubidium products currently trade at around $US1200 per kilogram.

The company also cites forecasts suggesting the global rubidium market could grow from approximately $US4.46 billion in 2023 to $US7.2 billion by 2032, driven by increasing demand from electronics, telecommunications, defence and advanced technologies against a backdrop of constrained global supply.

Caruso believes the market's relatively small size could also mask its key strategic importance.

"There's a rarity about it. It's a supply chain demand story, but it's also a supply chain constraint," he said. "It is very specialised."

Rubidium's uses extend well beyond atomic clocks and GPS systems into a wealth of devices and machines used in everything from quantum computing to biomedical research.

It also plays an important role in defence technologies, where reliable precision timing and specialised chemical compounds are essential.

"One of the most important uses for rubidium is in defence," Caruso said.

Caruso cited the example of the rubidium-enhanced flares emitted by fighter jets like the McDonnell Douglas F-15 Eagle, which burn at specific wavelengths designed to match the radiant intensity of aircraft exhaust, successfully tricking the tracking algorithms of modern infrared-guided surface-to-air or air-to-air missiles.

"It's a very specialised thing."

Positioning for the future

Everest already holds a granted mining lease at Mt Edon in Western Australia's Paynes Find greenstone belt, an area well serviced by existing road and rail infrastructure and recognised for its highly prospective pegmatite systems.

The company has also received a grant from MRIWA under its Mining, Equipment, Technology and Services Innovation Program, supporting Everest's collaborative research with ECU through matched funding and project facilitation.

For Everest, the immediate priorities are clear: secure recognition of rubidium as a critical mineral in Australia, complete pilot-scale processing and position Mt Edon as a new source of secure supply for global markets increasingly focused on diversification.

If those milestones are achieved, a metal that has spent decades largely outside the spotlight could become an increasingly important part of Australia's critical minerals story.

Epiroc wins large equipment order for copper mine in Botswana

Epiroc AB, a leading productivity and sustainability partner for the mining and infrastructure industries, has won a large order from global mining company MMG Limited for underground equipment for a major copper mine in Botswana.

MMG is listed on the Hong Kong stock exchange, and its major shareholder is the Chinese state-owned company China Minmetals Corp. Together with mining contractors China Huaye and 23MCC – also subsidiaries of China Minmetals – MMG ordered a fleet of Epiroc face drilling rigs, production drilling rigs, cable bolting rigs, loaders, and mine trucks. The machine fleet will support the expansion of the Khoemacau Copper Mine, a major underground mine located in the Kalahari Copper Belt in northwest Botswana.

The equipment order is valued at around SEK 610 million (USD 64 million) and was booked in the third quarter 2026. Epiroc will also provide a remote-control solution for the loaders, as well as spare parts, tools and on-site service.

"Epiroc has a long-standing cooperation with MMG, China Huaye and 23MCC," says Helena Hedblom, Epiroc's President and CEO. "We are proud to be a trusted partner to Chinese mining companies as they expand and operate internationally. This commitment is part of our broader mission to support customers across the globe with leading technology and expertise. With this supply of advanced underground equipment for the Khoemacau expansion in Botswana, we look forward to helping MMG enhance productivity, efficiency and safety."

Epiroc is continuing its build-out of aftermarket facilities in Botswana to support customers' operations in this important mining region. Epiroc also supports MMG's collaboration with Botswana's Ministry of Higher Education to develop the country's future mining workforce through the new Centre of Mining Excellence hosted at Maun Technical College.

Xia Weiquan, President of Africa Operations at MMG, says: "I believe this fleet from Epiroc, including important on-site technical support, will significantly enhance our underground mining productivity and safety in Botswana. With partners like Epiroc, MMG will also continue to build a local talent pipeline with skilled mining professionals and a sustainable future for Botswana."

The ordered equipment includes the Boomer M20 S face drilling rig, Simba E70 S ITH production drilling rig, Cabletec M10 S cable bolting rig, Scooptram ST18 S loader, and Minetruck MT65 S. The "S" indicates the machines are part of the Smart series, being ready for automation and remote control. Epiroc will also provide customised training programs and simulators, as well as on-site services and parts inventory to ensure maximum performance of this large-scale mining operation.

Delivery of the equipment will start in the fourth quarter 2026 and is expected to be completed by the second quarter 2028.

India revives talks with Zambia to invest in critical minerals, sources say

India has resumed talks with Zambia to explore investment opportunities in copper and other critical minerals, two sources said, as New Delhi looks increasingly overseas for raw materials to meet rising demand from its rapidly growing economy.

Officials from India's Ministry of Mines held preliminary discussions with Zambian officials on August 26, the two people familiar with the talks said, requesting anonymity because the discussions were confidential.

One of the sources said the two sides did not discuss a stalled project that had halted talks earlier.

Reuters reported in April that talks between India and Zambia had stalled over a lack of assurances from Lusaka on mining rights for an area of 9 000 km2 awarded to India last year.

India's Ministry of Mines did not respond to a Reuters request for comment. A spokesperson for Zambia's Ministry of Mines said they could not confirm anything for now.

Khanij Bidesh India, India's main vehicle for securing critical mineral supplies overseas, is also evaluating investment opportunities in Australia, Brazil, Canada, Russia and Indonesia, and is in talks about a project in Malawi.

India has been in talks with several African countries to acquire critical mineral blocks on a government-to-government basis, while also exploring opportunities in Australia and Latin America.

Africa, and the Democratic Republic of Congo and Zambia in particular, can play an important role in meeting India's growing requirements for copper and cobalt, said a spokesperson for the Federation of Indian Mineral Industries.

"We believe Indian companies should primarily be encouraged to pursue brownfield and near-production projects, along with long-term offtake arrangements," the spokesperson said.

India is the world's second-biggest buyer of refined copper and its copper imports have risen sharply since the 2018 closure of Vedanta's Sterlite Copper smelter. It may have to import 91% to 97% of its copper concentrates by 2047, the government has said.

STRENGTHENING THE BOND

A guide to improving splice joint reliability

Splice joints represent the weakest point of any rubber conveyor belt. It is estimated that splice joint problems account for some 80% of time-consuming conveyor stoppages and lost productivity. The more splice joints there are then the greater the risk. In this special feature, Rob van Oijen, one of the world's most experienced and highly regarded application engineers, provides invaluable advice on how to improve splice joint reliability.

COMPATIBILITY

There are a huge variety of different rubber compounds. Their creation involves a process where a range of very precisely measured chemical additives, 'cross-linking agents', polymers such as carbon black, reinforcements, plasticisers, antioxidants, anti-degradants and zinc oxide to name but a few, are mixed together according to very specific, unique recipes. No two manufacturer's rubber compound recipes are the same. Some may be more similar than others, but they are never the same.

To achieve strong, reliable splice joints, it is essential that the splicing material rubbers (unvulcanised adhesion rubber, unvulcanised cover rubber and the unvulcanised rubber used on the reinforcement fabric have very similar physical properties (such as adhesion) and behavioral characteristics compared to the rubber used to make the belt, including the outer cover rubber and the skim (inter-ply) rubber. Ideally, they should come from the same source.

Perhaps even more importantly, the various materials must allow them to be bonded together, including vulcanised materials in the belt against un-vulcanised splice materials used to build up the splice and any solvents used as a cleaner and rubber solution.

Up to 80% of unplanned stoppages are caused by splice problems.

Best advice: It is always best to use splicing materials supplied by (or recommended by) the manufacturer of the belt. For this and other reasons to be explained later, avoid buying 'generic' splice materials in bulk.

'TASK-SPECIFIC' SPLICE MATERIALS

The more specialised the belt grade, such as fire resistant for example, the more critical matching (compatibility) becomes. If the rubber materials used to create the splice joint do not have the equivalent resistance to fire, oil or heat, then a weak spot is automatically created both in terms of how the rubber reacts to exposure and its adhesive properties.

The negative effects of incompatibility are unlikely to be seen in the very short term but over time, reliability will suffer, leading to increasingly more stoppages to carry out splice repairs and, in the case of fire resistance, greater risk exposure.

Best advice: Once again, avoid using generic splice materials. Whenever possible, it is always best to use splicing materials (a full splicing kit) supplied or recommended by the belt manufacturer.

ONLY USE GOOD QUALITY SPLICE MATERIALS

In addition to ensuring that the splice materials match the belt rubber, there is also the question of quality. Rubber represents the biggest single influence on the performance and longevity of a conveyor belt. It also represents some 70% of the volume and up to 50% (or more) of the cost of making a belt. Consequently, in these times of ever-increasing price competition, led and dominated by manufacturers in South and East Asia, primarily China, rubber is the biggest target for savings. Cost-cutting practices include the use of unregulated*, low-grade ingredients, increased use of large proportions of rejected and used rubber and reduced quantities (or total omission) of essential ingredients such as antioxidants.

(* Not compliant with European safety and environmental REACH and POPs (Persistent Organic Pollutants) regulations designed to regulations protect human health and the environment by restricting or banning chemicals that pose hazards including those chemicals or substances that may have category 2 carcinogenic classifications. Manufacturers based outside of Europe and the UK are not subject to these regulations).

Best advice: Avoid using 'cheap' low-grade splicing materials because their price always reflects the quality of the product. Importers of these products should be aware that non-compliant products cannot be legally imported, sold, or used within the EU or UK market.

OZONE AND ULTRAVIOLET RESISTANCE.

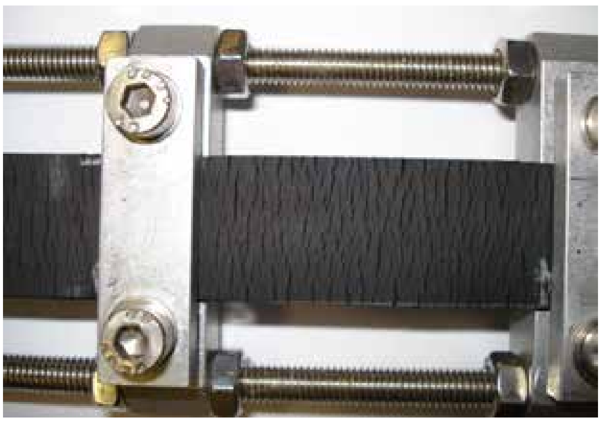
Aside from the resistance that all forms of rubber needs to have against elements that cause damage and premature ageing, another form of resistance that every rubber compound must have, which is being able to resist the effects of exposure to ground-level ozone (O3) and ultraviolet light (UV) from sunlight and artificial (fluorescent) lighting.

Exposure (to light and air) is, of course, unavoidable and the damage they cause is considerable. The early signs of ozone attack are small cracks in the rubber surface, in some cases within weeks of first being fitted with much

Rubber splice materials should have equivalent resistance properties.

Manufacturer's splice kits are invaluable for special cover grades.

Manufacturers based outside of Europe and the UK are not subject to REACH and POPs regulations.



The damage caused by ozone and ultraviolet exposure is considerable.

worse to come as the rubber becomes increasingly brittle and inflexible. Cracks form in rubber that is under tension at the points where the strain is the greatest, so splice joints are particularly vulnerable.

Best advice: Always insist on written confirmation that the splice materials you are buying are fully resistant to the effects of ozone (O3) according to EN ISO 1431 testing methods and ultraviolet light (UV). If they are not resistant then they will begin to deteriorate and lose strength and elasticity prematurely.

'SHELF-LIFE' AND STORAGE

As with most products in the commercial world, buying large quantities usually brings a price benefit. However, the downside is that different 'task-specific' materials have different individual restrictions regarding their functional lifetime, after which their effectiveness begins to decline quite rapidly. There are no standard guidelines. It is just a question of what is in the mix, how their molecular structure and behaviour (effectiveness) changes over time, their curing speed at ambient temperature and so on. This means that shelf-life can range from one month following manufacture up to 12 months, with various permutations in between.

Generally speaking, splice materials for speciality belting have the shortest shelf-life (as short as only one month), with certain fire, oil or heat-resistant types ranging from 3 to 6 months and the longest (up to 12 months) is more typical for 'regular' abrasion resistant belts. The shelf life is dependent on being stored according to the manufacturer's recommended conditions shown on the packaging, especially ambient temperature.

To add further complexity, recommended shelf-life varies between manufacturers. Just as the rubber compound recipes used for the outer covers and inter-ply skims vary from manufacturer to manufacturer, so does the recommended shelf-life for the various rubber-based splice materials. These include uncured inter-ply rubber (used to rebuild the belt carcass), the uncured cover rubber used to rebuild the belt's cover area and uncured rubberised fabrics used as reinforcements in heavy duty / high tensile splices.

Best advice: Be aware of storage recommendations and do not use once the use-by date has passed, especially once opened. To do so is a false economy and the first thing that suffers is the all-important adhesion properties.

SPLICING METHODS

The primary splicing methods are cold-glue splicing and hot vulcanisation using a heated press. Cold glue splicing is generally seen as the easiest, fastest (lowest cost?) method, although the preparation work is quite similar to hot vulcanisation and the glue needs at least 6-8 hours cure time, although many take a massive risk of restarting the conveyor too quickly, which can lead to early failure. Although hot vulcanisation using a mobile press requires handling and setting up the press, in comparison to cold gluing, it produces a stronger, longer lasting and more durable joint that is especially needed on the heavier duty applications commonly found in mining and quarrying.

Shelf-life largely depends on what is in the mix

A finger splice is stronger and more reliable.

THE ADVANTAGES OF FINGER SPLICING

For many years, the step splice has been the most commonly used splicing method but when looking to reduce the frequency of stoppages caused by splice joint failure by improving reliability, the increasingly popular choice is finger splicing. A step splice requires the removal of the length of the step of subsequent layers of fabric plies so that the two belt ends can be overlapped and either glued or hot vulcanised together. However, the main disadvantage is that it will always create a proportional loss of tensile strength equivalent to the strength of one ply.

By comparison, finger splicing, where several 'fingers' are interlocked and bonded together using a hot vulcanising press creates a splice that is typically stronger, flatter and more reliable than a conventional step splice while retaining a much higher level of longitudinal tensile strength. Another reason for the increased reliability is that in dynamically stressed conditions (when the belt is working under load) it is vastly superior in terms of resistance to dynamic failure.

Best advice: Hot vulcanisation, especially when used to create a finger-splice joint, produces a stronger, longer lasting and more durable joint that is often needed for the heavier duty applications commonly found in mines and quarries.

AUTHOR

Rob van Oijen

Turn ground support data into actionable insights

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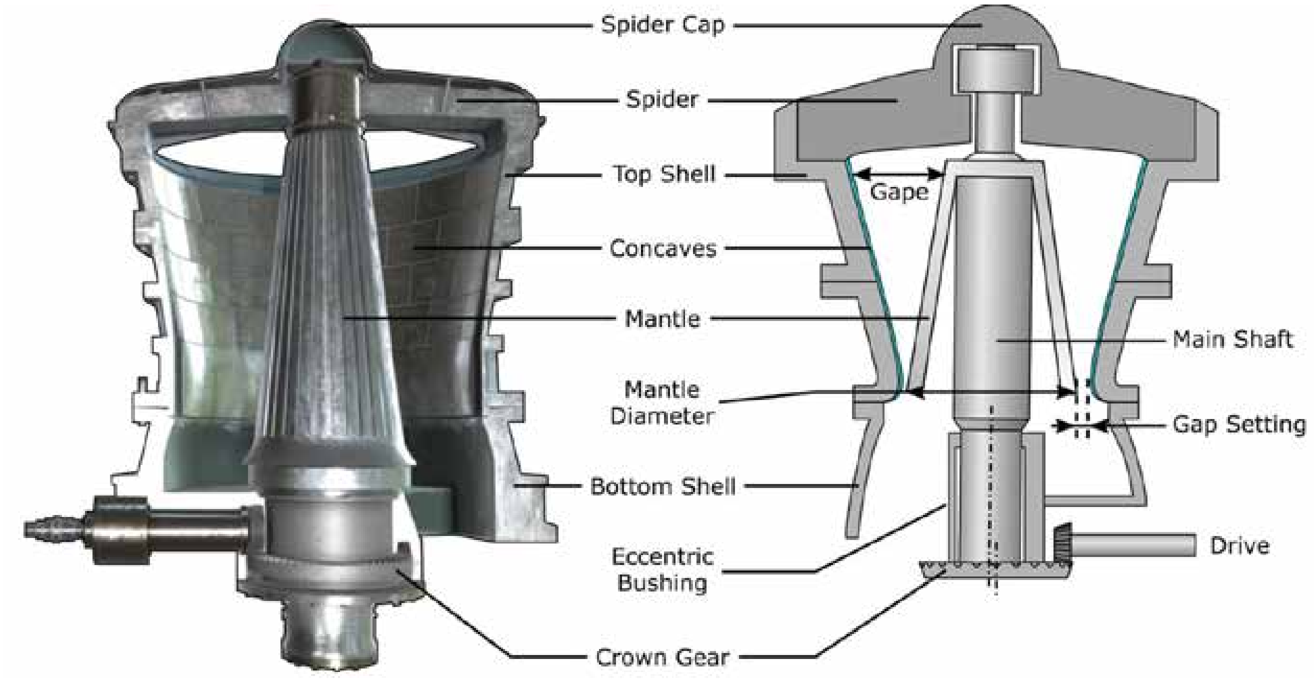
How crushing and sizing technologies transformed mining

Crushing and sizing have been fundamental to mining since the first humans struck stone against stone to break ore free from its host rock. What began as a rudimentary, labour intensive activity evolved over centuries into one of the most sophisticated branches of mineral processing, driven by the relentless industrial demand for greater throughput, finer control, and improved efficiency. From early hand powered stamp mills to the giant gyratories and high pressure grinding rolls that define today's high capacity operations, each technological leap has reshaped how mines extract value from the earth. The history of crushing is, in many ways, the history of mining itself: a story of engineering ingenuity, rising production expectations, and the continual refinement of machines designed to tame the geological materials that underpin modern industry. Understanding this evolution provides essential context for the equipment and methodologies now standard across global mining and quarrying operations, and highlights how far the sector has travelled – and where it is likely to go next.

Crushing sits at the heart of modern mining and quarrying, shaping everything that follows in the value chain. Whether the objective is to liberate mineral content, produce construction aggregates, or prepare feed for downstream comminution, the ability to reduce raw rock to controlled, predictable sizes underpins both process efficiency and product quality. Across hard rock mines, surface quarries, and bulk materials operations, engineers rely on a suite of crushing technologies – each exploiting a different mechanical principle – to turn unyielding geological material into a manageable, classifiable product. What follows is a technical examination of the core crushing mechanisms and the multi stage reduction process that defines contemporary plant design.

GYRATORY CRUSHER EXPLANATION

Crushing is rarely a single-step activity. In most operations,

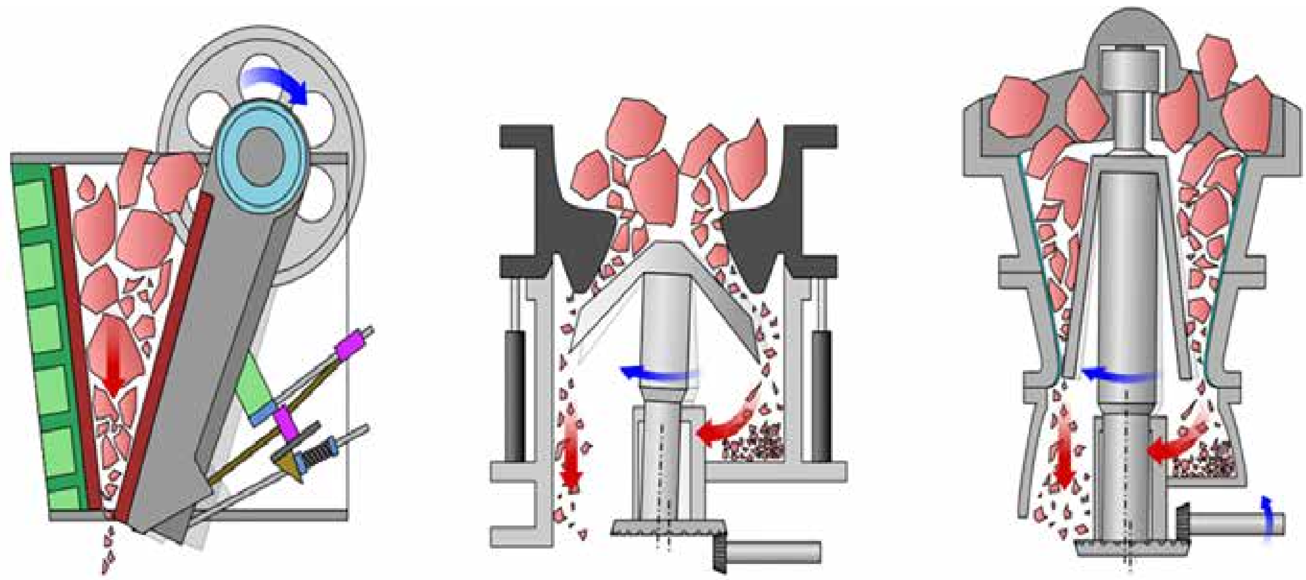


it unfolds as a staged sequence in which progressively finer crushers are deployed to achieve the required size distribution. Primary crushers – typically jaw or gyratory machines – accept run of mine feed and deliver a first reduction, producing fragments suitable for handling and conveying. Secondary and tertiary units then take over, applying more precise and often more intense forces to refine the material to specification. Screening is integral throughout, separating fractions, controlling circulating loads, and ensuring that only material requiring further reduction proceeds downstream. The interplay between crushing and screening determines throughput, energy consumption, and final product quality.

JAW CRUSHERS EXCPLAINED

Compression crushing remains the most widely used mechanism in hard rock mining. By applying pressure between two surfaces until the rock fails, it exploits the inherent compressive strength of geological materials. Jaw crushers achieve this through the familiar action of a fixed and a moving jaw, creating a powerful nip that fractures large blocks. Cone crushers apply the same principle with greater finesse: a rotating mantle works against a stationary concave, generating continuous compressive loading ideal for abrasive ores and competent aggregates. Because breakage occurs along natural planes of weakness, compression machines deliver predictable product shapes and are well suited to high tonnage duties.

Impact crushing operates on a very different principle. Here, high velocity collisions between rock and a rapidly rotating rotor fitted with hammers or blow bars generate the breakage. The energy transfer is instantaneous, producing sharp, angular fragments and high reduction ratios. Impact crushers and hammer mills excel with



softer, less abrasive materials such as limestone, dolomite, and certain sedimentary rocks. However, when confronted with highly abrasive ores, wear rates escalate dramatically, making careful material selection and maintenance planning essential.

Attrition crushing – abrasion through grinding – belongs primarily to the fine grinding and mineral processing domain. In ball and rod mills, steel media interact with the ore as the mill rotates, gradually reducing particle size through frictional and impact forces. This mechanism is indispensable where ultra fine liberation is required, particularly in metalliferous mining where downstream flotation or leaching demands precise particle-size control. Attrition is not typically used for primary size reduction but is fundamental to beneficiation circuits.

Shear crushing, though less common in hard rock applications, plays an important role in specific materials handling scenarios. Roll crushers apply lateral forces as material is drawn between counter rotating rolls, encouraging breakage along natural bedding or cleavage planes. This makes them effective for friable, layered materials such as coal, clay, and certain industrial minerals. Their ability to produce minimal fines and maintain consistent product sizing ensures continued relevance in specialised sectors.

Together, these mechanisms form the backbone of industrial crushing practice. Each offers distinct advantages, limitations, and wear characteristics, and the art of plant design lies in selecting and combining them to suit the geology, throughput targets, and downstream requirements of a given operation. As mines pursue higher efficiency and quarries demand tighter product specifications, understanding the fundamentals of crushing and sizing remains essential for engineers tasked with keeping material flowing and processes optimised. Crushers form the backbone of modern comminution practice, and understanding their distinctions is essential for designing efficient, reliable, and cost effective crushing circuits. Although the fundamental objective is always the same – reducing run of mine or quarried material to a controlled size – the machines used at each stage differ markedly in geometry, operating principle, reduction ratio, and suitability for specific rock types. What follows is a detailed examination of the major crusher classes used across primary, secondary, and tertiary duties in mining and quarrying.

The primary crushing stage is where raw rock, often up to 1,500 mm in size, first encounters mechanical reduction. The purpose at this point is not fine sizing but producing a manageable product that can be conveyed, stored, or fed into downstream crushers without choking or excessive wear. Primary machines must therefore be robust, abrasion resistant, and capable of handling high tonnages. Jaw crushers and gyratory crushers dominate this category, both relying on compressive force but differing significantly in configuration and performance characteristics.

Jaw crushers remain the most widely deployed primary units in both mining and construction. Their V shaped chamber, formed by a fixed jaw and a moving jaw, delivers a powerful nip that fractures large blocks as the moving jaw oscillates. Simplicity of design, reliability, and tolerance for hard, abrasive feed have made jaw crushers a universal choice. Feed sizes up to 1,500 mm are common, with product sizes typically ranging from 50 mm to 300 mm depending on the closed side setting and material properties. Single toggle designs offer lower cost and easier maintenance, while double toggle machines provide a more uniform product and higher crushing efficiency at the expense of greater mechanical complexity.

Gyratory crushers, by contrast, are the workhorses of large scale mining operations. Their vertical, conical chamber and rotating mantle create continuous compression against a stationary concave, enabling high throughput and steady, uninterrupted operation. Gyratories generally achieve higher reduction ratios than jaws and can produce smaller product sizes in a single pass. They also handle extremely hard materials with ease. However, their capital cost, foundation requirements, and maintenance demands

Double shaft Shear Crusher

Shear Crusher

are greater, making the choice between jaw and gyratory machines a matter of throughput targets, desired product size, and budget.

Once primary reduction has been achieved, secondary crushing takes over. Here the objective shifts toward producing a more uniform, controlled particle size – typically reducing material from 50–300 mm down to 6–100 mm. Secondary crushers must balance reduction ratio, product shape, and wear considerations, and the most common machines in this stage are cone crushers, roll crushers, and impact crushers.

Cone crushers are the mainstay of secondary and tertiary circuits in hard rock mining. Their rotating mantle and stationary concave bowl apply continuous compression, producing a more cubical and consistent product than jaw crushers. Standard cones, with deeper chambers, generate coarser output in the 25–100 mm range, while short head cones are engineered for finer reduction between 6 mm and 25 mm. Fine or tertiary cones push this further, producing sub 6 mm material where required. Their ability to deliver precise particle shape makes them indispensable in aggregate production and in mineral processing circuits where uniformity aids downstream separation.

Roll crushers occupy a more specialised niche, particularly where soft, friable, or layered materials are involved. Using one or two rotating cylinders – either smooth or toothed – they compress and shear material to achieve reduction. Single roll machines press feed against a fixed plate, while double roll units compress material between two counter rotating cylinders. Smooth rolls are suited to gentle reduction, whereas toothed rolls provide improved grip and breakage for materials such as coal, clay, salt, and certain limestones. Roll crushers are valued for low energy consumption, minimal fines generation, and predictable product sizing.

Impact crushers introduce a different breakage mechanism altogether. Instead of compression, they rely on high speed impact from hammers or blow bars mounted on a rotor. As material enters the chamber, it is struck repeatedly and shattered, producing angular, cubical fragments. Horizontal shaft impactors (HSI) use a horizontal rotor to throw material against fixed anvils or curtains, while vertical shaft impactors (VSI) accelerate material upward and outward, causing it to collide with an anvil ring or a cloud of material. HSIs are widely used for secondary reduction of less abrasive rocks such as limestone and dolomite, while VSIs are typically reserved for the final shaping stage, eliminating elongated particles and enhancing cubicality – particularly important in high spec aggregate production.

Hammer crushers, although often grouped with impact machines, deserve separate mention due to their versatility. Used across mining, cement, coal, and metallurgy, they employ a rotor fitted with multiple hammers to deliver high speed impact suitable for soft to medium hard materials with high moisture content, such as coal, gypsum, clay, and certain limestones. Single stage hammer crushers offer simplicity and low cost where coarse product is acceptable, while multi stage

designs provide tighter control over final size and shape for more demanding applications. Their high throughput and low energy consumption make them attractive for operations requiring rapid processing of large volumes of softer material.

Together, these crusher types form the foundation of modern comminution circuits. Selecting the right machine for each stage – primary, secondary, and tertiary – requires careful consideration of feed characteristics, desired product size, throughput requirements, and operating cost. As mines and quarries continue to push for higher efficiency and tighter specifications, understanding the strengths and limitations of each crusher class remains essential for engineers tasked with designing and optimising material handling systems.

Tertiary and quaternary crushing represent the final refinement stages in a modern comminution circuit, where the objective shifts from simple size reduction to the production of highly controlled, fine, and often shape critical material. At this point in the process, feed is already substantially reduced, and the machines deployed are selected for their ability to deliver products typically below 6 mm with tight gradation control. These stages are essential in applications such as manufactured sand, industrial minerals, and high specification aggregates for specialist concrete mixes, where particle geometry directly influences performance.

Fine cone crushers remain a mainstay of tertiary duty. Their short crushing chambers and steep geometry allow them to generate fine product in the 2–6 mm range with excellent shape characteristics. They operate on the same compressive principle as standard cones but are engineered for higher reduction ratios and more precise control over the final gradation.

Vertical shaft impactors (VSI) are equally prominent in tertiary and quaternary circuits, particularly where particle shape is paramount. By accelerating material through a vertical rotor and directing it against an anvil ring or autogenous cloud, VSIs create a highly cubical product with minimal flaky or elongated particles. This makes them indispensable in the production of premium manufactured sand and in aggregate plants supplying concrete and asphalt markets with strict shape requirements.

High pressure grinding rolls (HPGR) offer a different approach, using two counter rotating rolls to compress material in a choke fed environment. The intense pressure applied across a narrow gap induces micro fracturing within the particles, improving downstream grinding efficiency and producing a fine, uniform product. HPGRs have become increasingly common in hard rock mining, particularly in metalliferous operations seeking energy efficient alternatives to conventional milling.

Autogenous (AG) and semi autogenous (SAG) mills, though traditionally associated with primary grinding, can also serve as final reduction units in specific flowsheets. By using the ore itself – or a combination of ore and steel media – as the grinding agent, these mills generate fine, liberated particles suitable for subsequent beneficiation. Their ability to handle variable feed and deliver consistent product makes them valuable in large scale operations where throughput is a critical driver.

Selecting the correct tertiary or quaternary crusher is a nuanced decision shaped by material characteristics,

required product size, desired particle shape, and the broader process flowsheet. In many cases, a combination of machines – such as a fine cone followed by a VSI – delivers the optimal balance of reduction, shape, and efficiency.

Beyond machine type, several engineering factors govern crusher selection. Material hardness dictates the level of force required; hard, competent rock typically favours compression machines, while softer materials may be better suited to impact or roll based systems. Abrasiveness influences wear rates and therefore the economic viability of certain crusher types. Moisture content and stickiness can affect chamber performance, potentially causing blockages or reducing throughput, and may necessitate specific design features or ancillary equipment.

Feed size and desired output size define the number of crushing stages and the type of machine required at each point. Primary crushers must accommodate the largest particles, while tertiary and quaternary units are selected for their ability to deliver fine, tightly controlled product. Reduction ratio – the relationship between feed and product size – remains a central parameter in determining the appropriate sequence of machines.

Production capacity is equally critical. Throughput targets, measured in tonnes per hour, determine the scale of equipment required and influence the configuration of the overall circuit, including screens, conveyors, and recirculating loads. Product shape and gradation requirements further refine the selection process; cubical particles are typically associated with compression and VSI machines, while impact units may produce more angular fragments.

Operational considerations also weigh heavily. Maintenance regimes, wear part availability, and component life cycles directly affect uptime and cost. Energy consumption – now a major focus in both mining and quarrying – must be evaluated across the entire circuit, as different crusher types exhibit markedly different power profiles. Noise and dust emissions, increasingly regulated in environmentally sensitive or urban locations, may also influence equipment choice.

Capital and operating costs remain fundamental. Initial investment encompasses purchase, installation, and commissioning, while operating costs include energy, wear parts, labour, and routine maintenance. The physical footprint of the crusher and its compatibility with existing plant layout must be assessed to ensure seamless integration with feeders, screens, and conveyors.

A clear understanding of these factors enables engineers to select the most appropriate crushing equipment for their specific application. As comminution continues to evolve – driven by efficiency, sustainability, and increasingly stringent product specifications – the ability to match crusher type to material, throughput, and desired outcome remains central to successful plant design and operation.

Why screen media has become a critical lever for plant performance

As mining operations process lower-grade ores, manage increasingly complex ore bodies and work to maintain throughput in challenging economic conditions, greater attention is being paid to every element of the comminution and classification circuit. One area that is often overlooked is screen media.

For many years, screen media was viewed primarily as a consumable, with selection decisions largely driven by wear life and replacement costs. While these considerations remain important, solutions such as Weir's ENDURON® screen media are demonstrating that media selection can have a far broader impact on plant performance: throughput, classification efficiency, recovery, product quality and recirculation loads can all be influenced by screen media selection, with improvements in these areas often contributing to lower circuit energy consumption.

As operators seek new opportunities to optimise their plants, screen media is increasingly becoming a strategic process variable rather than simply a maintenance consideration.

DIFFERENT ORES REQUIRE DIFFERENT SOLUTIONS

The starting point is recognising that there is no universal screening solution. Different commodities present very different challenges.

In high-tonnage copper and iron ore operations, material is often highly abrasive and throughput requirements are significant. Here, the focus is on handling large volumes of material while maintaining wear life and processing efficiency.

In precious metal applications such as gold, however, classification accuracy becomes particularly important because downstream grinding and recovery processes can be significantly influenced by achieving the desired cut size. Gold ores can also contain significant clay content, increasing the risk of blinding and pegging if the screen media is not properly selected.

In coal, industrial minerals and some aggregate applications, product specifications often become the primary driver, making cut-point accuracy and consistency essential.

This application-focused philosophy sits at the heart of the ENDURON® screen media portfolio. Rather than relying on a limited range of products, ENDURON® screen media is engineered to support a diverse range of operating environments. Aperture geometry, media material and panel design are selected according to the requirements of the application, allowing operators to optimise both performance and reliability.

LOOKING BEYOND THE SCREEN DECK

Successful screen media selection also requires operators to look beyond the ore itself. Moisture content is one of the most important considerations because wet material can rapidly accumulate on the deck, leading to blockages and a reduction in screening efficiency. Particle size distribution (PSD) is equally important. Ideally, feed material should be distributed evenly across the screen deck to maximise utilisation of the screening surface and promote effective separation.

Effective screening also depends on particle stratification. As material travels across the deck, finer particles must

Aperture design and open area influence how efficiently material passes across the screening surface.

migrate through the bed and reach the screen surface to have an opportunity to pass through the apertures. Poor stratification can significantly reduce screening efficiency, particularly when processing high volumes of near-size material. Screen media design, open area and aperture configuration can all influence how effectively stratification occurs and impacts overall screening performance.

Importantly, not every screening problem originates with the screen media. In many situations, challenges observed at the screen are symptoms of upstream issues elsewhere in the circuit: incorrect crusher settings, poorly configured screen stroke and speed combinations, uneven feed distribution and excessive bed depths can all contribute to inefficient screening, blinding and pegging. For this reason, effective optimisation requires an understanding of the entire circuit rather than a narrow focus on the screen itself.

WHY APERTURE DESIGN MATTERS

Aperture selection is another area where significant performance improvements can be achieved.

Many operators naturally focus on the required cut size, but there are several additional considerations. Near-size particles, which sit close to the target separation size, are often the most difficult fraction to separate and can have a substantial impact on efficiency. Moisture content, material shape and product specifications also need to be considered when selecting aperture geometry.

Square apertures remain the most widely used option because they provide a balance between capacity, efficiency and wear life across a broad range of high-tonnage applications. Slotted apertures can increase throughput and are often better suited to handling elongated particles that might otherwise become trapped in the corners of square openings. For particularly difficult ores, self-cleaning designs can offer significant benefits by allowing material to pass through more effectively while reducing the likelihood of blockage.

In coal and industrial mineral applications, ENDURON® screen media plays a direct role in product quality. Aperture accuracy, material selection and even details such as relief angles are carefully engineered to deliver accurate and consistent cut sizes while maintaining throughput performance. As product specifications become increasingly stringent, these design considerations become even more important.

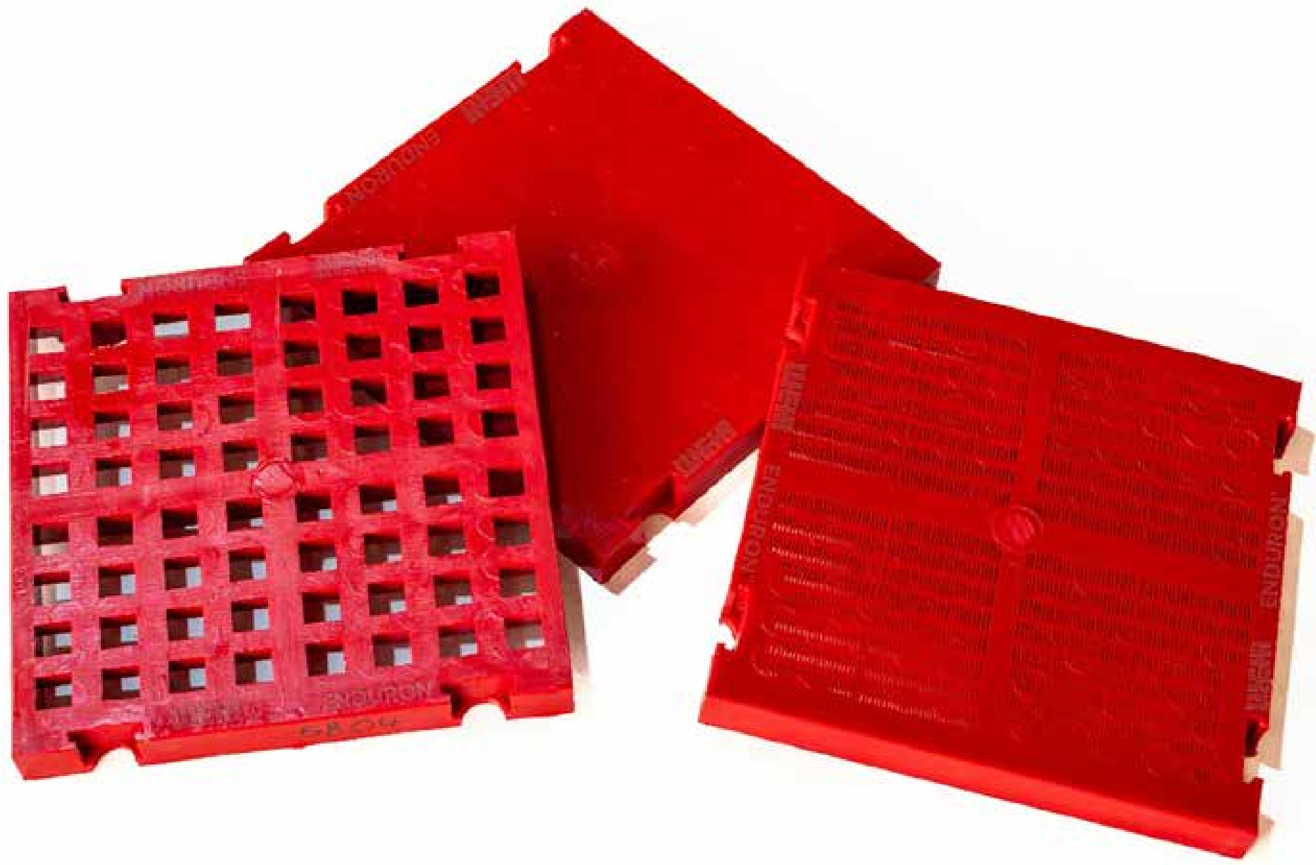
ADDRESSING BLINDING AND PEGGING

Among the many operational challenges associated with screening, blinding and pegging remain the most persistent.

Addressing these issues requires a combination of engineering and application knowledge. ENDURON®

Aperture design and open area influence how efficiently material passes across the screening surface.

screen media incorporates engineered aperture geometries and carefully selected polyurethane formulations designed to maintain effective open area and support efficient material passage. The flexibility of polyurethane can help dislodge trapped particles before they accumulate and reduce performance.



Different aperture geometries are used to address specific material characteristics and screening challenges.

ENDURON® polyurethane screen media is engineered to withstand abrasive conditions while maintaining consistent operation.

Panel thickness and flexibility must also be carefully balanced. Excessive thickness can limit flexibility, while overly soft materials may compromise overall performance. Finding the right combination is critical to achieving both long wear life and effective screening. Self-cleaning ENDURON® panel aperture designs provide another solution by allowing adjacent polyurethane sections to move with different amplitudes, helping to dislodge trapped material and minimise blinding and pegging.

BALANCING COMPETING PERFORMANCE OBJECTIVES

One of the most common mistakes in screening is focusing too heavily on a single performance metric.

Operators frequently prioritise wear life or open-area percentage without fully considering the impact on overall plant performance. High-flow panels may increase throughput through greater open area, but thinner bridges between apertures can reduce wear life. Conversely, standard panels may offer longer service life but can restrict tonnage in applications where capacity is the primary objective.

The strength of the ENDURON® screen media portfolio is that it gives operators flexibility to select the most appropriate solution for their operational objectives. Whether the priority is throughput, classification accuracy, wear life or a balance of all three, the media can be tailored to meet the specific requirements of the application.

MEETING THE DEMANDS OF MODERN PROCESSING PLANTS

This balanced approach is becoming increasingly important as market conditions place additional demands on mineral processing operations.

As ore grades decline, operators are under growing pressure to maintain throughput while controlling operating costs. This is driving interest in screen media with higher open-area designs, improved anti-blinding characteristics and materials capable of performing reliably under increasingly demanding conditions. At the same time, tighter product specifications are creating greater demand for accurate and consistent separation performance.

Reducing recirculation loads has also become a major focus. Poorly matched screen media can cause large volumes of material to recirculate unnecessarily, increasing energy consumption and reducing circuit efficiency. By selecting the appropriate ENDURON® screen media solution, operators can reduce recirculation, improve classification efficiency and lower total cost of ownership across the plant.

Material science continues to support these improvements. Advances in polyurethane and rubber compounds are delivering improved wear resistance, enhanced durability and better screening performance. In Australia, for example, there has been growing interest in fire-retardant rubber panels driven by safety requirements and the need to perform reliably in high-temperature operating environments.

Maintenance is another area where innovation is creating value. Operators increasingly seek fixing systems that simplify installation and panel replacement, helping reduce maintenance time and minimise downtime. In demanding primary screening applications, thicker rubber feed-zone panels combined with rider bars can significantly improve wear life by absorbing impact energy and protecting the screening surface from excessive abrasion.

THE FUTURE OF SCREEN MEDIA OPTIMISATION

Looking ahead, digital technologies are likely to play an increasingly important role in screen media management.

The industry is moving towards more data-driven decision making, with emerging technologies enabling operators to monitor panel wear, throughput and screening performance in real time. As these solutions mature, emerging AI-enabled monitoring platforms may in future support wear prediction, maintenance planning and screen media optimisation, helping operators identify maintenance requirements and improve screen media selection and replacement strategies.

This philosophy underpins the continued development of the ENDURON® screen media portfolio. By combining engineered screen media, process expertise and integration with ENDURON® screening equipment, Weir is helping customers optimise the performance of the entire screening circuit rather than viewing screen media as an isolated consumable.

Ultimately, screening is about far more than separating particles. Its performance influences downstream equipment, energy consumption, product quality, recovery and profitability. For mining operations seeking to maximise productivity and sustainability, screen media is increasingly proving to be one of the most valuable and least appreciated levers for plant optimisation. ENDURON® screen media is helping operators unlock that potential by transforming screening from a maintenance requirement into a strategic advantage.

AUTHOR

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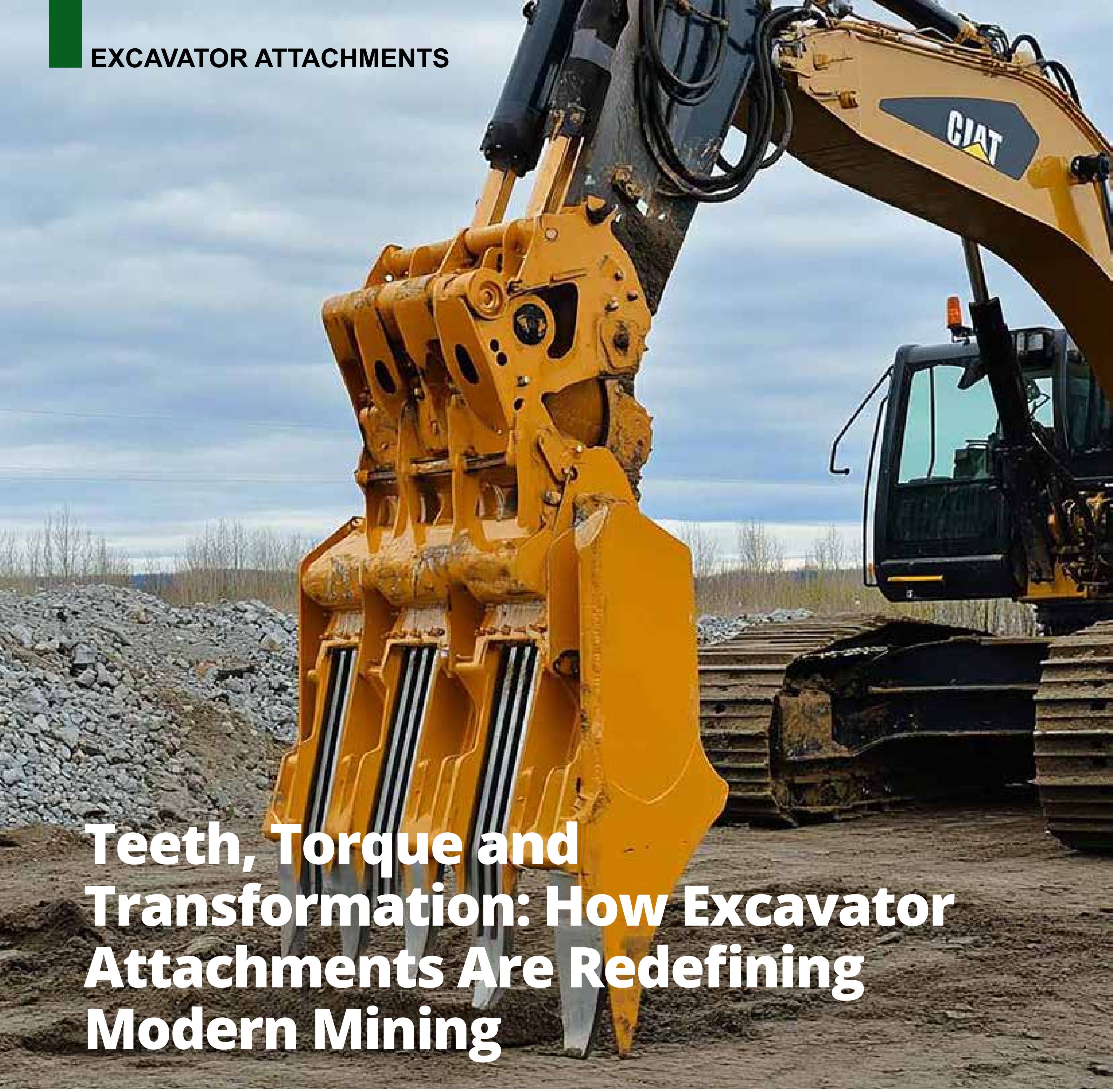


Teeth, Torque and Transformation: How Excavator Attachments Are Redefining Modern Mining

MINING EXCAVATOR ATTACHMENTS: ENGINEERING, APPLICATION, AND EVOLVING CAPABILITIES

Mining excavators have long been the backbone of surface and underground operations, but their true versatility emerges through the attachments engineered to extend their capabilities far beyond simple digging. These attachments transform a single base machine into a multi functional production asset, capable of breaking, loading, trenching, ripping, sorting, and handling materials under conditions that would defeat most other equipment. As mines pursue higher productivity, lower operating costs, and safer working environments, excavator attachments have become a critical area of innovation, blending mechanical robustness with hydraulic sophistication and, increasingly, digital optimisation.

THE ROLE OF EXCAVATOR ATTACHMENTS IN MODERN MINING

Attachments allow operators to tailor an excavator to the geology, production targets, and environmental constraints of a specific site. In coal and hard rock operations alike, the right attachment can reduce blasting requirements, improve fragmentation, accelerate loading cycles, and minimise machine wear. They also support selective mining, enabling operators to separate ore from waste with greater precision. In an era where mines are under pressure to reduce carbon emissions and energy consumption, attachments that improve efficiency or reduce the need for secondary equipment have become strategically important.

BUCKETS: THE FOUNDATIONAL ATTACHMENT

The bucket remains the most widely used excavator attachment, but its design has diversified dramatically. Heavy duty rock buckets are built with reinforced side cutters, abrasion resistant steels, and aggressive tooth profiles to penetrate hard strata. Coal buckets, by contrast, prioritise volume over penetration, using lighter construction and smooth edges to handle friable material

without excessive degradation. In selective mining, high capacity clamshell buckets allow precise extraction from narrow seams or stockpiles, while trapezoidal buckets support trenching for dewatering and infrastructure works.

The engineering behind bucket design is increasingly data driven. Wear patterns are analysed to optimise liner placement, tooth geometry is refined to reduce breakout force, and advanced steels such as Hardox and Domex extend service life. Some manufacturers now integrate sensors to monitor fill factors, cycle times, and tooth condition, feeding real time data into fleet management systems.

HYDRAULIC BREAKERS: REDUCING DEPENDENCE ON BLASTING

Hydraulic breakers have become indispensable in mines seeking to reduce explosives use or manage oversize material at the face. Modern breakers deliver high impact energy through nitrogen charged accumulators and precision engineered pistons, allowing operators to fracture boulders, split hard rock, and shape benches

without secondary blasting. Their value is most evident in environmentally sensitive regions or operations where vibration control is essential.

Breakers must be matched carefully to the excavator's hydraulic flow and pressure. Undersized breakers stall and overheat; oversized units damage the boom and slew ring. Proper alignment, lubrication, and tool selection – whether moil point, chisel, or blunt – determine both productivity and longevity. Mines increasingly adopt automatic lubrication systems and noise reduction housings to improve reliability and operator comfort.

RIPPERS: MECHANICAL POWER FOR TOUGH GROUND

Ripper attachments provide a lower cost alternative to breakers in certain geological conditions. Single shank rippers are used to tear through compacted overburden, shale, or weathered rock, loosening material for subsequent loading. Multi shank rippers support trenching and site preparation. Their simplicity is their strength: fewer moving parts mean lower maintenance, and the ability to work without hydraulic impact reduces stress on the excavator.

In coal operations, rippers are often used to expose seams without blasting, reducing contamination and improving recovery. In hard rock mines, they are deployed during pre split operations or to break frost bound ground in colder climates.

GRAPPLES AND MATERIAL HANDLING ATTACHMENTS

Sorting grapples, demolition grapples, and log grapples extend excavator utility into material handling, stockpile management, and waste sorting. In mining, grapples are used to handle timber supports, remove debris, manage scrap, and load irregular material. Hydraulic rotation allows precise placement, while high strength jaws withstand abrasive loads.

For underground mines, compact grapples support maintenance tasks and emergency response, enabling rapid removal of obstructions or collapsed material. In surface operations, they reduce reliance on wheel loaders for certain tasks, improving fleet flexibility.

COMPACTION WHEELS AND PLATES

Although less glamorous than breakers or buckets, compaction attachments play a vital role in tailings management, haul road construction, and reclamation. Compaction wheels densify soil and overburden layers, improving stability and reducing long term subsidence. Hydraulic compaction plates offer greater versatility, allowing operators to compact material in confined spaces or on slopes where rollers cannot operate safely.

DRILLING AND AUGER ATTACHMENTS

Augers and drill heads transform excavators into multi purpose drilling rigs. In mining, they are used for sampling, geotechnical investigations, dewatering wells, and infrastructure works. Modern augers incorporate flighting designed for abrasive conditions, while hydraulic drill

heads can deliver significant torque for deep or wide diameter holes. Their integration with excavators reduces the need for dedicated drilling equipment in early stage development or small scale operations.

CRUSHING AND SCREENING ATTACHMENTS

A major innovation in recent years has been the rise of crusher and screener buckets. These attachments allow operators to process material directly at the face, reducing haulage requirements and enabling on site recycling of waste rock for road base or backfill. Crusher buckets use jaw or impact mechanisms to reduce oversize, while screener buckets separate fines from coarse material. For remote mines, this capability can significantly reduce fuel consumption and improve logistical efficiency.

WEAR MANAGEMENT AND MAINTENANCE CONSIDERATIONS

Attachments are subject to extreme wear, and their maintenance directly affects excavator performance. Tooth systems must be replaced before they blunt, as worn teeth increase fuel consumption and stress the hydraulic system. Breaker tools require regular inspection for mushrooming or cracking. Ripper shanks must be monitored for bending, and bucket liners must be replaced before structural damage occurs.

Lubrication, hydraulic flow calibration, and proper operator training are essential. Mines increasingly use telematics to monitor attachment performance, predicting failures before they occur and scheduling maintenance during planned downtime.

DIGITALISATION AND THE FUTURE OF EXCAVATOR ATTACHMENTS

The next generation of attachments will be shaped by automation, sensor integration, and advanced materials. Smart buckets with load sensors will optimise truck loading cycles. Breakers will incorporate vibration monitoring to prevent structural damage. Augers will transmit real time geotechnical data to planning teams. Composite materials may reduce weight while maintaining strength, improving fuel efficiency and reducing boom stress.

Autonomous excavators will require attachments capable of self diagnosis, automated alignment, and integration with machine vision systems. In selective mining, AI assisted attachments may identify ore boundaries and adjust cutting profiles accordingly.

CONCLUSION

Mining excavator attachments are no longer peripheral tools; they are central to modern production strategy. Their evolution reflects the broader transformation of the mining industry – toward efficiency, precision, safety, and sustainability. By selecting and maintaining the right attachments, mines can unlock significant productivity gains, reduce operating costs, and extend the life of their equipment. As digital technologies merge with mechanical engineering, excavator attachments will continue to redefine what a single machine can achieve, making them one of the most dynamic and influential areas of mining innovation today.

Shuttle Cars: The hidden workhorses driving modern underground mining

In the modern mining industry, the shift toward autonomous systems is often described as a recent revolution, yet for mining engineers it is more accurately understood as the latest chapter in a long evolution of mechanised haulage underground. Shuttle cars sit at the centre of that narrative. Long before automation became a strategic priority, these machines reshaped the rhythm and productivity of room and pillar operations across multiple commodities. Their introduction in the mid twentieth century marked a decisive break from manual haulage and animal drawn tubs, allowing continuous miners to operate at a pace that older transport methods could never sustain. As production faces advanced deeper and further from main headings, the shuttle car became the indispensable link between cutting machines and the mine's conveyor network.

Gordon Barratt of Mining & Quarry World offers an in depth examination of the components and systems that underpin an effective shuttle car.

A BRIEF HISTORY OF THE SHUTTLE CAR

The shuttle car has become one of the defining machines of room and pillar mining, but its origins stretch back to a period when underground haulage relied on hand loaded tubs and animal drawn carts. By the early twentieth century, companies such as Jeffrey Manufacturing (est. 1877) and Joy Manufacturing (est. 1916) were already mechanising cutting and conveying, yet haulage remained tied to rails and locomotives.

The breakthrough came in the 1940's, when Joy introduced the first true shuttle car – an electrically powered, rubber tyred hauler designed to receive material directly from the newly developed continuous miner. By the 1950's, shuttle cars were standard equipment in room and pillar mines, with Joy's 21SC and 22SC models leading the market and Jeffrey, Goodman Manufacturing and Lee Norse quickly developing their own versions.

The 1960's and 1970's brought rapid refinement: dual motor configurations, hydraulic steering, solid rubber tyres and reinforced frames capable of absorbing the shocks of deeper, more demanding operations. Manufacturers such as Long Airdox, Fairchild International and Bucyrus Erie expanded the field, producing machines tailored to different seam heights and production requirements.

By the 1980's and 1990's, shuttle cars were incorporating electronic controls, improved braking systems and early diagnostic technologies. Battery powered variants emerged alongside traditional cable powered designs, reducing cable handling hazards and improving mobility in complex headings.

The twenty first century has pushed the shuttle car into a new technological era. Modern machines – produced by Komatsu (Joy Global), Caterpillar (Bucyrus), Prairie Machine, Fletcher, Phillips and others – feature collision avoidance sensors, onboard diagnostics, refined articulation, LED lighting and increasingly autonomous control systems. Battery electric shuttle cars have become more common, supporting mines seeking lower emissions and improved ventilation.

Despite the rise of continuous haulage systems, the shuttle car remains a cornerstone of room and pillar mining. Its evolution – from mid century innovation to modern, sensor equipped hauler – mirrors the broader transformation of underground mining itself: from manual labour to mechanisation, electrification and automation.

Today, the fundamental question remains unchanged: how does material move from the working face to the surface with efficiency, reliability and minimal exposure to risk? The answer, as every mining engineer knows, still begins with the shuttle car. Its role has not diminished; it has evolved. The modern shuttle car is a heavy duty, battery or cable powered hauler built to operate in confined headings, absorbing the harsh conditions of underground work while delivering consistent tonnage. It collects fragmented material directly from the continuous miner, transports it through the entry, and discharges it into the conveyor system or feeder breaker. The fundamentals of its function have remained constant for decades, but the engineering behind it has advanced dramatically: improved traction systems, enhanced braking, refined articulation, collision avoidance technologies and increasingly sophisticated onboard diagnostics.

Understanding how these machines operate is central to maintaining productivity underground. Their drivetrains, electrical systems, control logic and structural components must withstand relentless loading cycles, abrasive environments and tight turning radii. When any part of that system falters, production falters with it. Rebuilds, repairs and component overhauls are therefore not merely maintenance tasks but strategic interventions that preserve the continuity of mining operations.

The mission to keep material moving efficiently is ultimately a commitment to the continuity of an industry that depends on robust, well engineered haulage systems. Shuttle cars have carried material from the face for generations, and with the right expertise behind them, they will continue to do so as mining enters its next technological era.

In an underground operation, the shuttle car serves as the essential bridge between the cutting action at the face and the mine's haulage system. Once the continuous miner has fragmented and gathered the material, the shuttle car positions itself to receive the load directly from the miner's conveyor boom. Its task is deceptively simple yet absolutely central to the efficiency of room and pillar production: it carries freshly cut material through the entry and delivers it to the conveyor or feeder breaker, ensuring that the miner can continue cutting without interruption.

The effectiveness of this arrangement lies in its rhythm. Continuous miners are designed to work without long pauses, but their output is only as steady as the haulage system supporting them. A well maintained shuttle car keeps that flow intact, reducing idle time and sustaining the high volume cycles that modern underground operations demand. Its electric motors, traction systems and reinforced chassis are engineered to absorb constant loading, abrasive conditions and tight manoeuvring spaces. When rebuilt to specification, a shuttle car returns underground capable of handling heavy loads and harsh environments with the reliability expected of frontline production machinery.

In essence, the shuttle car is not merely a transporter; it is the mechanism that keeps the face connected to the wider mine, enabling continuous mining to function as a true continuous process.

Mechanically speaking, the underground shuttle car is one of the most demanding pieces of equipment in a room and pillar mine. Although its task appears straightforward – receiving material from the continuous miner and transporting it to the conveyor or feeder breaker – the machine itself is a dense assembly of interdependent systems, each engineered to survive the relentless punishment of the underground environment. Every component must endure abrasive material, confined headings, constant loading cycles and the ever present risk of impact. When any part weakens, production feels it immediately, which is why the mechanical integrity of a shuttle car is inseparable from the productivity of the operation.

At the centre of the machine are its electric motors, the true driving force behind haulage. Most shuttle cars rely on dual motors that deliver the horsepower required not only to propel the vehicle but also to operate its loading and discharge functions. These motors must deliver consistent torque in low visibility, uneven conditions, and their reliability determines whether the miner can maintain a continuous cutting rhythm.

Supporting this powertrain is the chassis and frame, built from high strength steel and designed to absorb the constant shocks of underground work. The frame carries the weight of the motors, the conveyor or bucket system, and the load itself, all while resisting deformation from collisions with ribs, roof irregularities or debris. A shuttle car's structural integrity is not cosmetic; it is the backbone that allows every other system to function safely.

Mobility underground depends on the tyres and suspension. Solid rubber tyres eliminate the risk of flats, while heavy duty suspension components help the car traverse uneven floors, wet entries and debris strewn headings. Without this stability, the shuttle car cannot position itself accurately at the miner or discharge point, and even minor misalignment can disrupt the entire production cycle.

Steering and braking systems provide the precision needed to operate in tight spaces. Hydraulic steering allows operators to manoeuvre through narrow entries with fine control, while advanced braking systems ensure the car can stop reliably under load. These systems are fundamental to safety, especially when multiple machines are working in close proximity.

The bucket or conveyor system is the shuttle car's load handling mechanism. It receives material directly from the continuous miner and holds or transfers it until discharge. Its design must balance capacity, durability and smooth material flow, because any interruption in loading or unloading slows the miner and reduces output.

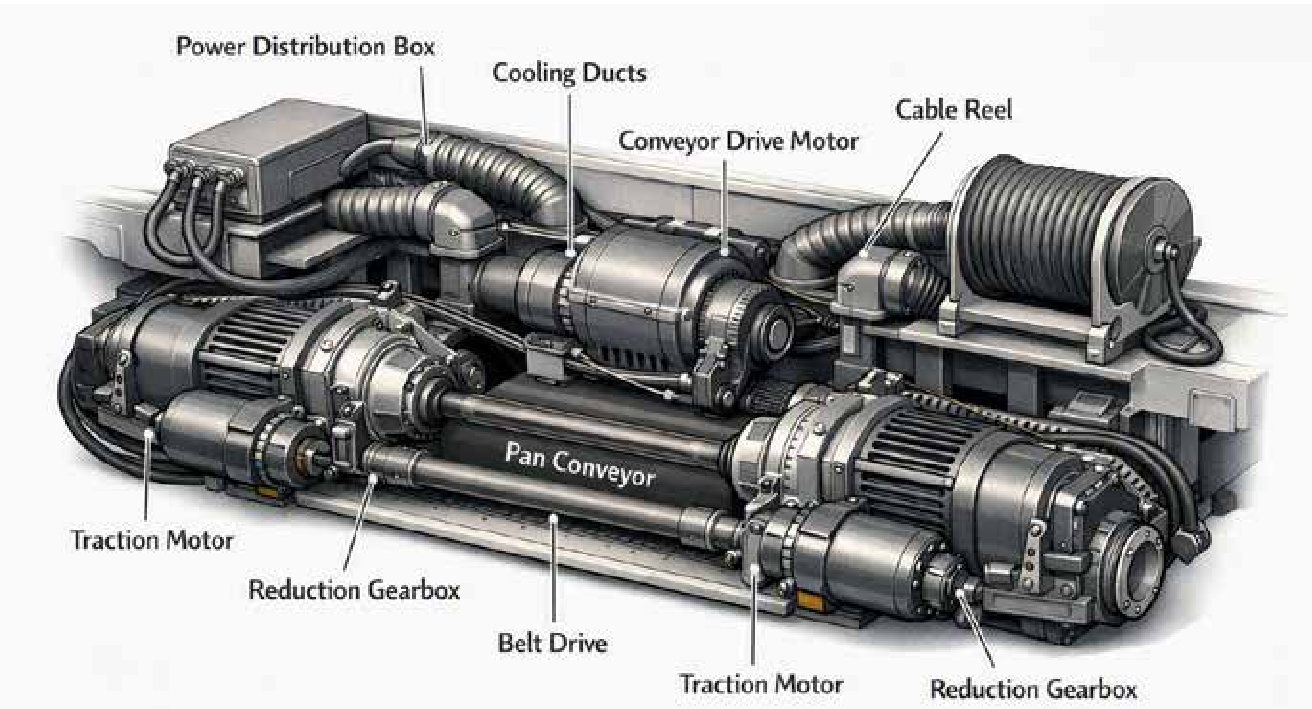
Modern shuttle cars also rely on sophisticated control systems. Operator interfaces, safety interlocks and monitoring technologies allow for smoother operation, better diagnostics and enhanced protection for personnel. These systems are increasingly important as mines adopt more automated and semi autonomous equipment.

Finally, lighting and safety features complete the machine's operational profile. Bright LED lights, backup alarms and emergency stop controls are essential in the low visibility, high risk environment of an underground mine. They protect operators, maintain situational awareness and reduce the likelihood of accidents.

A shuttle car is therefore far more than a simple hauler. It is a complex mechanical organism whose performance depends on the health of every component. When each system – from motors to frames, tyres to control modules – functions as intended, the shuttle car becomes a reliable, resilient and indispensable part of modern underground production.

ELECTRIC MOTORS

Electric motors are the beating heart of the shuttle car, the core components that determine whether the machine can deliver the relentless, uninterrupted haulage cycles demanded in modern underground mining. Although the shuttle car appears, at first glance, to be a simple



Shuttle car electric motor layout

transporter, its performance is governed almost entirely by the behaviour, durability and efficiency of its motors. These motors do far more than propel the vehicle; they sustain the entire operational rhythm of continuous mining, converting electrical energy into the torque, traction and functional power required to move heavy loads through confined headings.

Most shuttle cars are equipped with dual electric motors, a configuration that has become standard across the industry because of the unique demands of underground haulage. Each motor contributes a portion of the total horsepower required not only to drive the vehicle forward but also to operate its auxiliary functions – loading, conveying, and discharging. This dual motor arrangement ensures that power delivery is both distributed and resilient. If one motor experiences reduced performance, the second can compensate to a degree, preserving operational continuity until maintenance can be performed. In this sense, the motors are not simply components; they are the foundation of the shuttle car's reliability.

The horsepower produced by these motors must be sufficient to overcome several simultaneous challenges. First, the shuttle car must haul dense, abrasive material – often several tonnes per load – across uneven floors, wet entries and debris strewn headings. This requires high torque at low speeds, a characteristic electric motors excel at delivering. Unlike combustion engines, electric motors provide immediate torque without the need for gear changes or throttle response delays, allowing the shuttle car to manoeuvre precisely in tight spaces while still generating the force needed to move heavy loads.

Second, the motors must operate in an environment that is inherently hostile to electrical systems. Underground headings are characterised by dust, moisture, vibration, and constant shock loading. Motors must therefore be sealed, insulated and mounted in ways that protect them from contamination and mechanical stress. The housings are typically constructed from high strength steel or reinforced alloys, designed to resist impact from falling debris or collisions with ribs. Internal components – windings, bearings, rotors – must be engineered to withstand continuous duty cycles without overheating or degrading.

Cooling is another critical aspect of motor performance. Shuttle car motors often operate for extended periods with minimal downtime, generating significant heat. Effective cooling systems – whether air cooled, liquid cooled or integrated into the motor's housing – are essential to prevent thermal overload. Excessive heat can damage insulation, reduce efficiency and ultimately lead to motor failure. In the confined environment of an underground mine, where ambient temperatures may already be elevated, maintaining optimal motor temperature becomes a central engineering challenge.

The motors also play a direct role in the shuttle car's traction and control systems. Because the motors drive the wheels or traction assemblies, their responsiveness determines how smoothly the car accelerates, decelerates and positions itself at the continuous miner or discharge point. Modern shuttle cars incorporate advanced motor controllers that regulate power delivery with precision, allowing operators – or autonomous systems – to manoeuvre the vehicle with fine control. This is especially important in narrow entries where even slight misalignment can disrupt the loading process and slow production.

Beyond propulsion, the motors power the shuttle car's conveyor or bucket system. This requires a different type of torque profile: steady, consistent rotational force that keeps material flowing smoothly from the miner to the discharge point. Any fluctuation in motor performance can cause surging, stalling or uneven loading, all of which reduce efficiency and increase wear on mechanical components. The motors must therefore deliver stable power under varying loads, adjusting automatically to changes in material density or flow rate.

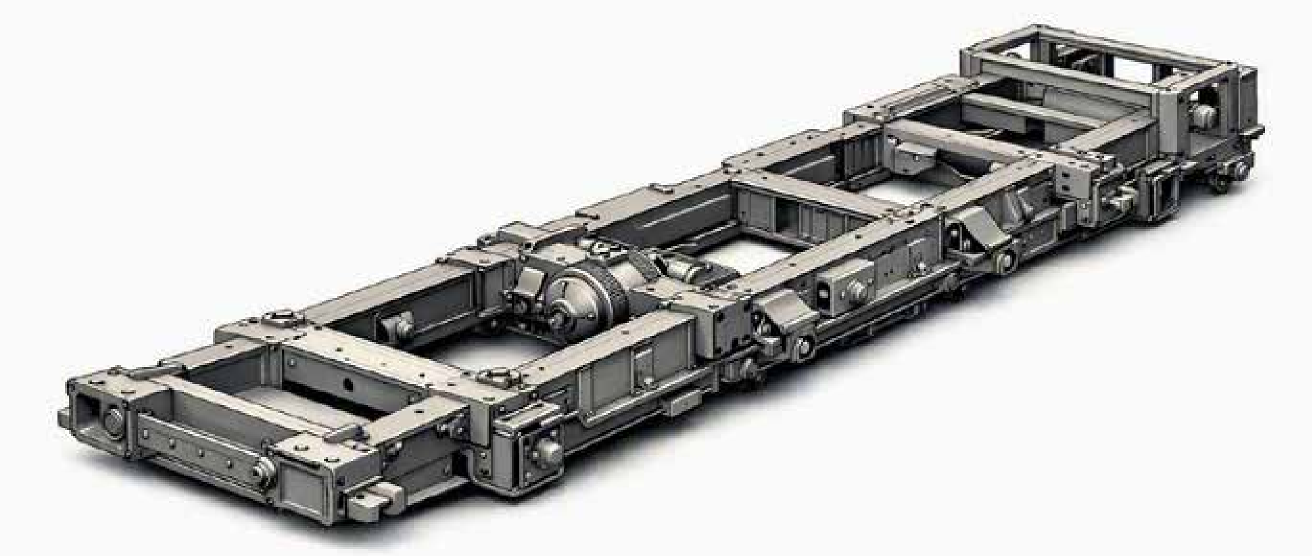
Electrical integrity is equally vital. Shuttle car motors are integrated into complex electrical systems that include power cables or battery packs, controllers, safety interlocks and diagnostic sensors. The motors must be compatible with these systems, responding instantly to commands and providing feedback on performance. Modern designs incorporate onboard diagnostics that monitor motor temperature, load, vibration and electrical consumption. These systems allow maintenance teams to identify emerging issues before they lead to failure, reducing downtime and improving overall fleet reliability.

The dual motor configuration also enhances redundancy and operational resilience. In high production environments, where continuous miners operate at full capacity, any interruption in haulage can halt the entire mining cycle. By distributing power across two motors, shuttle cars reduce the risk of catastrophic failure. Even if one motor experiences a fault, the machine may still be able to complete a haul cycle or move to a safe location for repair. This redundancy is a strategic advantage in mines where uptime is directly tied to profitability.

From a maintenance perspective, electric motors are among the most critical components requiring regular inspection and overhaul. Bearings must be checked for wear, windings for insulation integrity, and housings for signs of impact or contamination. Rebuilds often involve complete disassembly, cleaning, rewinding, bearing replacement and rebalancing. When performed correctly, a rebuilt motor can deliver performance comparable to a new unit, extending the life of the shuttle car and reducing capital expenditure.

In the broader context of underground mining, the evolution of shuttle car motors reflects the industry's shift toward electrification, automation and efficiency. Modern motors are more powerful, more efficient and more intelligent than their predecessors. They integrate seamlessly with autonomous navigation systems, collision avoidance technologies and advanced control logic. As mines push deeper and operate in more challenging geologies, the demands placed on these motors will only increase, making their design and maintenance even more central to operational success.

Ultimately, the electric motors of a shuttle car are far more than mechanical components. They are the engines of productivity, the systems that convert electrical power into the physical movement that keeps the mine functioning. Their performance determines whether continuous mining can truly be continuous. Their reliability underpins the



safety, efficiency and output of the entire operation. And their engineering sophistication embodies the decades of innovation that have transformed underground haulage from manual labour into a highly mechanised, technologically advanced process.

CHASSIS AND FRAME

The chassis and frame of a shuttle car form the structural foundation upon which every other system depends. In underground mining – where machinery is subjected to constant shock loading, abrasive conditions, confined spaces and unpredictable geological environments – the integrity of this structure is not merely a matter of durability but of operational survival. The chassis and frame determine whether the shuttle car can endure the relentless punishment of daily haulage cycles, maintain alignment under load, and protect the critical mechanical and electrical systems housed within.

High strength steel has become the material of choice for shuttle car construction because it offers the optimal balance of toughness, rigidity and resistance to deformation. Underground headings impose forces that are both repetitive and extreme: collisions with ribs, impacts from roof irregularities, vibration from uneven floors, and the constant weight of heavy loads being transported from the face to the conveyor system. A chassis built from conventional steel would fatigue rapidly under these conditions, developing cracks, bends or structural weaknesses that compromise safety and performance. High strength steel, by contrast, provides the resilience needed to absorb these stresses without losing its shape or integrity.

The frame of a shuttle car is engineered as a unified, load bearing structure. It must support the weight of the motors, the conveyor or bucket system, the operator's compartment (where applicable), and the material being hauled. This means the frame must resist torsional forces – twisting caused by uneven ground or asymmetrical loading – as well as compressive forces generated when the car is fully loaded. The geometry of the frame is therefore carefully designed to distribute stress evenly, preventing localised points of weakness that could lead to failure.

In addition to supporting mechanical components, the chassis acts as a protective shell for the shuttle car's internal systems. Electrical wiring, hydraulic lines, control modules and motor housings are all vulnerable to damage from debris, water ingress and impact. The frame must shield these systems while still allowing access for maintenance. This dual requirement – protection and accessibility – drives the design of reinforced panels, removable covers and strategically placed mounting points.

The harshness of the underground environment also demands that the chassis and frame resist corrosion. Moisture, chemical exposure and abrasive dust can degrade metal surfaces over time. Protective coatings, galvanisation, and specialised paint systems are often applied to extend the life of the structure. Even with these measures, regular inspection is essential, as corrosion can undermine the strength of welds, joints and load bearing members.

Welding quality is another critical factor in chassis construction. The joints between frame components must be capable of withstanding repeated shock loads without cracking. Precision welding techniques, rigorous quality control and post weld inspection ensure that the frame behaves as a single, cohesive unit. Any weakness in a weld can propagate under stress, leading to structural failure that affects the entire machine.

The design of the chassis also influences the shuttle car's manoeuvrability. Underground mines often require equipment to navigate tight turning radii, narrow entries and irregular pathways. The frame must therefore be compact enough to fit within these constraints while still providing sufficient strength. Articulation points, steering linkages and suspension mounts are integrated into the frame in ways that maximise mobility without compromising durability.

Because shuttle cars "take a beating," as the original text notes, the chassis and frame are among the most frequently inspected and repaired components. Over time, even high strength steel can deform under repeated impact. Bent frame rails, cracked welds, dented panels and misaligned mounting points are common issues that require attention. Restoring a chassis to proper condition is not simply a matter of straightening metal; it involves re establishing the structural geometry that allows the machine to operate safely and efficiently.

A well maintained chassis ensures that the shuttle car remains stable under load, aligns correctly with the continuous miner and discharge point, and protects its internal systems from damage. When the frame is compromised, the entire machine becomes vulnerable: motors may shift out of alignment, conveyors may bind, steering may become imprecise, and safety systems may fail. In this sense, the chassis is not just a physical structure but the backbone of the shuttle car's operational reliability.

The expertise required to evaluate and repair shuttle car frames is highly specialised. Technicians must understand not only the mechanical design of the machine but also the stresses imposed by underground conditions. They must be able to identify subtle signs of fatigue, measure alignment accurately, and restore structural integrity through precise welding, reinforcement and component replacement. The quality of this work directly affects the shuttle car's performance, longevity and safety.

Ultimately, the chassis and frame of a shuttle car represent the intersection of engineering strength and practical necessity. They are designed to endure impacts, resist deformation, support heavy loads and protect critical systems – all while operating in one of the most demanding industrial environments on earth. Their condition determines whether the shuttle car can continue to function as the essential link between the working face and the mine's haulage network. In underground mining, where every component is pushed to its limits, the chassis and frame are the silent guardians that keep the machine – and the operation – moving.

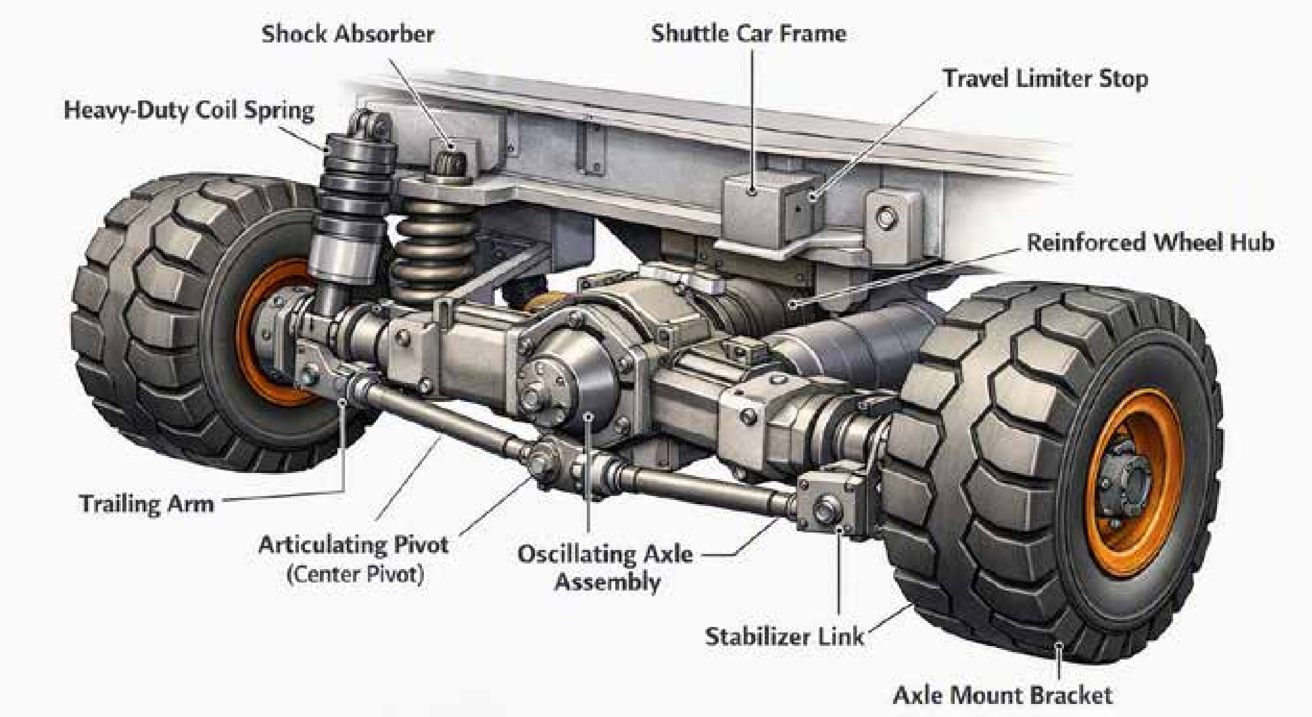
TYRES AND SUSPENSION

The tyres and suspension system of a shuttle car form the essential interface between the machine and the underground environment, determining whether it can navigate the rough, uneven and often unpredictable terrain that characterises room and pillar operations. Although these components may appear straightforward compared to motors, frames or control systems, they are in fact among the most heavily stressed elements of the entire machine. Their design, material composition and mechanical behaviour directly influence the shuttle car's stability, manoeuvrability and long term reliability.

Underground mines present a terrain unlike any surface environment. Floors are frequently uneven, rutted or sloped, shaped by geological conditions, water ingress, debris accumulation and the constant movement of heavy machinery. Shuttle cars must traverse this terrain repeatedly, often under full load, while maintaining precise alignment with continuous miners and discharge points. To achieve this, the tyres and suspension must absorb shock, maintain traction and resist damage from abrasive surfaces.

Heavy duty tyres are therefore indispensable. Unlike pneumatic tyres used in surface vehicles, shuttle cars typically rely on solid rubber tyres. This design choice is driven by necessity. Underground operations are rife with sharp debris, fractured rock, metal fragments and irregular surfaces that would puncture or tear conventional tyres within minutes. Solid rubber eliminates the risk of flats entirely, ensuring that the shuttle car can continue operating without interruption. The absence of air also means the tyre cannot deform catastrophically under load, providing a stable and predictable contact patch even when carrying several tonnes of material.

The composition of these tyres is engineered for durability. High density rubber compounds are selected for their resistance to abrasion, tearing and heat build up. The tyres must withstand constant friction against rough floors, repeated impacts from debris and the grinding effect of turning in confined spaces. Their hardness is carefully balanced: too soft, and they would wear rapidly; too hard, and they would transmit excessive vibration to the chassis, increasing fatigue on structural components and reducing operator comfort. The optimal compound allows the tyre to flex slightly under load, improving traction while still resisting damage.



Shuttle car suspension

The tread pattern of solid rubber tyres also plays a role in performance. Although underground floors are generally dry, water accumulation, mud and slurry can occur, especially in deeper or older workings. Tread designs help maintain grip in these conditions, preventing slippage that could compromise positioning at the miner or feeder breaker. In tight headings, where manoeuvring space is limited, reliable traction is essential to avoid collisions or misalignment.

Complementing the tyres is the shuttle car's heavy duty suspension system. Suspension is often overlooked in discussions of underground machinery, yet it is fundamental to the shuttle car's ability to operate smoothly and safely. The suspension must absorb the constant shocks generated by uneven floors, preventing these forces from transferring directly into the chassis, motors and conveyor system. Without effective suspension, the machine would experience excessive vibration, leading to accelerated wear, structural fatigue and reduced component life.

The suspension system typically consists of reinforced springs, dampers and mounting assemblies designed to handle continuous heavy loads. These components must operate under conditions far more severe than those encountered by surface vehicles. Every haul cycle subjects the suspension to repeated compression and rebound, often with sudden impacts when the car encounters dips, ridges or debris. The system must respond instantly, maintaining stability without bottoming out or allowing excessive oscillation.

A well designed suspension also improves manoeuvrability. Shuttle cars must position themselves with precision at both the continuous miner and the discharge point. If the suspension is too stiff, the car may bounce or skid on uneven ground, making fine adjustments difficult. If it is too soft, the machine may lean or sag under load, affecting alignment and increasing the risk of collisions. The suspension must therefore strike a balance between rigidity and flexibility, supporting the weight of the machine while still allowing controlled movement.

The interaction between tyres and suspension is critical. Solid rubber tyres transmit more vibration than pneumatic ones, placing greater demands on the suspension to absorb shock. Conversely, the suspension relies on the tyres to provide initial cushioning and traction. When both systems are functioning correctly, the shuttle car moves smoothly through the entry, maintaining stability even when fully loaded. When either system deteriorates, the effects are immediate: reduced traction, increased vibration, misalignment, and ultimately a decline in production efficiency.

Maintenance of tyres and suspension is therefore essential. Solid rubber tyres, though resistant to flats, can still suffer from chunking, cracking or uneven wear. Suspension components can fatigue, lose tension or suffer damage from repeated impacts. Regular inspection ensures that these systems continue to perform as intended, preserving the shuttle car's ability to navigate the underground environment safely and reliably.

In the broader context of underground mining, heavy duty tyres and suspension systems are not merely mechanical components; they are the foundation of mobility. They allow the shuttle car to traverse terrain that would immobilise lesser machines, maintain the rhythm of continuous mining, and withstand the relentless punishment of daily operation. Their design reflects decades of engineering refinement, shaped by the realities of underground work and the demands of high production mining.

Ultimately, the tyres and suspension system are what allow the shuttle car to do its job: move material efficiently, safely and consistently through one of the harshest industrial environments on earth. Their strength and reliability underpin the entire haulage process, ensuring that the machine remains a dependable link between the working face and the mine's conveyor network.

STEERING AND BRAKING SYSTEM

The steering and braking systems of a shuttle car are among its most critical operational components, responsible for ensuring that the machine can navigate the confined, irregular and often hazardous spaces of an underground mine with precision and safety. Although haulage capacity and motor power often dominate discussions of shuttle car performance, the ability to manoeuvre accurately and stop reliably is equally fundamental. Without these systems functioning at peak capability, the shuttle car cannot position itself correctly at the continuous miner, cannot align with the feeder breaker, and cannot operate safely in close proximity to other machinery and personnel.

Underground mines impose unique demands on steering systems. Entries are narrow, turning radii are tight, and visibility is limited. The shuttle car must often manoeuvre within centimetres of ribs, roof supports and other equipment. Hydraulic steering has therefore become the standard in modern shuttle car design because it provides the fine control necessary for such environments. Unlike mechanical steering systems, hydraulic steering delivers smooth, responsive movement even under heavy load. The operator can make precise adjustments with minimal effort, allowing the shuttle car to position itself accurately at the loading point and maintain alignment during travel.

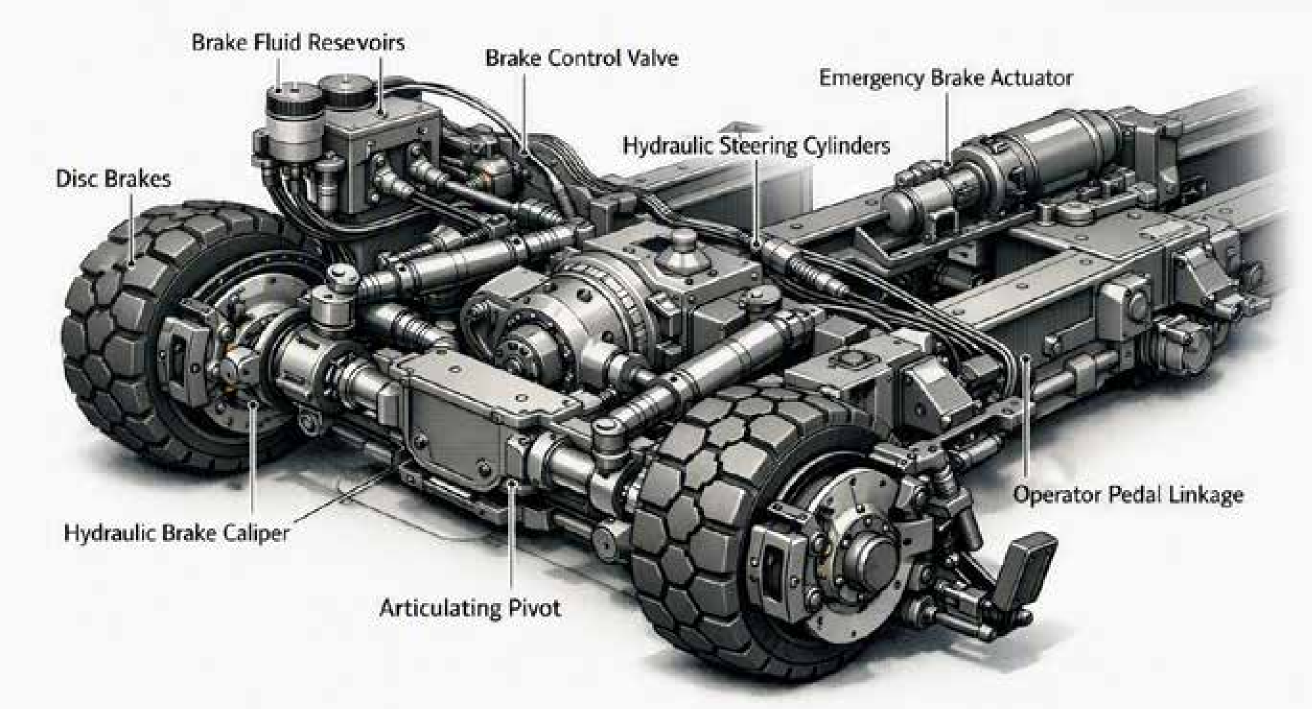
Hydraulic steering systems rely on pressurised fluid to transmit force from the operator's controls to the steering cylinders. This arrangement offers several advantages. First, hydraulic systems can generate significant force, enabling the shuttle car to turn its wheels even when fully loaded or when the tyres encounter resistance from debris or uneven ground. Second, hydraulic steering absorbs shock and vibration, preventing sudden jolts from affecting the operator's control. Third, the system can be integrated with modern control modules, allowing for enhanced responsiveness and compatibility with semi autonomous or automated navigation technologies.

The steering linkage and cylinders must be engineered to withstand constant stress. Underground conditions expose these components to abrasive dust, moisture, impact and vibration. High strength materials, sealed joints and reinforced mounting points are essential to ensure longevity. Any degradation in steering performance – such as sluggish response, reduced turning radius or hydraulic leakage – can compromise safety and disrupt production, making regular inspection and maintenance vital.

If steering determines how the shuttle car moves, braking determines how it stops – and in underground mining, stopping is often more critical than moving. Reliable braking systems are essential for preventing collisions, controlling descent on sloped entries, and ensuring that the shuttle car can halt immediately if personnel or equipment enter its path. Advanced braking systems have therefore become integral to shuttle car design, combining mechanical robustness with precise control.

Most shuttle cars employ multi layered braking systems that include service brakes, emergency brakes and parking brakes. Service brakes are used during normal operation, allowing the operator to slow or stop the machine smoothly. These brakes must respond instantly, even when the shuttle car is carrying a full load. Emergency brakes provide a fail safe mechanism, engaging automatically if the primary system fails or if the operator activates an emergency stop. Parking brakes secure the machine when stationary, preventing unintended movement on uneven or sloped ground.

The braking system must be capable of dissipating significant energy. When a fully loaded shuttle car decelerates, the brakes absorb the kinetic energy generated by the moving mass. This produces heat, which must be managed to prevent brake fade or component damage. High performance brake materials, cooling pathways and robust housings are therefore essential. In addition, braking systems must resist contamination from



dust, water and debris, all of which can impair performance if they infiltrate brake assemblies.

Modern shuttle cars increasingly incorporate electronic monitoring and control systems that enhance braking reliability. Sensors track brake temperature, wear levels and hydraulic pressure, providing real time feedback to operators and maintenance teams. These diagnostics allow emerging issues to be identified before they lead to failure, reducing downtime and improving safety. In some designs, braking systems are integrated with collision avoidance technologies, enabling automatic braking if the shuttle car approaches an obstacle too quickly.

The interaction between steering and braking is central to safe underground operation. Precise steering allows the shuttle car to navigate tight spaces, while reliable braking ensures that it can stop immediately when required. Together, these systems provide the control necessary to operate in close proximity to continuous miners, feeder breakers, roof supports and personnel. Their performance directly affects production efficiency: a shuttle car that cannot manoeuvre accurately or stop reliably will slow the mining cycle, increase the risk of accidents and place additional strain on other equipment.

Maintenance of steering and braking systems is therefore a strategic priority. Hydraulic lines must be inspected for leaks, steering cylinders for wear, brake pads for degradation, and control modules for proper function. Any decline in performance can have immediate operational consequences. In the demanding environment of underground mining, where equipment is pushed to its limits every shift, the health of these systems is inseparable from the safety and productivity of the entire operation.

Ultimately, the steering and braking systems of a shuttle car are not merely functional components; they are the mechanisms that allow the machine to operate with precision, control and confidence in one of the most challenging industrial environments. Their engineering reflects decades of refinement, shaped by the realities of underground work and the need for absolute reliability. In the confined spaces of a mine, where every movement matters, these systems ensure that the shuttle car remains a safe, efficient and indispensable link in the haulage chain.

BUCKET OR CONVEYOR

The bucket or conveyor system within a shuttle car is the central mechanism that enables the machine to fulfil its primary purpose: receiving, holding and transporting fragmented material from the continuous miner to the mine's haulage network. Although it may appear to be a simple load handling component, its design, durability and performance are fundamental to the efficiency of room and pillar operations. Without a reliable bucket or conveyor system, the shuttle car cannot maintain the steady flow of material that continuous mining demands.

At its core, the bucket or conveyor system is engineered to accept material directly from the continuous miner's discharge boom. This moment of transfer is one of the most critical points in the entire production cycle. The system must be positioned with precision, withstand the force of incoming material, and maintain a smooth flow without spillage or blockage. Any interruption at this stage slows the miner, disrupts the rhythm of production and reduces overall output.

Two primary designs are used in shuttle cars: bucket style load compartments and conveyor based systems. Each design reflects a different engineering philosophy and operational requirement.

Bucket systems rely on a robust, high capacity compartment constructed from reinforced steel. The bucket must be strong enough to absorb the impact of material being dropped into it, resist abrasion from sharp or coarse fragments, and maintain structural integrity under full load. The interior surfaces are often shaped to promote smooth material flow, preventing accumulation in corners or along edges. The bucket's geometry also influences how easily the shuttle car can discharge its load, whether by tipping, sliding or transferring into a feeder breaker.

Conveyor systems, by contrast, incorporate a continuous belt or chain assembly that moves material through the shuttle car as it is loaded. This design allows for more controlled handling, reducing the risk of surging or uneven distribution. The conveyor must be capable of operating under heavy load, maintaining consistent speed and resisting wear from abrasive material. Rollers, bearings and drive mechanisms must be engineered to withstand constant duty cycles, while the belt or chain must be constructed from materials that balance flexibility with durability.

Regardless of design, the load handling system must accommodate the realities of underground mining. Material arriving from the continuous miner is not uniform; it varies in size, density and moisture content. The bucket or conveyor must be able to handle fine particles, large fragments and everything in between without jamming or overloading. It must also operate in confined spaces, often with limited visibility, requiring the system to be forgiving of minor misalignments during loading.

Durability is a defining requirement. The bucket or conveyor system is subjected to constant abrasion, impact and vibration. Reinforced steel plates, wear resistant liners and hardened components are essential to prolong service life. In conveyor systems, the belt or chain must resist tearing, stretching and chemical degradation. Bearings and rollers must be sealed against dust and moisture, while drive motors must deliver consistent torque under varying load conditions.

The discharge process is equally important. The bucket or conveyor must release material smoothly and efficiently into the mine's haulage system. Any hesitation or blockage at this stage can cause spillage, increase cleanup time and disrupt the miner's cutting rhythm. The discharge mechanism – whether a tipping bucket, sliding gate or conveyor extension – must be engineered for reliability, ensuring that the shuttle car can complete each cycle without delay.

Modern shuttle cars often integrate sensors and control systems into their load handling components. These technologies monitor belt speed, bucket fill levels, motor load and system temperature, providing real time feedback to operators and maintenance teams. Such diagnostics help identify emerging issues before they lead to failure, reducing downtime and improving overall productivity.

The bucket or conveyor system also plays a role in safety. A well designed load compartment prevents material from spilling into the entry, reducing slip hazards and protecting personnel. Smooth, predictable operation reduces the risk of sudden movements that could endanger operators or damage nearby equipment. In conveyor equipped shuttle cars, emergency stop mechanisms and safety interlocks ensure that the system can be halted instantly if necessary.

Ultimately, the bucket or conveyor system is far more than a simple container or belt. It is the mechanism that connects the continuous miner to the wider haulage network, enabling the mining process to function as a continuous, high efficiency cycle. Its engineering reflects decades of refinement, shaped by the demands of underground work and the need for absolute reliability. In the harsh environment of a mine, where every component

is pushed to its limits, the bucket or conveyor system remains a critical element of the shuttle car's performance and the productivity of the entire operation.

CONTROL SYSTEM

The control system of a modern shuttle car is the central nervous system of the machine, the integrated suite of technologies that governs how it moves, responds, communicates and protects both itself and the personnel around it. As underground mining has evolved toward higher production rates, tighter safety standards and increasing levels of automation, the sophistication of shuttle car control systems has grown accordingly. What was once a basic set of operator levers and switches has become a coordinated network of electronic modules, hydraulic interfaces, safety interlocks and diagnostic tools designed to ensure smooth, predictable and safe operation in one of the harshest industrial environments.

At the core of the control system are the operator controls, the interface through which human input is translated into mechanical action. These controls must be intuitive, responsive and durable, allowing operators to manoeuvre the shuttle car with precision even in low visibility, confined headings. Joysticks, switches and pedals are engineered to withstand constant vibration, dust exposure and physical impact. Their layout is designed to minimise operator fatigue, enabling fine steering adjustments, controlled acceleration and accurate positioning at both the continuous miner and the discharge point. In modern designs, these controls are often supported by electronic assist systems that smooth operator input, reducing abrupt movements and improving overall machine stability.

Safety interlocks form another essential component of the control system. Underground mines are environments where multiple machines operate in close proximity, where personnel may be present near moving equipment, and where visibility is often limited. Safety interlocks ensure that the shuttle car cannot perform certain actions unless specific conditions are met. For example, the conveyor or bucket system may be prevented from operating unless the machine is correctly positioned, or the motors may be inhibited if a guard or access panel is open. These interlocks reduce the risk of accidental activation, protecting both operators and maintenance personnel.

Emergency stop systems are integrated into the control architecture as well. These systems allow the shuttle car to be halted instantly if a hazardous situation arises. Emergency stop buttons are placed in accessible locations, and in some designs, remote stop capabilities are included to allow personnel outside the machine to intervene if necessary. The reliability of these systems is paramount; they must function flawlessly even under heavy load, electrical disturbance or mechanical stress.

Monitoring systems represent one of the most significant advancements in shuttle car control technology. Modern machines are equipped with sensors and diagnostic modules that continuously track the performance of critical components. Motor temperature, hydraulic pressure, conveyor speed, steering response, brake condition and electrical load are all monitored in real time. This information is displayed to the operator through onboard screens or indicator panels, allowing immediate awareness of emerging issues. In addition, data can be logged for maintenance teams, enabling predictive maintenance strategies that reduce downtime and extend component life.

These monitoring systems also contribute to operational efficiency. By providing feedback on load conditions, conveyor performance or motor strain, they allow operators to adjust their driving behaviour to maintain optimal production flow. In some designs, the control system can automatically regulate certain functions – such as conveyor speed or traction power – to prevent overloads or maintain consistent material flow.

The integration of control systems with broader mine wide technologies is becoming increasingly common. Shuttle cars may communicate with continuous miners, feeder breakers or central control stations, sharing information about load status, machine location or operational readiness. This connectivity supports coordinated production cycles, reduces idle time and enhances situational awareness across the working section. As autonomous and semi autonomous mining technologies continue to develop, the shuttle car's control system becomes even more critical, serving as the interface between human oversight and automated machine behaviour.

Environmental resilience is a defining requirement of all control system components. Underground mines expose electronics to dust, moisture, vibration, heat and electromagnetic interference. Control modules must be sealed, shock mounted and insulated to ensure reliable performance. Wiring harnesses must be routed and protected to prevent abrasion or accidental damage. Connectors must resist corrosion and maintain secure contact even under constant movement. The durability of these components directly affects the shuttle car's reliability; any failure in the control system can halt production immediately.

Ultimately, the control system of a shuttle car is far more than a collection of switches and sensors. It is the integrated framework that allows the machine to operate with precision, safety and efficiency in an environment where mistakes carry significant consequences. Its engineering reflects decades of refinement, shaped by the demands of underground work and the need for absolute reliability. As mining continues to advance technologically, the control system will remain the defining element that enables shuttle cars to function as dependable, intelligent and safe links in the haulage chain.

LIGHTING AND SAFETY FEATURES

Lighting and safety features on modern shuttle cars are far more than auxiliary additions; they are integral components that shape how the machine operates within the demanding environment of an underground mine. In confined headings where visibility is limited, multiple machines work in close proximity, and hazards can emerge without warning, the presence of reliable lighting, audible alerts and emergency stop mechanisms becomes essential to both operational efficiency and worker protection.

Bright LED lighting has become the standard across contemporary shuttle car designs, replacing older incandescent or halogen systems that were prone to failure and offered limited illumination. LEDs provide a powerful, focused light output capable of cutting through dust, shadow and low visibility conditions. Their durability is particularly valuable underground: LEDs resist vibration, shock and temperature fluctuations far better than traditional bulbs, ensuring that the shuttle car maintains consistent visibility throughout its shift. Proper illumination allows operators to position the machine accurately at the continuous miner, navigate uneven or debris strewn floors, and maintain awareness of personnel and equipment around them. In an environment where misjudging a distance by even a few centimetres can lead to collisions or production delays, lighting becomes a critical operational tool.

Backup alarms serve a different but equally important function. Underground mines are acoustically complex spaces where machinery noise, ventilation systems and geological echoes can mask the movement of equipment. Shuttle cars frequently reverse in tight entries, often with limited sightlines and minimal clearance. Audible backup alarms cut through ambient noise, alerting nearby workers that the machine is moving in reverse. This simple but effective feature reduces the risk of accidental contact, particularly in areas where multiple machines operate simultaneously or where workers may be performing tasks near the haulage route. The alarm's distinct tone is engineered to be recognisable even in high noise environments, ensuring that personnel can react quickly and safely.

Emergency stop buttons complete the trio of essential safety features. These controls are strategically placed on the shuttle car to allow immediate shutdown of the machine if a hazardous situation arises. Whether a worker enters the vehicle's path, a mechanical fault occurs, or an unexpected obstruction appears, the emergency stop provides a direct and instantaneous method of halting all motion. The reliability of these systems is paramount: they must function flawlessly under load, in dusty conditions, and even when the machine's electrical systems are under strain. Their presence reflects the broader safety philosophy of underground mining, where rapid response mechanisms are necessary to mitigate risks inherent to confined, high activity environments.

Together, these lighting and safety features form a comprehensive protective framework that enhances both operational control and worker wellbeing. Bright LED lights improve visibility and reduce navigational errors; backup alarms increase situational awareness for everyone in the vicinity; emergency stop buttons provide a critical safeguard against unforeseen hazards. In combination, they transform the shuttle car from a simple haulage machine into a safer, more predictable and more responsible piece of underground equipment.

As mining continues to evolve toward higher production rates and more technologically advanced systems, these safety features remain foundational. They ensure that shuttle cars can operate efficiently without compromising the wellbeing of operators or other workers in the mine. In the demanding environment of underground operations, where every component is pushed to its limits, lighting and safety systems stand as essential elements that uphold the integrity, reliability and safety of the entire haulage process.

Feeling Centered: The Zen of Conveyor Belt Tracking

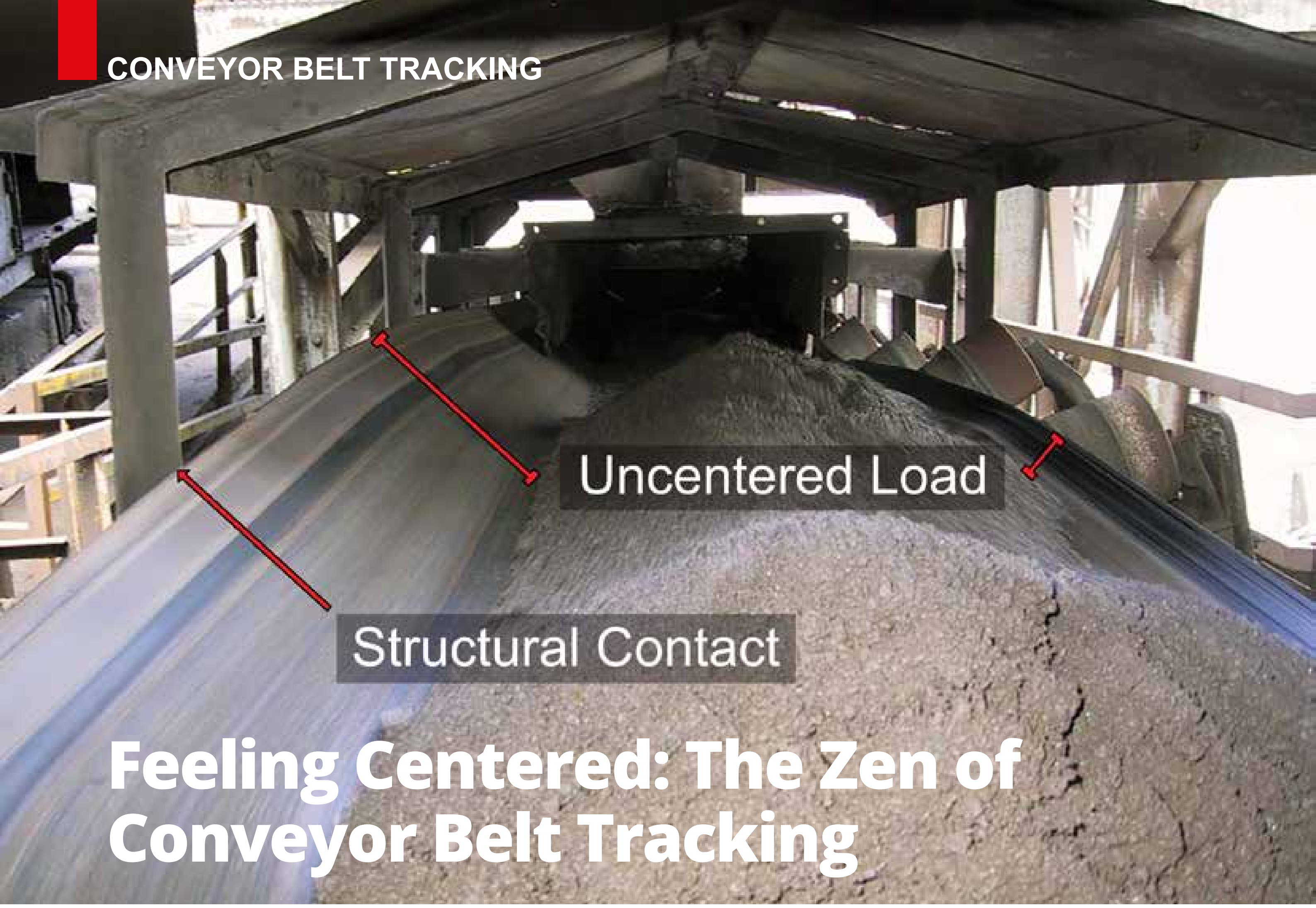


Figure 1: Off-center load on a mistracking belt that's reaching up to contact the conveyor structure.

The moment a conveyor belt wanders, material spills, system safety and productivity quickly degrade, and operating costs rise. Spillage fouls idlers and pulleys, causing them to seize, leading to friction damage on the belt and potentially becoming a fire hazard. When a high-speed belt edge contacts the stringer, it can cause fraying, shredding, or splice damage and cut through steel mounts. [**Figure 1**]

Mistracking is prevented by first understanding the basic patterns of belt behavior and then following established procedures to carefully align the structure and components to correct fluctuations in the belt's path.

Mistracking Indicators:

- Belt edge damage
- Excessive spillage
- Idler/Pulley fouling
- Off-center belt at head or tail pulley

COMMON CAUSES OF MISTRACKING

There are three general groups of common causes for mistracking.

Belt and Splice – If the belt is poorly manufactured or stored improperly, it can bow or camber. Poor installation of a vulcanised or mechanical splice can result in a splice that causes belt tracking problems. Exposure to weather or to chemicals can degrade the carcass (plies or cords) and the cover of the belt, leading to bowing, cambering or cupping due to unequal shrinkage between the top and bottom covers.

Conveyor Structure – Inaccurate alignment during the construction of the stringer, structural alignment degradation, machinery collision, seismic activity, or ground settling all spark the need for realignment.

Improper Loading – The load's center of gravity will seek the lowest point of the troughing idlers, so if the belt is not center loaded, the weight of the cargo pushes the belt toward the conveyor's more lightly loaded side.

SMARTER TRACKING

Standard tracking provided by conveyor OEMs is often inadequate, especially as the system settles and ages.

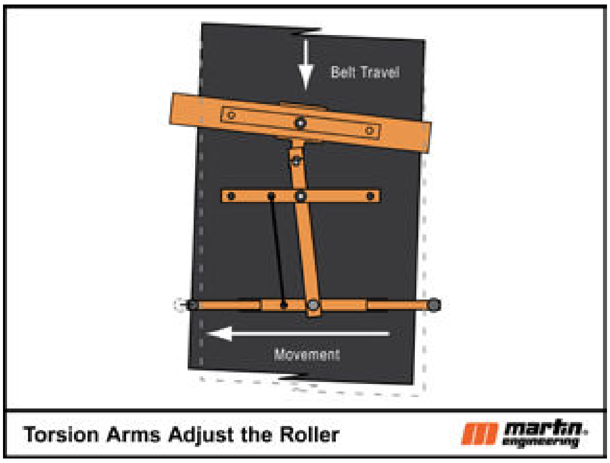


Figure 2: Sensing slight variations in the belt path helps make immediate micro-adjustments.

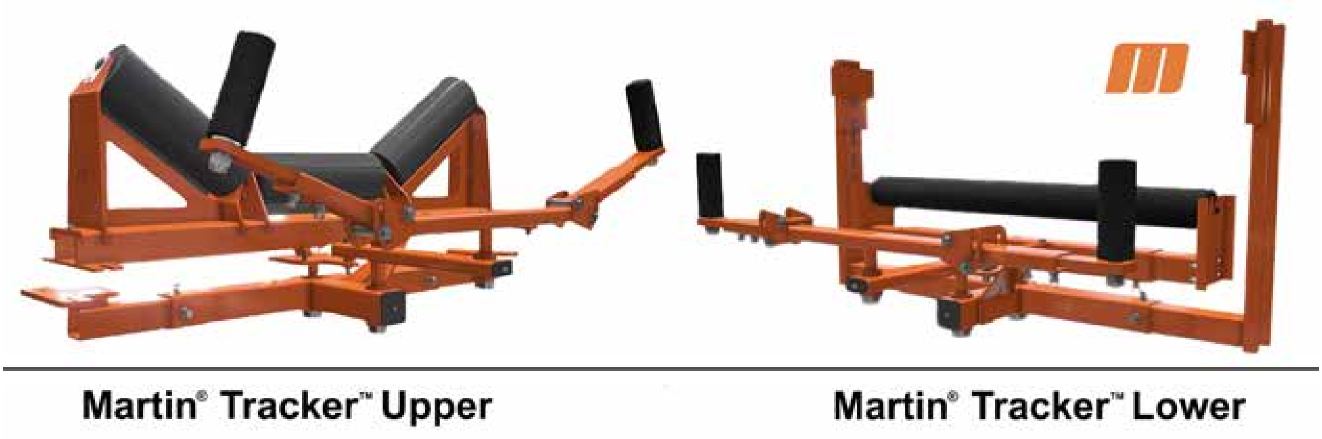


Figure 3: The upper unit for the conveyor carrying side and the lower for return side.

Switch mechanisms that detect mistracking and stop the system are excellent for safety, but they can lead to excessive downtime. Rollers attached to the stringer prevent contact but cause the belt to fold over on itself. Neither of these is a preventive measure.

Multi-Pivot Belt Trackers like Martin® Trackers™ use long arms to control a pivot roller. The guide rolls detect very slight misalignments and make immediate corrections. The longer arms require considerably less force to move the pivot roller, resulting in less counterforce and drag on the belt. [**Figure 2**]

By reducing the energy required to correct the belt, wear on both the conveyor and tracking equipment is reduced, resulting in a longer, more efficient service life. This design has also been adapted for the belt return and reversing belts. [**Figure. 3**]

BELT TRACKER PLACEMENT

To avoid units competing and contradicting each other's steering action, they should be positioned approximately 20 to 50 meters (70 to 160 ft) apart, depending on the severity of the mistracking problem. For proper loading, unloading, and settling, it is recommended to place trackers in some critical areas. [**Figure 4**]

Typically elevated 10-20 millimeters (1/2 to 3/4 in.) higher than the rolls of the adjacent conventional idlers, a center roll or pivot roll increases the belt's pressure on the tracking device, improving the corrective friction between the belt and the aligning roll. This is applicable to both troughed (carrying side) and at (return side) self-aligning idlers. It helps to have rubber-covered rollers rather than "steel can" idlers.

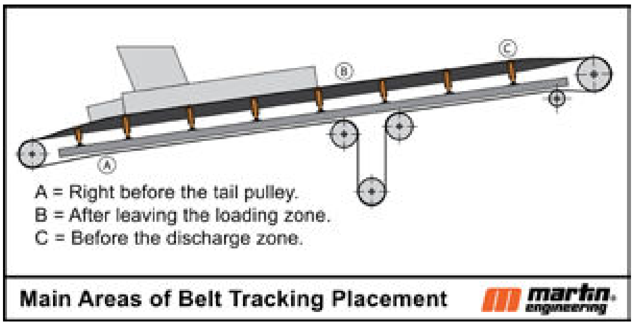


Figure 4: A Martin expert draws out a quick sketch to help an attendee visualise the solution.

CONCLUSION

The long-term benefits to efficient conveyor operations are well known. Keeping the belt centered and moving quickly is the key to high production, a low cost of operation and a safer workplace.

AUTHOR

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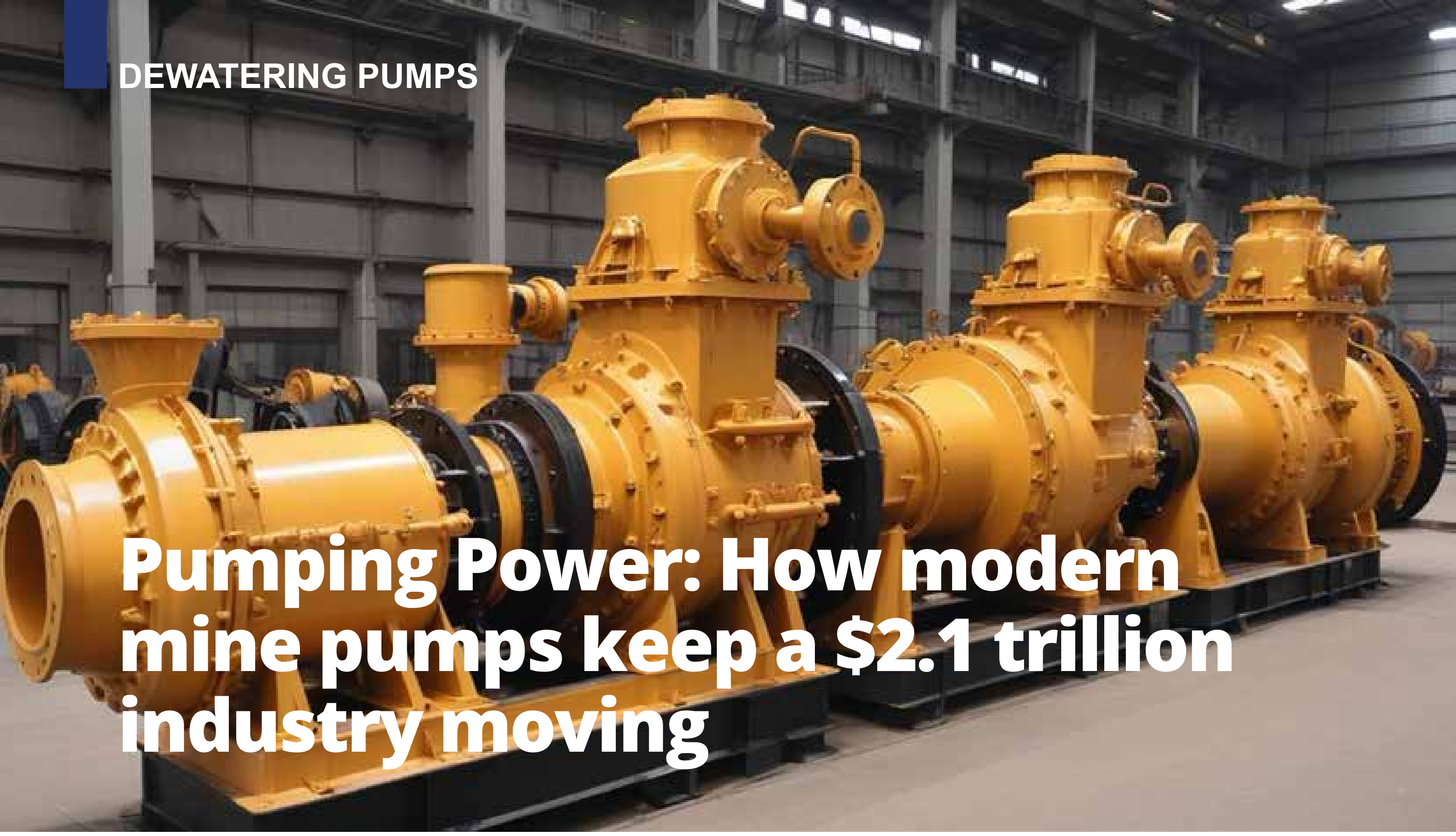
Dave Mueller is a long-time employee of Martin Engineering, having started his career with the company in 1986 and has since established himself as an expert in conveyor accessories. A graduate of Penn Foster College with a B.A. in Business Management, Dave has 10 years in Research & Development on conveyor products, 26 years as Conveyor Product Manager, is a prolific contributor of articles, and has several patents.



Pumping Power: How modern mine pumps keep a $2.1 trillion industry moving

Mining is, at its core, a story of movement – of rock, of ore, of water, of slurry, of chemicals, and of the vast industrial systems that transform raw geology into economic value. In 2023, the global mining sector was valued at roughly $2.1 trillion, representing 6-7% of global GDP – a reminder that almost every modern technology, infrastructure system and energy transition pathway begins with materials extracted from the earth. As the industry grows toward a projected $3.7 trillion by 2033, the technologies that keep mines safe, dry and productive become ever more critical. Among these, pumps are the quiet workhorses: essential, omnipresent, and often overlooked. *Gordon Barratt of Mining & Quarry World and Coal International* explores the evolution of mining pumps, the technologies shaping today's operations, and the case studies that illustrate how modern pump systems are redefining reliability, efficiency and safety across global mining.

A BRIEF HISTORICAL VIEW: PUMPS THROUGH THE MINING DECADES

The relationship between mining and pumping technology is as old as industrial mining itself. In the late 1800,s, as deep hard rock mining expanded, water control became a defining engineering challenge. Early dewatering relied on gravity-fed drainage tunnels and rudimentary steam-driven pumps. As mines pushed deeper, multi-stage pump stations were installed at various levels to lift water to the surface.

A vivid historical example comes from the diamond mines of Kimberley, where Cecil Rhodes built his first fortune supplying pumps to keep the open pits dry enough to mine. Modern research into kimberlite dewatering shows how these early systems evolved into sophisticated ring-tunnel drainage networks and deep pumping boreholes capable of managing groundwater at depths exceeding 650 metres .

Image of daily life at the Kimberley Mine

Historical images of some of the early mining pumps being used

By the mid 20th century, electrically driven pumps – such as those used at Hodbarrow Mine in Cumbria – became standard, offering higher reliability and greater control. Today, pump technology has diversified dramatically, with specialised systems for slurry transport, chemical handling, dewatering, tailings management and process fluid circulation.

Mining pumps today fall broadly into two categories: centrifugal pumps and air-operated double-diaphragm (AODD) pumps. Each serves distinct roles across surface and underground operations.

Centrifugal pumps dominate above-ground mining and mineral processing, where they handle corrosive chemicals, reagents and process fluids essential to extraction and refinement. Their impeller-driven design allows continuous, high-volume flow – ideal for:

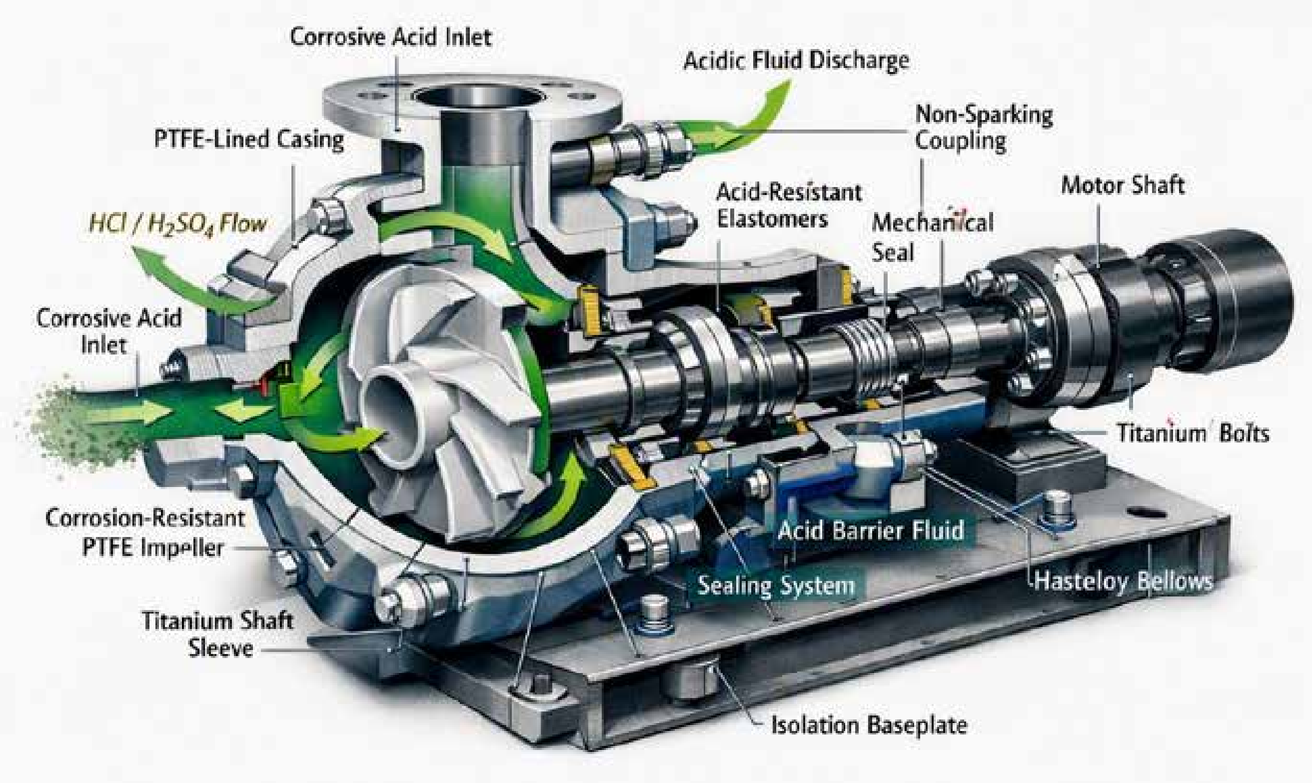
- **Leaching and smelting circuits**
- **Acid treatment and reagent dosing**
- **Separation, flotation and thickening**
- **Sintering and concentrate handling**

These pumps are engineered to withstand aggressive chemicals such as hydrochloric acid, sulfuric acid and caustic soda, making them indispensable in copper, gold, lithium and rare-earth processing.

Case studies highlight their importance. At BHP's Olympic Dam, GIW MDX450 slurry

Air operated double diaphragm pump

Centrifugal pump



Acid resistant chemical-process pump cutaway

pumps significantly reduced downtime by improving wear life in highly abrasive conditions . Similarly, Metso's heavy-duty Orion HR pumps at the Mungari Gold Mine cut annual shutdowns from three to one through redesigned polyurethane liners, saving hundreds of maintenance hours and improving throughput metso.commetso.com. Pumps upgrade significantly reduces plant shutdowns at Mungari Gold Mine – Metso.

Wilden Brahma Pump

Slurry pumps – another centrifugal variant – remain central to tailings transport and concentrate movement. Canadian operations, for example, rely heavily on high-performance slurry pumps to maintain production continuity in harsh climates and abrasive ore environments.

AIR-OPERATED DOUBLE-DIAPHRAGM (AODD) PUMPS: THE DEWATERING SPECIALISTS

Below ground, the priorities shift. Water becomes the enemy – intruding through rock strata, accumulating in headings, sumps and declines, and threatening both safety and productivity. Here, AODD pumps excel.

Their advantages include:

- **Ability to handle suspended solids:** Mine water often contains sludge, debris, tailings and abrasive particles. AODD pumps can pass large solids without clogging, thanks to configurable diaphragm and valve designs.

- **Self-priming and dry-running capability:** Ideal for fluctuating sump levels and intermittent inflows.

- **Operation without electricity:** Air-driven systems eliminate spark risks, making them suitable for explosive atmospheres and confined underground spaces.

- **Portability:** Lightweight frames allow rapid relocation between headings, temporary pits and emergency flood zones.

- **Minimal maintenance:** With no mechanical seals and fewer moving parts, diaphragm and valve replacements can be done quickly on-site.

AODD pumps are widely used in underground gold, nickel and coal mines. For example, Wilden Brahma pumps have proven effective in gold mine dewatering, handling heavy sludge with large internal clearances that prevent blockages . In Western Australia, Tsurumi submersible and diaphragm pumps are routinely deployed in nickel mines for reliable underground water control.

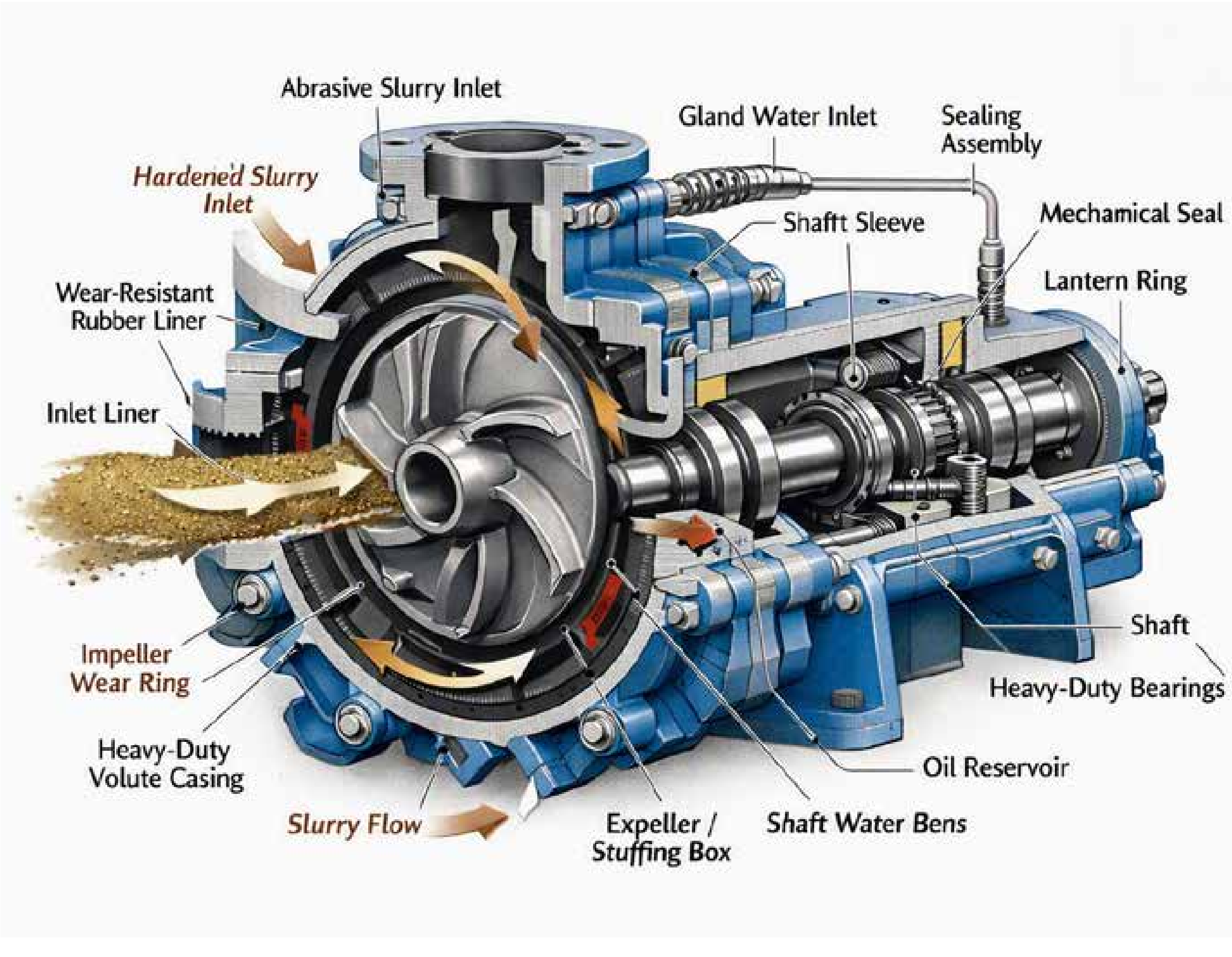
WILDEN BRAHMA PUMPS DELIVER RELIABILITY IN GOLD MINE DEWATERING

The most successful deployment of Wilden Brahma pumps in mining occurred at a gold operation where conventional diaphragm pumps repeatedly failed under heavy solids loading. The mine's dewatering system had been plagued by blockages and mechanical wear caused by abrasive slurries and tailings. Each stoppage required manual clearing, which increased downtime and exposed maintenance crews to hazardous conditions.

When engineers introduced the Wilden T810 Brahma Flapper Pump, the transformation was immediate. Its flap valve design allowed solids up to fifty millimetres to pass freely through the pump body, eliminating the clogging that had crippled earlier systems. The top inlet and bottom discharge configuration pushed solids directly out of the pump, preventing sediment accumulation and maintaining consistent flow even in thick, viscous slurries.

The Brahma's air driven mechanism proved invaluable in the underground environment, where electrical equipment posed explosion risks. Operating entirely on compressed air, the pump delivered reliable suction lifts of more than seven metres and could run dry without damage. Maintenance demands fell sharply because the pump's internal geometry contained fewer moving parts and no mechanical seals.

Within months, the mine reported a dramatic improvement in uptime and a measurable reduction in maintenance expenditure. The pumps were easily relocated between headings and sumps, providing flexibility during seasonal



Slurry pump engineering cutaway

flooding and emergency drainage. Their success led to wider adoption across other mining sites for drilling mud transfer, sludge removal and tailings management.

The case demonstrated that Wilden Brahma pumps could handle the most abrasive and solids laden fluids encountered in mining while maintaining safety and reliability. By replacing ball check diaphragm pumps with the Brahma's flap valve technology, the operation turned a chronic bottleneck into a stable, efficient process – proof that robust design and simplicity can outperform complexity in the harshest industrial environments.

OTHER PUMP TECHNOLOGIES IN TODAY'S MINING MARKET

While centrifugal and AODD pumps dominate, several specialised pump types support niche but critical applications:

- **Peristaltic (hose) pumps:** Ideal for high-density slurries up to 80% solids, outperforming centrifugal pumps when slurry SG exceeds 1.3. They are widely used in cobalt, vanadium and lime slurry applications .
- **Piston-actuated diaphragm pumps:** Used in large-scale dewatering where high lift and robust solids handling are required. These systems are common in open-pit operations with fluctuating groundwater inflows.
- **Liquid ring vacuum pumps:** Essential in coal mining for gas extraction, ventilation support and water removal from sealed areas .
- **High-capacity borehole pumps:** Used in deep open pits and remote sites to lift water from significant depths. SAER's 100 kW borehole pumps are a typical example, often deployed in large-scale dewatering campaigns .
- **Pontoon-mounted pump systems:** Common in Australian mines where water bodies must be managed dynamically. Calpeda's floating pump platforms illustrate how modular systems can be adapted to changing pit geometries .

DEWATERING: THE CRITICAL OPERATIONAL PRIORITY

Dewatering is more than water removal – it is a safety, productivity and environmental function. Pumps prevent flooding, maintain access to ore bodies, protect electrical infrastructure, and ensure machinery can operate without interruption. They also support water treatment, helping mines manage contaminants before discharge.

Modern dewatering systems integrate:

- **Variable-speed pump control**
- **Remote monitoring and telemetry**
- **High-wear-resistant materials**
- **Redundant pump trains for reliability**
- **Filtration and solids separation systems**

Case studies from Tanzania, Australia and North America show how integrated pump systems – such as Godwin's diesel-driven units – are enabling deeper mining, faster response to inflows and improved environmental compliance.

SELECTING THE RIGHT PUMP: KEY CONSIDERATIONS

Choosing the correct pump requires evaluating:

- **Fluid characteristics** (corrosiveness, solids content, viscosity)
- **Required flow rate and head**
- **Depth and suction lift conditions**
- **Power availability (air, diesel, electric)**
- **Material compatibility** (metallic vs non-metallic wetted parts)
- **Maintenance accessibility**
- **Environmental and safety constraints**

Effective maintenance planning – filtration, inspection schedules, spare parts availability – extends pump life and reduces downtime.

Mining has always depended on the movement of materials, and pumps sit at the centre of that motion. What is changing today is the sophistication of the technology behind them. Modern pump engineering is making mines more effective and efficient by transforming how water, slurry, reagents and tailings are handled across both surface and underground operations.

The most significant gains come from advances in materials science. Corrosion resistant polymers, hardened alloys and elastomers designed for abrasive slurries have extended pump life dramatically. Where older pumps suffered rapid wear in acidic or high solids environments, today's chemical process and slurry pumps can operate for far longer intervals without intervention. This reduces maintenance downtime and stabilises production, particularly in mineral processing circuits where flow continuity is essential.

Intelligent control systems have also reshaped pump performance. Variable speed drives, remote telemetry and automated monitoring allow pumps to respond instantly to changing conditions. Mines can now adjust flow rates, suction lift and discharge pressure in real time, optimising energy use and preventing failures before they occur. In dewatering, this means pumps can adapt to fluctuating groundwater inflows, maintaining safe working conditions without constant manual oversight.

Design innovation has played an equally important role. Air operated double diaphragm pumps, for example, have become indispensable underground because they can run dry, handle large solids and operate without electrical components. Slurry pumps with redesigned volutes and impellers now move thicker, more abrasive mixtures with greater efficiency, improving tailings transport and reducing pipeline blockages. Even niche technologies such as peristaltic hose pumps have gained traction for high density slurries that would overwhelm conventional centrifugal designs.

Together, these developments have made pumping systems more reliable, more adaptable and more economical. Mines benefit from fewer stoppages, lower energy consumption and safer working environments. As operations go deeper and ore bodies become more complex, the ability of pumps to manage water, chemicals and slurry with precision becomes a decisive factor in overall productivity. In short, pump technology is no longer a background utility; it is a strategic enabler of modern mining efficiency.

CONCLUSION: PUMPS AS THE PULSE OF MODERN MINING

From the steam-driven pumps of the 19th century to today's advanced slurry, chemical and dewatering systems, pumps have shaped the evolution of mining as profoundly as any other technology. As the global mining sector accelerates toward $3.7 trillion in value, pump innovation will continue to underpin safety, efficiency and sustainability across every commodity and every continent.

For Mining & Quarry World readers, the message is clear: pumps are no longer peripheral – they are strategic assets. Their performance determines production continuity, environmental compliance and operational resilience. And as mines go deeper, ore becomes more complex, and water management grows more challenging, the importance of selecting the right pump – and maintaining it well – has never been greater.

THE WATER IMPERATIVE: RESILIENCE, RESPONSIBILITY AND INNOVATION IN UNDERGROUND MINING

Water scarcity has emerged as one of the most significant constraints on industrial development, reshaping how mines plan, operate, and invest. Underground mining – coal, metals, and industrial minerals alike – now functions within a global context where water availability influences economic output as profoundly as energy demand or commodity prices. Projections indicate that by 2050, global water consumption will have risen by more than half compared with levels at the turn of the millennium. As many as 3.9 billion people may be living in regions where water scarcity directly affects communities, agriculture, and industrial activity. Although mining represents a relatively modest share of global water withdrawals, its local footprint can be substantial, particularly in water stressed regions where underground operations must balance production demands with environmental responsibility and community expectations.

Across the industrial landscape, more than seventy percent of freshwater withdrawals and pollution originate from seven major sectors, mining among them. The geographical contrasts are striking. In the Middle East and North Africa, only a small fraction of available water is allocated to industry, while South Asia – despite facing severe water stress – directs nearly half of its water resources to industrial activity. Underground mines operating in such regions must navigate a complex interplay of regulatory pressure, hydrogeological constraints, and social licence, all while maintaining safe, productive working environments.

THE UNDERGROUND WATER CHALLENGE

Water management underground differs fundamentally from surface operations. Inflows from aquifers, faults, and old workings can introduce significant volumes of water into the mine environment, demanding continuous pumping, sump control, and engineered drainage systems. At the same time, core operational processes

depend on reliable water supplies: drilling, bolting, dust suppression, equipment cooling, and hydraulic systems all require water of consistent quality.

Longwall operations illustrate this dependency with particular clarity. Modern shields rely on high pressure emulsion systems, where water quality directly influences valve performance, corrosion rates, and hydraulic reliability. Dust suppression at the shearer and AFC requires steady water delivery to maintain visibility and reduce respirable dust exposure. In bord and pillar mines, drilling and bolting demand water for flushing and cooling, while dust control remains essential for both safety and compliance. Across all underground methods, water chemistry – hardness, dissolved solids, suspended particulates – can affect equipment life, maintenance schedules, and overall system efficiency.

HYDROGEOCHEMICAL IMPACTS AND WATER QUALITY RISKS

Mining's influence on water quality is often more significant than its volumetric consumption. Extractive processes can alter hydrogeochemical conditions, mobilising heavy metals and other contaminants that persist in the environment due to their non biodegradable nature. Acidic or saline mine drainage, if unmanaged, can introduce elevated concentrations of iron, manganese, sulphates, and trace metals into local watercourses. These contaminants degrade aquatic ecosystems, reduce water availability for agriculture and communities, and increase treatment costs for downstream users.

Effluent treatment has therefore become a core engineering responsibility. Modern underground mines increasingly rely on multi stage treatment systems – neutralisation, precipitation, filtration, membrane separation – to ensure that discharged or recycled water meets stringent quality standards. Heavy metal removal is particularly critical, as these elements accumulate in biological systems and can cause long term ecological harm.

THE ONE WATER FRAMEWORK IN MINING

Growing global concern over water availability has accelerated adoption of the One Water concept – a framework recognising that all water, whether surface, groundwater, recycled, or reclaimed, has inherent value and must be managed in an integrated, equitable, and sustainable manner. Underground operations are already reflecting this shift.

Closed loop water systems are becoming standard practice, reducing freshwater abstraction and minimising wastewater discharge. Mines are investing in improved process water recycling, higher grade treatment technologies, and advanced monitoring systems capable of tracking water quality and consumption in real time. These measures not only reduce environmental impact but also enhance operational resilience, particularly in regions where water supply is unpredictable or heavily regulated.

COAL PREPARATION AND MINERAL PROCESSING: THE HEART OF WATER RECOVERY

Coal preparation plants – and mineral processing facilities more broadly – play a central role in mine water management. Modern plants increasingly rely on thickener circuits, filter presses, and high efficiency clarifiers to recover water from slurry streams. By maximising water recovery from fines and tailings, processing plants reduce the volume of contaminated water requiring treatment and minimise the need for freshwater intake.

In some regions, mines now operate with water recycling rates exceeding ninety percent, demonstrating that high productivity processing can coexist with stringent water stewardship. These systems also reduce the footprint of tailings storage facilities, improve water balance stability, and strengthen compliance with environmental regulations.

ALTERNATIVE WATER SOURCES AND REGIONAL INTEGRATION

As water scarcity intensifies, alternative water sources are becoming essential components of mine water strategies. Treated municipal wastewater, desalinated water, and reclaimed industrial effluents increasingly supplement or replace traditional groundwater and surface supplies. For underground operations, integrating urban wastewater into process circuits – whether for dust suppression, drilling, hydraulic systems, or mineral processing – offers a practical route to reducing freshwater abstraction while contributing to regional water management objectives.

This integration provides dual benefits: it reduces pressure on natural water sources and helps prevent untreated urban wastewater from entering rivers and aquifers. Such approaches strengthen environmental performance and enhance social acceptance, demonstrating that mining can operate responsibly within water stressed regions.

ENGINEERING WATER STEWARDSHIP FOR THE FUTURE

The future of underground mining will depend on engineering solutions that treat water not as an expendable input but as a critical, finite resource. Mines that adopt integrated water management – combining hydrogeological modelling, advanced treatment technologies, closed loop recycling, and alternative water sourcing – will be better positioned to maintain productivity, meet regulatory expectations, and operate sustainably in increasingly constrained environments.

Water stewardship is now a core operational discipline, as essential to longwall performance, bord and pillar safety, and processing efficiency as ventilation, ground control, or power supply. In a world where water scarcity is reshaping industrial strategy, underground mining has both an obligation and an opportunity: to demonstrate that responsible resource extraction can coexist with sustainable water management, and to lead by example in regions where water is as valuable as the minerals extracted beneath them.