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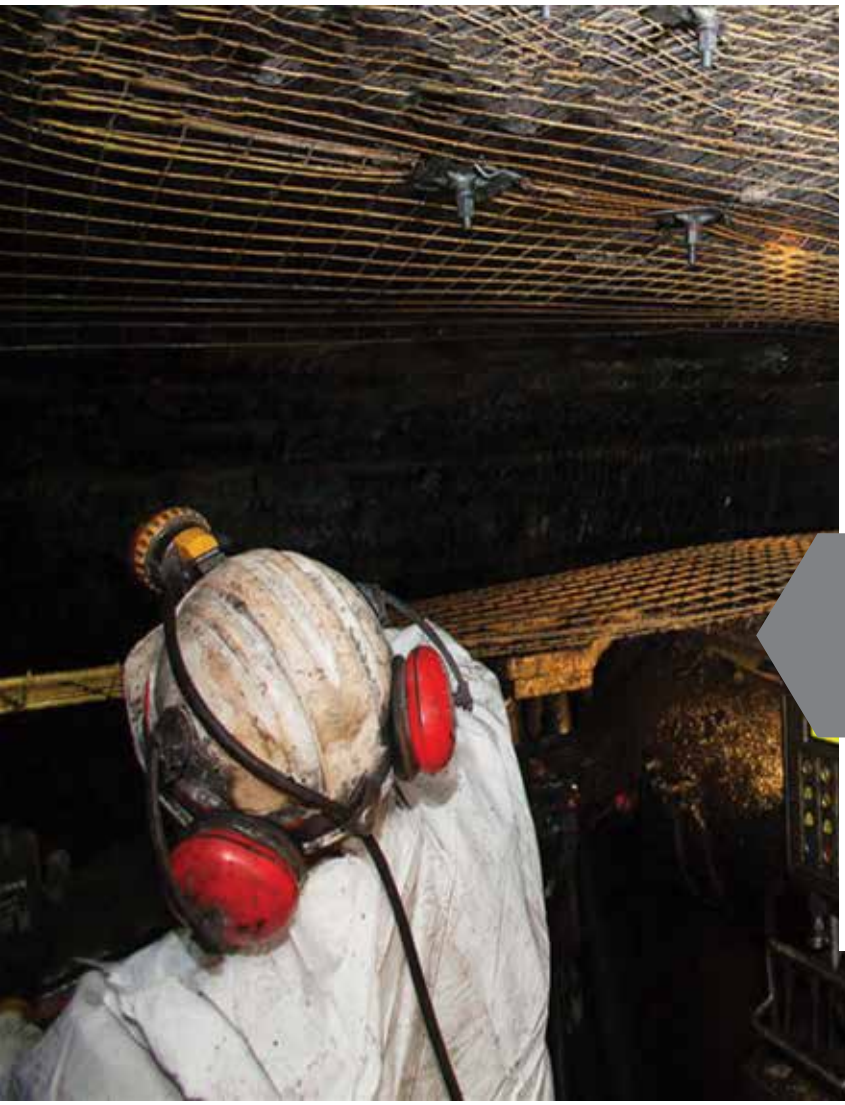

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Extending a helping hand – Dunlop conveyor belting launch new conveyor belt app

Netherlands-based Dunlop Conveyor Belting have become the first major conveyor belt manufacturer in the world to launch a unique App specifically designed to enable users to quickly and easily access technical guidance and calculation tools. Dunlop Belt Buddy enables the user to make a wide range of on-the-spot calculations including belt thickness and weight, roll size and belt length from a coiled roll, transition distance and convex curve layout and even motor power and capacity calculations. The App also contains full details of on the Dunlop product range as well as a huge library of reference documents such as technical bulletins and splice manuals.

Announcing the launch of Belt Buddy, sales & marketing director Andries Smilda declared “Dunlop Belt Buddy is a first for our industry and I am absolutely certain that it will prove to be a fantastic tool for our customers and future customers. We have always said that when you buy Dunlop you get a lot more than just top quality conveyor belts and the Belt Buddy App proves that to be 100% true”. “Providing the best and most honest technical support and guidance is part of our tradition. It always has been. Conveyor belt technology is surprisingly complex but most belt manufacturers and suppliers try to play that down so that they can focus on selling lots of belting at crazy low prices to often unsuspecting end-users”.

Dunlop’s head of application engineering, Rob van Oijen, shares Smilda’s obvious enthusiasm for Belt Buddy. “Conveyors rarely only operate 9 to 5 and a great many are literally in constant motion. One of the reasons why we have developed this App to allow our customers access to technical calculations and other crucial information regardless of the time of day or their location. The whole idea is to help them achieve the best performance and longest, most reliable working life from their conveyor belts. I think Belt Buddy will prove to be an invaluable tool to anyone who is involved with conveyors”.

Video library heavily pumped up

Customer training in Corona times? No difficult task for Tsurumi: on this website, the manufacturer has published numerous videos demonstrating the maintenance of dewatering and sewage pumps. They not only show how things are done technically, but also provide valuable insights into the design of the pumps.

Once again, the Japanese are breaking new ground in order to maintain their traditionally close contact with customers even during the crisis. After all, companies and construction sites do not stand still and the pumps have to run.

Especially when water with high solid content is pumped, components such as the impeller and the inlet opening are exposed to high mechanical stress. At some point, a replacement is simply due. To ensure that everything can continue running, it is best for the operator to help himself – instead of waiting for the technician from the dealer or the manufacturer.

In professional films, Tsurumi shows how to proceed. Some maintenance jobs are done in no time, others take a little longer. The running time of the films reflects this – they last from about one minute to over an hour. It is remarkable that Tsurumi shows in detail which steps are to be carried out and what tools are needed. No previous knowledge is required, the didactics are exemplary. The new video library at Tsurumi.eu is therefore a must for plant managers and pump operators. It supplements the operating handbook that comes with the pump. Various other videos are already being planned.

The manufacturer is testing even more ways to get closer to the customer: with training sessions that are broadcast live on the internet. They are interactive, so viewers can even ask questions simultaneously. Via Zoom, the stream can be accessed on any computer, tablet or mobile phone. Or simply viewed directly in the browser without any app. Tsurumi publishes the link to the next session on Facebook. Registration is not necessary.

RPMGlobal advances mine design process

RPMGlobal's Strategic Design Optimiser (SDO) for stope development and design will hit its first mine site in 2021 following an inaugural sale to a Canadian mine.

During RPMGlobal's extensive testing period, the company perfected SDO's ability to evaluate and analyse strategic scenarios for robust decision making in mining.

SDO features the industry standard mine shape optimiser (MSO), which generates first past development using RPM Global's development optimiser.

This eliminates the need to draw every part of the mine design, allowing end-users to perform strategic design work in one package.

Miners can use SDO to make small tweaks to designs in one area and have these changes apply to the rest of the design, a task that would take days to edit manually in conventional computer-aided design (CAD) based programs.

SDO combines parametric design principles with leading optimisation algorithms so miners can generate, change and update designs on the fly.

The SDO design tool emphasises visual results on plots, graphs and tables so users can interpret the best scenario quickly and with confidence and eliminate unviable scenarios early in the design process.

RPM Global chief executive officer Richard Mathews said the sale to a Canadian mining customer reflects its team's

dedication to bring SDO to the market through industry collaboration with its partners.

"It's very pleasing to see SDO gaining traction in the North American market and we are confident this sale will spur further interest in our leading strategic design packages heading into 2021," Mathews said.

"RPM remains committed to providing its customers with the most advanced mining technology solutions and our continued investment in the design and scheduling suite will help ensure mine planners continue to unlock new levels of capability.

"We are passionate about assisting the industry solve complex problems at every stage of the mining value chain and we are looking forward to helping many more operations deliver a fundamental step-change in the mine planning and design phase."

Delays in closing Colorado plants are costly in money and air quality

Under the Regional Haze provision of the federal Clean Air Act, states must submit a plan to reduce haze to the Environmental Protection Agency. This rule – aimed at limiting air pollution in national parks and wilderness areas – requires that Colorado submit its plans to the EPA by July 2021 and reduce pollution by 2028.

In November, the Colorado Air Quality Control Commission (AQCC) ruled that several coal and gas plants in the state must be retired no later than 31 Dec. 2028 – earlier than the initially planned date. These early retirements would significantly improve air quality and count as an essential move towards reducing Colorado's carbon pollution.

Based on EPA calculations, the impact of early retirement of the Tri-State Generation and Transmission Association's Craig Station Unit 3 in Moffat County, the Platte River Power Authority's Rawhide Energy Station north of Fort Collins, and Colorado Springs Utilities' Ray D. Nixon Power Plant could equal

taking 1.3 million cars off the road for an entire year in terms of carbon reduction.

If the Craig, Rawhide and Nixon units are retired early – following the precedent of coal-fired Hayden Generating Station's units 1 and 2, operated by Xcel Energy (which, as of Jan. 4, are on track to close ahead of schedule) – Coloradans could save about $68 million, and nitrous oxide, sulfur dioxide, and carbon could be reduced by 10,000, 12,000, and 19.4 million tons, respectively.

Colorado communities, public lands, and air, coal utilities successfully worked to contest it.

Recently, the AQCC voted to reverse its decision to retire the Craig, Rawhide and Nixon coal-plant units by 2028. As of now, all three plants are slated to close voluntarily by 2030.

In a state where air quality poses a significant health threat, it's time that heavily-polluting coal plants are retired. Further, utilities could save their customers $346 million by replacing these three coal plants with solar and $534 million by replacing them with wind energy by 2023, according to a 2019 report by Strategen Consulting for the Sierra Club, which opposed the AQCC's December reversal.

After a summer of record-breaking wildfires and orange-tinged skies, Coloradans understand the dire threat of air pollution and climate change.

Colorado can no longer lag in its efforts to move away from coal, and utilities only make the transition to clean energy proceed more slowly.

Within the next decade, policymakers and regulatory agencies must make crucial decisions to reduce climate change. No longer do we have the choice to remain idle and bow to the needs of industry.

South Africa's Standard Bank takes first step away

South Africa's Standard Bank will not fund any new coal-fired power plant projects, but will continue to provide finance to thermal coal mining projects and companies if they meet certain criteria.

Climate activists have been pressuring Standard Bank – Africa's largest bank by assets – to curb its lending to the coal, oil, and gas sectors, which together accounted for around 4% of its lending and commitments in December 2019.

Under a new fossil fuels financing policy, Standard Bank may only finance thermal coal mining projects that comply with international conventions on greenhouse gas emissions and the environment such as the Equator Principles. The bank justified its continuing financing of thermal coal extraction by saying most of Africa's electricity is still generated by burning coal.

"If we were to stop completely to fund any coal mining related activity, we could as well say we are stopping 80% of Africa's electricity generation and we do not think that would be a responsible thing to do," said Kenny Fihla, chief executive of Standard Bank Corporate and Investment Banking.

More than 80% of South Africa's power is generated by coal, and lenders have not kept pace with international peers on ending funding for thermal coal.

Standard Bank said it would not finance contractors or consultants to the thermal coal mining and coal-fired power generation sectors. But the bank will continue to finance new thermal coal mining projects and expansions, existing and new thermal coal mining companies, and existing coal-fired power generation utilities.

SCHADE Semi-Portal Reclaimers at new Samcheok Power Plant

By 2024, POSCO Energy of South Korea will have constructed a new coal-fired power station with two 1,050 MW generating units, in Samcheok in the north-east of the country. SCHADE Lagertechnik GmbH of Gelsenkirchen, Germany will supply four Semi-Portal Reclaimers to Doosan Engineering & Construction for the project.

SCHADE Semi-Portal Reclaimer during commissioning (example, photo SCHADE)

With this power plant project, "SC bluepower", POSCO Energy wants to set new standards in terms of impact on the environment. The emissions regulations of the South Korean government are very strict in comparison with most other countries of the world but this new plant, which will be built in a former limestone quarry, will be even more eco-friendly. In addition to other measures planned, dust emissions are to be reduced by almost 100%. A contributory factor will be the completely enclosed coal storage in which the SCHADE Semi-Portal Reclaimers will operate.

The four identical machines ordered have a reclaim capacity of 1,500 tph each, and their rail span is 57 m. The overall storage capacity at Samcheok is for 700,000 t of bituminous and sub-bituminous coals.

Supply of the SCHADE Semi-Portal Reclaimers will start in early 2021 and continue in successive stages until October. Installation is planned for 2022 and the test run for 2023. Before the Reclaimers are shipped to South Korea, Doosan Engineering & Construction will carry out extensive acceptance procedures at the SCHADE production facilities, including intensive tests on the machinery components.

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Poland's hard split

Coal-dependent EU member Poland aims to shut its last mine by the bloc's 2050 target, but experts warn the move to go green comes late and faces many hurdles.

Despite three decades of successful market reforms and strong growth since its transition from communism to democracy, Poland still relies on coal for around 80% of its power.

Its massive Belchatow brown coal-fired power station is the European Union's "single largest greenhouse gas emitter", according to the EU and several global environmental associations.

A relic of the communist era, Belchatow is fuelled by a vast nearby strip-mine and covers around 20% of Poland's energy needs.

Poland should have started weaning itself off coal decades ago to meet EU net-zero emissions targets, according to Professor Piotr Skubala, from the Silesian University in the heart of the southern coal region.

Coal mines still provide more than 80,000 heavily subsidised and politicised jobs and fuel a string of large state-owned utilities.

Polish emissions have remained high in recent years as the right-wing Law and Justice (PiS) government focused on coal.

But high mining costs and EU carbon taxes have made coal-based energy uncompetitive, forcing a rethink in Warsaw.

According to Grzegorz Wisniewski, head of the country's leading renewable energy think-tank IEO, Poland has around double the average energy costs – some 50 euros ($61) per megawatt hour – compared to the rest of the EU.

"Each year Poland remains dependent on coal will drive up energy costs dramatically," he told AFP.

Green Deal

Funds from the EU's Green Deal energy package are crucial to helping Poland achieve carbon neutrality, Climate Minister Michal Kurtyka says.

Various estimates peg the cost of going green at 700-900 bn euros ($855-1100 bn).

Access to EU funds was in jeopardy until recently as Poland and Hungary blocked Europe's budget and coronavirus recovery package over a move by Brussels to link funds to respect for the rule of law.

A compromise struck earlier this month unblocked the funds, freeing up to 56 bn euros for Poland's green transition between 2021-27.

An economist who chaired the COP24 climate summit in 2018, Kurtyka is optimistic that Poland's green energy sector – which now covers about 16% of its needs – can grow rapidly in the next 20 years to create 300,000 new jobs, replacing ones linked to coal.

"Nobody will be left behind," Kurtyka told AFP in a recent interview.

Solar boom

Some first steps are already being taken.

Poland announced last week that its first state-backed electric car plant will begin production by 2024, creating up to 15,000 jobs in coal-dependent Silesia.

Four state-owned energy companies including PGE – which runs Belchatow – Energa, Enea and Tauron Polska are backing the new plant via their ElectroMobility Poland venture, as part of the transition away from fossil fuels.

Poland's Belchatow brown coal-fired power station is the European Union's single largest greenhouse gas emitter, according to the EU

Ranked as Poland's largest utility, PGE has committed to 100% renewable energy by 2050 with a focus on wind energy, among others.

According to Kurtyka, launching its first atomic energy plant by 2033 is also part of Poland's green agenda, although experts like Wisniewski argue that the nuclear option will be too expensive to implement.

On the other hand, a government programme offering subsidies to equip households with solar panels has proven highly successful.

The "My energy" programme saw Poland nearly double solar power capacity this year to a total of 300,000 rooftop installations intended to also feed local grids.

"We aim to have one million by 2030," Kurtyka said, insisting that new networks of local energy grids will help dismantle the highly centralised communist-era system rooted in coal.

China Datang nears deal for Indonesian power projects

China Datang Corp. has bought a majority stake in PT Dian Swastatika Sentosa's thermal power plants in Indonesia for $394m.

The state-backed energy giant acquired a 75% stake in a DSS's subsidiary that operates the plants, according to an exchange filing recently, which confirmed an earlier report. DSS will remain as a minority shareholder for the assets.

The transaction will support DSS to further develop its power generation business and diversify its portfolio, the company said in the statement. Shares of DSS rose as much as 5.2% recently in Jakarta.

Headquartered in Central Jakarta, DSS was listed on the country's stock exchange in 2009. In addition to the three independent thermal power plants, it also directly operates four captive power plants with a total capacity of about 300 megawatts, according to its website. The company is also involved in coal mining and trading as well as fertilizer and chemical trading.

TNB says power plant revenue will not exceed 20% by 2030 on cleaner-energy transition

Tenaga Nasional Bhd (TNB) said its major coal-fired power plants' power purchase agreements are expiring "with no like-to-like replacement" and that the government-controlled utility's coal-fired power plant revenue contribution will not exceed 20% of total group revenue by 2030 in line with the company's transition to cleaner and sustainable energy.

TNB said in its latest investor presentation dated Dec 8, 2020 that its Jimah East electricity-generation facility, which was commissioned in 2019, was the last new coal-fired power plant for the group because TNB had pledged not to invest anymore in greenfield coal-fired power plants.

For the financial year ending Dec 31, 2020 (FY20), TNB said coal-fired power plant revenue contribution is expected to account for 20.7% of total group revenue.

FY21 and FY22 coal-fired power plant revenue contributions are seen at 22.1% and 21.9% respectively, according to TNB.For FY23 and FY24, coal-fired power plant revenues are anticipated to constitute 21.2% and 20% respectively of TNB's total group revenues, the company said.

TNB said that for FY25, coal-fired power plant revenue contribution is seen at 19.5%.

For the third quarter ended Sept 30, 2020 (3QFY20), TNB's net profit fell to RM1.01 billion from RM1.2 billion a year earlier while revenue dropped to RM11.11 billion from RM12.64 billion.

Cumulative net profit for the nine months ended Sept 30, 2020 (9MFY20) declined to RM2.38 billion from RM3.88 billion a year earlier while revenue was lower at RM33.65 billion versus RM38.76 billion, TNB said in its Bursa Malaysia filing on Nov 26, 2020.

Meanwhile, online reports indicate that the Jimah East power project is a 2,000MW coal-fired electricity-generation plant in Port Dickson, Negeri Sembilan.

It was reported that the Jimah East power project, comprising two coal-fired entities of 1,000MW each, is owned and run by Jimah East Power Sdn Bhd (JEP), which is a 70%-owned subsidiary of TNB.

It was reported that Mitsui & Co Ltd and The Chugoku Electric Power Co Inc hold a 15% stake each in JEP.

TNB's share price rose six senor 0.57% to 4.04pm to RM10.66 after some eight million shares were traded.

Designing for Safety: a new approach to belt conveyors

Conveyors are among the most dynamic and potentially dangerous areas of equipment at a mine or material processing site. Even though their safety and performance are critical to the operation's success, the impact of their contribution to overall efficiency is often unrecognized by management and workers alike. Operational basics of belt conveyor systems are too often a mystery to those employees, who have little understanding about the hardware installed and the performance required from the components.

The knowledge gap is understandable. The attention of personnel at a mine or coal handling operation is centered on the processing of the company's main product. The "care and feeding" of belt conveyors – that is, the adjustment, maintenance and troubleshooting that make a huge difference in safety, performance and profitability – is typically outside of their expertise. It's not that they don't care about conveyors, but the ongoing maintenance and service of these systems is often not part of their immediate focus or within their time constraints.

In addition, there is often a failure of the retiring workforce to pass along the wisdom they've gained over the years. Further, some industry experts have discussed the "missing generation" in mining-related jobs, exacerbating that knowledge gap. Although mining engineering seems to be regaining its "cool" in recent years, there still appears to be a general shortage of people in the 25-45 age range.

PROTECTING THE MOST VALUABLE ASSETS

"Personnel are the single most important resource of any mine or industrial operation, and engineers and designers are incorporating greater functionality into designs that will improve safety," observed Martin Engineering Chief Technology Officer Paul Harrison. "Standards continue to tighten, and MSHA retains a strong focus on worker safety, driving the need for equipment designs that are not just safe, but optimized for safety – that is, designed with safety as a fundamental priority. At the same time, there is increasing pressure for continuous and ever-increasing production."

To meet the demands for greater safety *and* improved production, some manufacturers have introduced equipment designs that are not only engineered for safer operation and servicing, but also reduced maintenance time. One example is a new family of heavy-duty conveyor belt cleaners, designed so the blade cartridge can be pulled away from the belt for safe access and replaced by a single worker.

The same slide-out technology has been applied to impact cradle designs. The systems are engineered so operators can work on the equipment safely, without breaking the plane of motion. "External servicing reduces confined space entry and eliminates reach-in maintenance, while facilitating faster replacement. The result is greater safety and efficiency, with less downtime," said Harrison.

Another example is a revolutionary new belt cleaner design that can reduce the need for bulky urethane blades altogether, an innovative belt cleaning system that has

received the Australian Bulk Handling Award in the “Innovative Technology” category for its design and potential benefits. The patented design delivers extended service life, low belt wear, significantly reduced maintenance and improved safety, ultimately delivering lower cost of ownership.

“Unlike conventional belt cleaners that are mounted at an angle to the belt, this unique cleaner is installed diagonally across the discharge pulley, forming a three-dimensional curve beneath the discharge area that conforms to the pulley’s shape,” explained Conveyor Products Manager Dave Mueller. “The design incorporates a matrix of tungsten carbide scrapers and is tensioned lightly against the belt to prevent damage to the belt or splices.”

Despite extremely low contact pressure between belt and cleaner, it has been shown to remove as much as 95% of potential carryback material. The novel approach has been so effective that in many operations, previously crucial secondary belt cleaners have become unnecessary, saving further on belt cleaning costs and service time.

POWER

Another trend in large operations is a need for enhanced automation and monitoring, including such tasks as load sensing, belt tracking, cleaner tensioning and lighting. “In most cases, electrical power is supplied only to the conveyor locations where it’s needed, such as the drive motor, and is not typically available for general purpose use,” Harrison continued. “In many operations, this lack of available power means that any monitoring of the conveyor must be done by technicians physically walking the length of the structure, which can be a difficult and time-consuming task when the systems are long and span difficult terrain.”

A more efficient approach is to employ sensors to transmit important data from remote points to a central location where it can be monitored in real time and recorded for later analysis. But intelligent monitoring systems for any conveyor system require power for extended operation. Due to the distances involved, cabled communication systems are not ideal, and therefore wireless communication systems are more advantageous. Options such as solar are not well

suited to the general conditions of a conveyor system, as monitoring devices are often required in an enclosed structure without access to sunlight, or for continuous operation during both day and night.

A conveyor is driven by a multi-kilowatt motor, and this power is readily available system-wide in

This slide-out belt cleaner is engineered to be accessed safely and replaced by a single worker.

The track-mounted systems can be serviced quickly and safely, with no reach-in maintenance.

The unique belt cleaner forms a 3-D curve beneath the discharge that conforms to the pulley’s shape.

The generator can be employed on virtually any steel roller.

the form of the moving belt. The motors driving the belts are typically sized with a considerable power safety factor to account for parasitic loads, such as rolls with damaged bearings, tracking devices (which may work almost continuously), sealing systems, belt cleaners and material changes due to different moisture levels and variable loads. For these reasons, engineers have searched for ways to take advantage of the available kinetic energy of the moving belt to bring power to the specific places where sensors and other devices would provide advantages.

In most conveyor designs, the belt runs on a set of rollers that provide support and guide the belt. The typical conveyor roller is a very reliable device, with key components such as bearings, seals and the "steel can" all well understood in the industry. Product designers theorized that they could draw power from a moving belt by attaching an independent generator directly to one of the rollers. In this way, they felt that power could be drawn from the conveyor without altering the structure of the system or affecting its physical configuration.

"Being able to add a generator to a roller delivers the benefit of utilizing the proven reliability of existing roller designs, while drawing power from the belt for a wide variety of electronic devices," said Mueller. The goal was to engineer a device with the versatility to retrofit existing idler designs, so operators would not be required to maintain a special stock of conveyor rollers, as the generator could be employed on virtually any steel roller.

Product engineers developed a design to accomplish this through the use of a magnetic coupling that attaches to the end of an existing roller. "The outside diameter of the generator matches the diameter of the roll, but places the generator outside the normal belt line to avoid the heavy loads and fugitive material that tends to damage existing design attempts," Mueller added. "The generator is held in a fixed position by the roll support system, but is not normally required to bear any of the material load."

The reliable power supply helps bring a new level of sophistication to conveyors, allowing designers to equip their systems with devices such as weigh scales, proximity switches, moisture sensors, pressure switches, solenoids and relays, as well as timers, lights and even additional safety mechanisms. Wireless communication can be used to transmit directly to a central controller, giving operators a cost-effective way to access data that has not been readily available in the past – and taking another step toward "smarter" conveyor systems.

In a related move toward safer, more productive material handling, one global conveyor technology innovator has introduced an automated pneumatic tensioning system for belt cleaners. The new device delivers precise monitoring and tensioning throughout all stages of blade life, minimizing the labor typically required to maintain optimum blade pressure and extending the service life of both the belt and the cleaner. Equipped with sensors to confirm that the belt is loaded and running, the system automatically backs the blade away during stoppages or when the conveyor is running empty, minimizing unnecessary wear to both the belt and cleaner. The result is consistently correct blade tension, with reduced power demand on start-up, all managed without human intervention.

CONTINUOUS IMPROVEMENT

With a properly trained staff and thoughtfully designed components, conveyor maintenance is becoming easier and safer than ever before. Thanks to new component designs and advanced engineering capabilities, the work environment has been drastically improved in recent years, and operators are reducing downtime due to cleanup and broken equipment. These gains should inspire operators to make time for a cost/benefit analysis of new technologies and assess the long-term gains of both increased efficiency and workplace safety.

"Managers concerned with the overall safety and cost of operation need to go through the numbers to see how the impact of rising labor costs for cleanup and maintenance, combined with the expense of potential fines or forced downtime, can affect the bottom line," Harrison concluded. Using new and emerging technologies like the ones described here, even poorly-performing conveyors often don't need to be replaced or rebuilt, but merely modified and reconfigured by knowledgeable and experienced technicians installing modern equipment. These improvements will help operations improve efficiency, reduce risk and contribute to regulatory compliance.

Winter coal shortages reveal Chinese energy vulnerabilities

Amid the coldest winter recorded since 1966, provinces across the People's Republic of China (PRC) struggled with the worst electrical blackouts seen in nearly a decade.

More than a dozen cities across Zhejiang, Hunan, Jiangxi, Shaanxi, Inner Mongolia, and Guangdong provinces-imposed limits on off-peak electricity usage in early December, affecting city infrastructure and factory production. Analysts expect power shortages to persist through at least mid-February *(SCMP, December 23, 2020)*.

Officials have repeatedly assured the public that residential heating would not be affected, and that China's electrical supply remained "stable" and "sufficient," even as energy spot prices continued to rise into the new year.

In one concerning sign, coal power plants outside of Beijing restarted production at the end of the year to supply the city's increased winter heating demands after being put into reserve in 2017. China's capital had previously been "coal-free" for three years.

During an executive meeting of the State Council on January 8, Chinese Vice Premier Li Keqiang signalled the central government's prioritization of energy security, declaring, "we must give priority to ensuring the people's safety and warmth through the winter, and intensify efforts to ensure energy security and stability" *(State Council, January 9)*.

The proximate causes for China's electricity shortages differed across provinces. Overall, coal production stoppages and reduced imports combined with higher-than-usual industrial production and seasonal heating needs contributed to restrict the domestic coal supply and send prices skyrocketing. Coal usually fuels more than half of China's electricity production; this winter, China's coal shortages have put increased pressure on its oil and natural gas supplies as well.

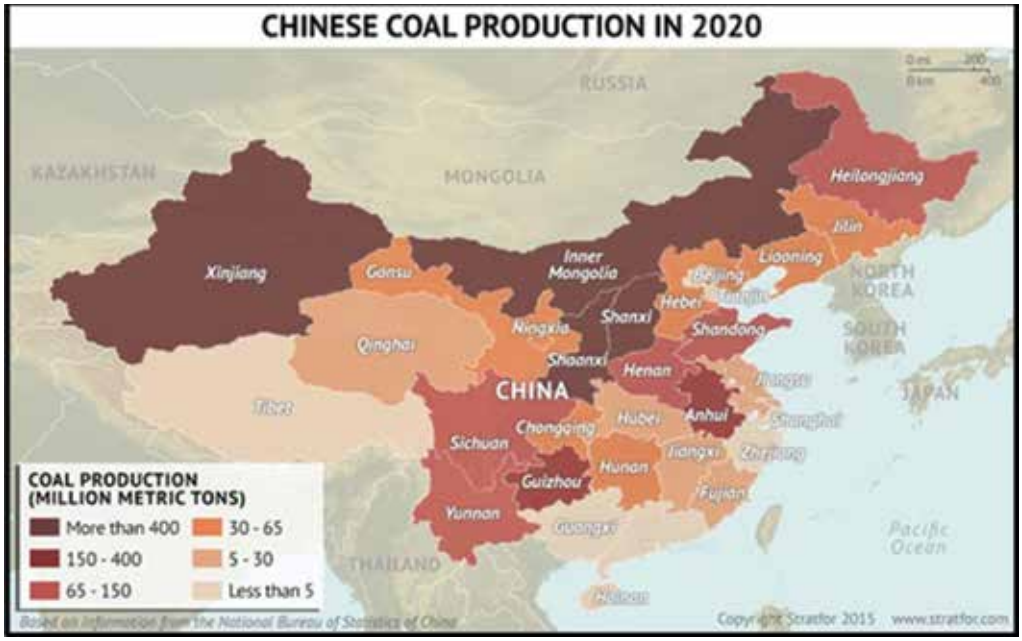
A lack of adequate national gas storage facilities has failed to keep up with demand even as an increasing number of users are planned to transfer their heating needs from coal to gas to meet decarbonization goals set under the 13th Five Year Plan (2016-2020).

In summary, a combination of factors has contributed to stretch China's energy supply this winter, resulting in historic power shortages causing widespread concern. This has come just as the country has tried to establish itself as a "self-reliant" global powerhouse and undermined its narrative of successfully recovering from the ongoing COVID-19 pandemic.

A VARIETY OF CAUSES

Higher Industrial Output, Seasonal Heating, and Equipment Failures

In November, China reported a startlingly high export growth of 21% compared to the previous year, capping off six months of continuous export growth as domestic industrial production benefited from coronavirus lockdowns elsewhere in the world *(SCMP, December 7, 2020)*. The



The map shows relative densities of coal production across China's provinces, based on extrapolation from 2015 data (Image source: Stratfor).

industry group China Electricity Council (CEC) predicted that China's total electricity consumption would increase by 2-3% in 2020 even after accounting for the impact of shutdowns earlier in the year.

This growth demonstrates the remarkable energy requirements necessitated by Chinese economy recovery from COVID-19, which has been spurred by government investments in so-called "new infrastructure" and industry. International energy analysts have observed that the recovery so far has been more "brown" than "green" and could set back national goals for becoming a carbon-neutral state by 2060.

The early onset of an unusually cold winter also contributed to boost energy consumption at the end of the year, with the energy consulting group Wood Mackenzie estimating that China's demand for thermal coal was 12% higher year-on-year in December. Throughout December, representatives from the National Development and Reform Commission (NDRC) repeatedly attributed the winter surge in electricity demand to the severe cold weather and high industrial growth.

Power shortages in southern provinces such as Hunan and Jiangxi followed record high year-on-year monthly industrial output increases of 7.4 and 7.9%, respectively, which overloaded local grid capacities. In Hunan, supply was also constricted by the recent shut down of two coal power plants which suffered equipment failures.

Production by hydropower plants was impacted by summer flooding and winter icing, further restricting the province's electricity supply. In Guangdong province, equipment failures at local power plants reportedly affected electricity and water supplies, forcing factories in major industrial cities such as Shenzhen, Zhuhai, and Dongguan to scale back production.

In Zhejiang province, power rationing in early December was imposed due to artificial constraints. Multiple city governments instructed public departments to limit electricity use to meet annual carbon emissions targets aimed at limiting energy use and improving energy efficiency. Following rebuke from the central government, provincial authorities walked back restrictions on power usage. A spokesperson from the NDRC took pains to underscore the correction, saying, "There is no shortage of power supply in Zhejiang".

Mining Production Shortages and Systemic National Supply Problems

Although China has announced ambitious goals to become a carbon-neutral country by 2060, it currently relies on coal for most of its energy consumption *(China Power, August 26, 2020)*. A renewed focus on the need to ensure energy security amid increasing global tensions (most notably with Australia) will likely also drive China to increase its reliance on coal in the near term.

Domestic coal mines had their operations impacted by the pandemic and were ill-equipped to deal with the surge in energy demand. Chinese media reported that some mines hit their annual production caps by the end of October, even as demand for coal continued to rise. Following a series of high-profile mining accidents and anti-corruption probes, national authorities moved to tighten scrutiny over local mining operations and slowed down production. After the NDRC's intervention to lift national targets for coal production in December, daily output of coal reportedly rose by 16% over the year's average production levels *(SCMP, January 5*).

While China's coal industry typically suffers from an overcapacity problem, its eastern and southern industrial base is comparatively undersupplied. The major coal-producing western provinces of Shanxi, Shaanxi, and Inner Mongolia should have been able to produce enough to avoid power shortages nationwide. But the afore-mentioned supply shortages this year were compounded by China's underdeveloped national electricity transmission systems.

IMPACT OF AUSTRALIAN COAL BANS

In November, China reportedly banned Australian coal imports after months of informal import quota restrictions, affecting more than $540 million in coal shipments stuck off the coast of China since October. While foreign media reports have frequently tied China's ban on Australian coal

to ongoing bilateral tensions, Bloomberg has reported that China's restrictions on coal imports could also have been due to domestic lobbying.

Officials from less developed western provinces such as Shanxi, Shaanxi, Inner Mongolia, and Xinjiang have long argued that China's domestic coal industry plays a "foundational role" in building energy security and stabilizing power supplies. Their views have gained support as China has grown increasingly isolated this past year.

In combination with continuing coal export restrictions from Mongolia due to Covid-19, the Australian ban caused Chinese coal imports to fall by almost 50% in November, representing a seven-month decline. Chinese officials have repeatedly denied the impact of the Australian bans on the winter power outages, and analysts have observed that Australian coal in previous years made up less than 7% of China's domestic coal supply – and so should have little bearing on the current shortages. But it is difficult to believe that there is no connection between the two.

CONCLUSION

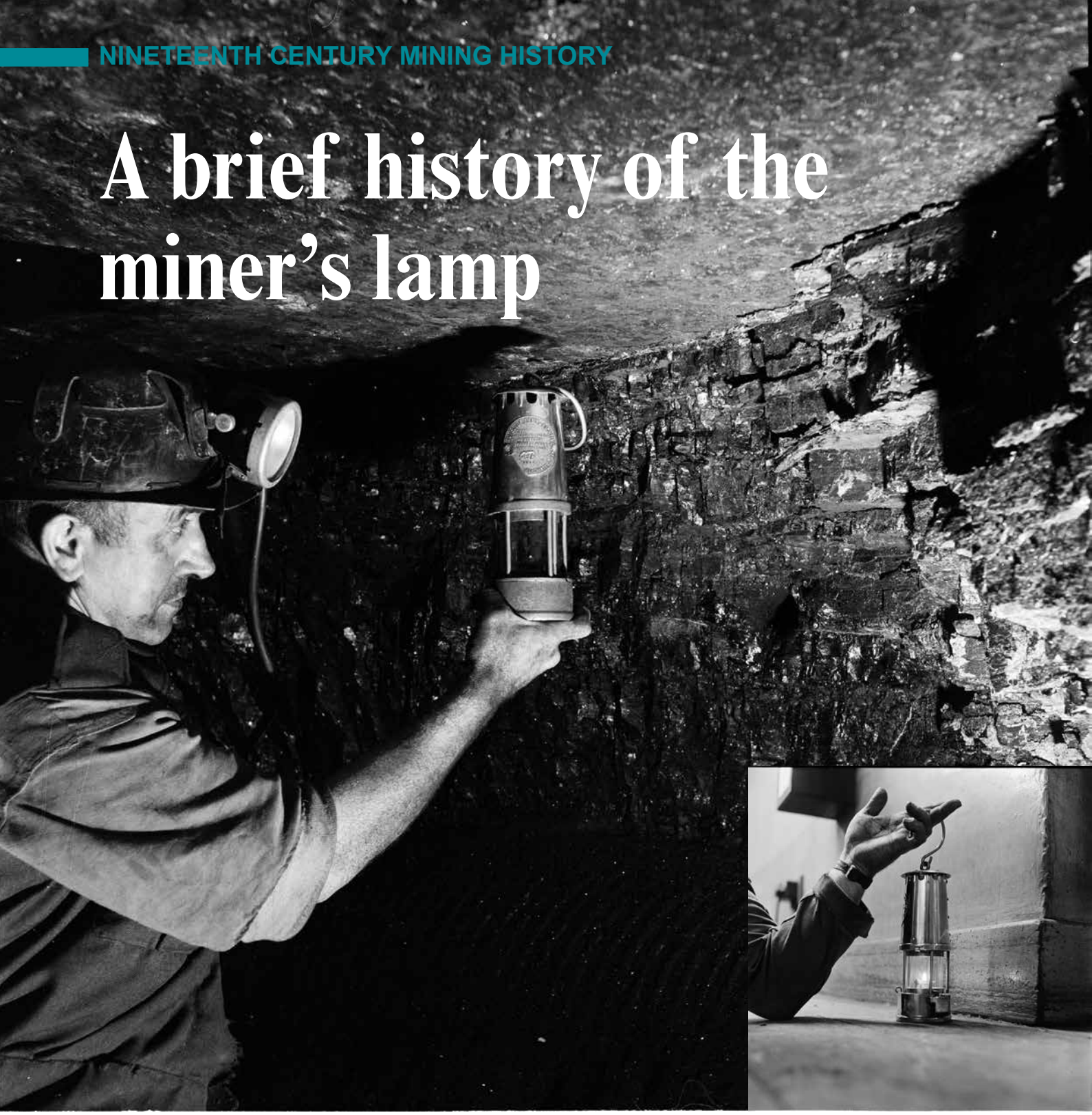
A white paper titled "Energy in China's New Era" published on December 21 underscored China's continued prioritization of "developing high-quality energy in the new era" and deepening the green reform of China's energy system *(SCIO, December 21, 2020)*. But even as the central government has moved forward with the February launch of a long-awaited emissions trading scheme (ETS) to curb carbon production, it is still grappling with the basic tasks of ensuring energy security *(SP Global, January 6)* and keeping spot prices for coal, oil, and gas down.

In response to the December power shortages, the NDRC increased coal and gas production quotas, while the NEA ordered state power grids to optimize operating procedures and increase supply. The NDRC also reportedly gave power plants approval to import coal "without clearance restrictions in mid-December in an apparent bid to stabilize prices.

Given that China's power consumption growth is expected to hit a three-year high in 2021, China's leadership will struggle to prioritize the stabilization of electricity supplies for industrial production and heating amid an unusually severe winter, and its efforts are likely to come into direct conflict with competing political priorities to reduce foreign energy dependence while simultaneously achieving ambitious decarbonization goals.

Elizabeth Chen is the editor of *China Brief*

A brief history of the miner's lamp



Coal miners were frequently at danger from explosive mixtures of methane gas in the atmosphere of the mine. At the beginning of the nineteenth century, pressure mounted to find an alternative to naked flames that would provide adequate and safe light to enable miners to work underground. In the end, two of the period's finest minds raced to produce the first safe lamp for the mining industry.

The Davy Lamp

Sir Humphry Davy successfully tested his prototype safe lamp at Hebburn colliery, Tyne and Wear, in early January 1816. Davy found that flame could not pass through the small apertures in fine gauze meaning the flame inside the gauze would not ignite the gas in the atmosphere outside the lamp. Davy was one of the most celebrated scientists of his day and his discovery, based on scientific principles, became the foundation for most flame-safety lamps that followed.

The Stephenson Lamp

At the same time that Davy was working on a design, George Stephenson had been creating his own lamp based on mechanical principles. While Stephenson later became well known for his work with locomotives, at the time he was an engineer and engine wright from High Pit, Killingworth in Northumberland. His lamp used fine tubes and an internal glass to separate the flame and the atmosphere, and was frequently championed by miners from the North-East.

The Clanny Lamp

A long-term worker in this field, the doctor William Reid Clanny, continued to refine his ideas on lamps after both Davy and Stephenson had moved on to other work. The culmination of his research was the invention, in 1839, of the lamp that now bears his name. The gauze around the flame was replaced with glass, both increasing the amount of light and shielding the flame.

The Mueseler Lamp

A significant lamp emerged from Europe soon after the Clanny lamp was introduced. The Mueseler lamp was designed by a Belgian engineer, Mathieu Louis Mueseler, in 1840. The lamp was similar to Clanny's but, by adding a conical internal chimney to aid the air flow within the lamp, Mueseler reduced the tendency for the internal glass to become sooty and so gave a clearer light.

The Marsaut Lamp

In 1882 Jean Marsaut, a French mining engineer, adapted a Mueseler lamp by replacing the internal chimney with a second conical gauze and added a full bonnet to protect the gauze. The lamp was highly praised and many manufacturers went on to produce their own variations on what became the blueprint for the modern mining lamp.

The Clowes Hydrogen Lamp

Soon after the introduction of the safety lamp underground, miners noticed that its flame changed if there were gases in the atmosphere. In the late-nineteenth century, lamp makers began to develop dedicated gas-testing lamps, such as the Clowes Hydrogen lamp, that would give more sensitive readings of methane levels.

High Candle Power Lamp

In the 1890s electric hand lamps were being developed and by the 1920s, the electric cap-lamp began to take over as the miner's main light source. To compete with the strong light produced by the new electric lamps, makers started to produce high-candle-power lamps. These were larger lamps, often with elaborate bonnets, that produced considerably more light.

The Flame-Safety Lamp

As electric lamps became the standard lighting equipment, flame-safety lamps were still used to test for gas. Deputies were required by law to carry a flame-safety lamp and an electric safety lamp during their pre-shift checks.

Garforth Lamps

The final development in flame-safety lamps came when Protector and Wolf, the last major flame-safety-lamp manufacturers, produced their Garforth lamps. The Wolf FG and the Protector GR6S were the result of many years of lamp development and research. By the 1990s, Protector had become the main supplier to the British coal-mining industry.

This article was first published on www.museumcrush.org.uk

Further details about exhibitions and events please contact **Mark Carlyle:** Curator of the National Coal Mining Museum (mark.carlyle@ncm.org.uk)

A new gallery looking at Davy and the development of the miners' lamp opened at the Museum in 2020.

Mining equipment technical condition monitoring

The Earth, being the main object and operational basis for mining, is exposed to the greatest impact because of extracting minerals. Protection of elements of the biosphere, including subsoil, should provide for the provision of scientifically based and economically justified completeness and complexity of use. The article discusses the need to monitor the technical condition of mining equipment, as applied to assessing its technical condition and reducing energy consumption by this equipment. The dependence of energy consumption on vibration parameters and temperature of equipment surfaces is shown. The data of the results of vibration parameters monitoring are given. Criteria are given for estimating the energy efficiency of operation of process equipment and, accordingly, the influence of these parameters on the environment.

INTRODUCTION

Ensuring safety at mining facilities is understood as a single system consisting of industrial safety, labour protection and environmental safety, one of the main tasks is the organization of an effective system for monitoring technological processes to ensure trouble-free operation of process equipment[1]. In the conditions of mining production, an objective and rapid assessment of the degree of ecological danger of a particular technological or organizational decision, the enterprise as a whole, is an urgent necessity[2]. Such an assessment is made possible by the results of a comprehensive diagnostic monitoring of machines and individual units of mining equipment using non-destructive testing methods[6-10].

MATERIALS AND METHODS

From all the variety of methods of non-destructive testing, to assess the technical condition of the equipment and its impact on the environment, Vibro-diagnostic's, thermal control and analysis of the parameters of lubricants, including Spectro-emission analysis of oils, were selected. Vibro-diagnostics quite fully characterizes the technical state of the object and the dissipation of energy. In **Figure 1**. Spectra are presented for the same drive point of the belt conveyor, before and after a certain operating time.

Spectrum 1 (see **Figure 1**) characterises the unbalance of the primary drive shaft. This defect refers to zone C (a limited operational state) according to[3]. At the same time, no operational intervention was required in the drive. Spectrum 2, when the drive is used, 10770 hours does not come out of the criteria for zone C, but characterizes, in addition to imbalance, another defect called the "shaft battle". The defect of the shaft battle most often characterizes the incompatibility of the shafts caused by the defects of the coupling, or which is much less often, defects in the shaft – wear, bending, cracking. A similar spectral pattern can be caused by a weakening of the attachment of the unit to the foundation. On this drive, as a result of visual and measurement control after the stop, it was revealed that

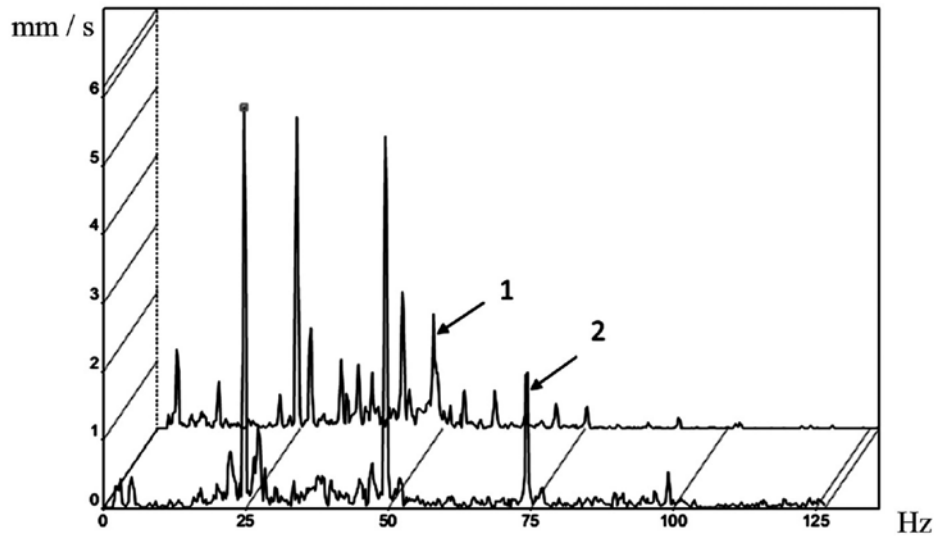


Figure 1: Comparison of vibration spectra for the drive of a conveyor belt: 1 - date of measurement on May 14, 2014; 2 - date of measurement 10/10/2015.

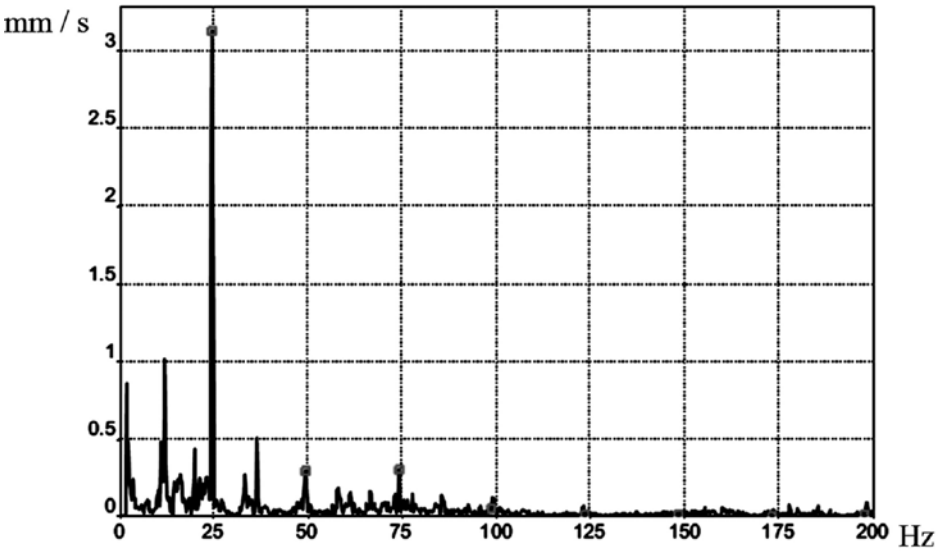


Figure 2: Spectrum vibro-diagnostics drive after the Maintenance.

the reactive traction of the drive was fixed to the foundation, which was caused by the previously revealed imbalance. The vibrational signal taken from the gears fixed on the reactive thrust (without the capital base) is usually of a complex nature, it usually contains oscillations over a wide range of frequencies: vibration with excitation frequency, its harmonics and possibly subharmonics, and sometimes other frequency components[4]. However, in the present work, we are not interested in the actual defect itself, but in its influence on energy consumption and damage to the environment. These electric drives use electric motors "Morley" GM66 400/800: rated power, 500 kW; voltage, 1.14 kV; nominal power factor, cosφ = 0.87; speed, 1493 rpm. The vibration spectrum after maintenance is shown in **Figure 2**. At the same time, the overall level of vibration decreased three-fold, although some imbalance remained.

RESULTS AND DISCUSSION

To estimate the energy consumption of the drive motor, the power (kW) was calculated, before and after the maintenance of the drive:

Formula 1

$P1 = 1.73 \cdot U \cdot I1 \cdot \cos\varphi$, kW (1) $P2 = 1.73 \cdot U \cdot I2 \cdot \cos\varphi$, kW

Formula 2

$P2 = 1.73 \cdot U \cdot I2 \cdot \cos\varphi$, kW

Where:

$P1$, $I1$ – power (kW) and current (A) of the electric motor corresponding to the state of the battle of the shaft, before the maintenance;

$P2$, $I2$ – power (kW) and current (A), electric motor corresponding to the combat state after maintenance; cosφ – the nominal value of the motor power factor; U – rated mains voltage (kV).

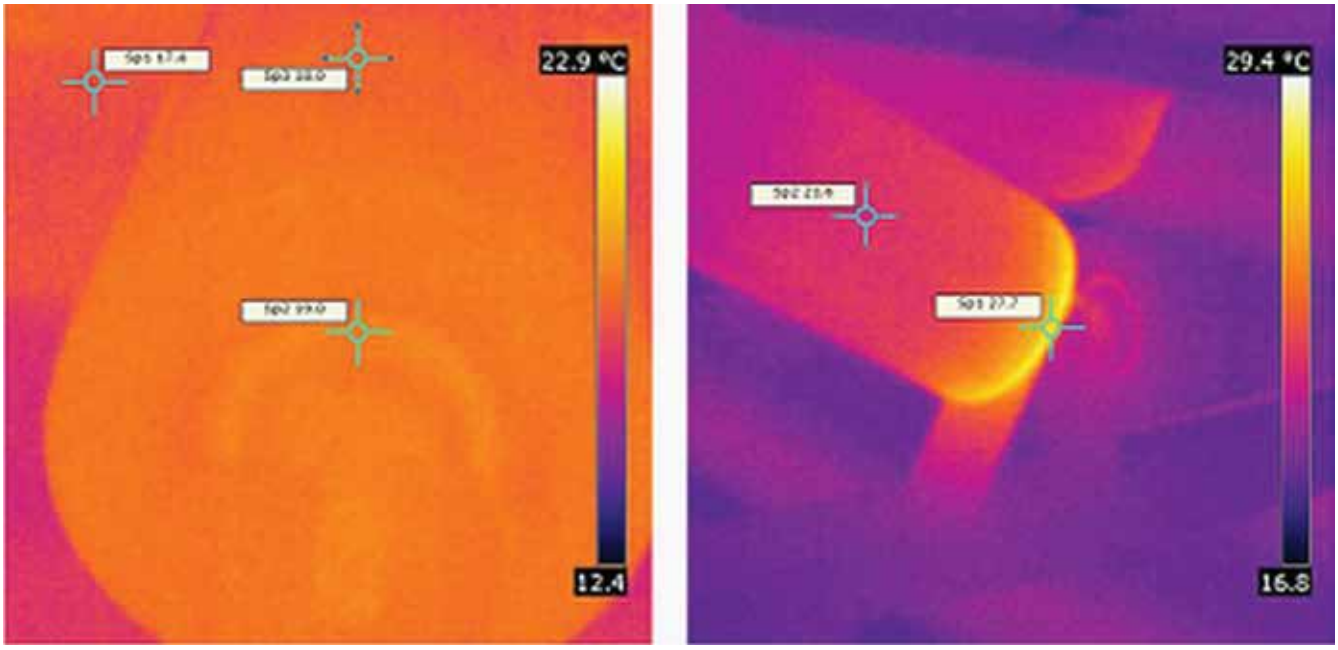
Formula 3

$P1 = 1.73 \cdot 1.14 \cdot 198.00 \cdot 0.87 = 340.1$ kW

Formula 4

$P2 = 1.73 \cdot 1.14 \cdot 183.70 \cdot 0.87 = 315.6$ kW

To determine the currents, the data of the work of the conveyor drive motors received from the ACS 800 frequency inverters over a period of one shift (mean current per shift, with the same torque and speed assignments) was used. Electricity losses (kW · h), caused by the weakening of the reactive traction of the drive, are determined by the formula:



a **b**

Figure 3: The thermograms working rollers: a) defect-free; b) – with slight defect.

Formula 5
$\Delta W = (P2 - P1) \cdot n$, kW · h

Where:
n – is the number of operating hours of the drive per month, hour.

Formula 6
$\Delta W = (340.1 - 315.6) \cdot 630 = 15\,430$ kW · h

To compensate for the additional energy consumption, only one engine will have to burn about 6 tons of coal per month. This results in emissions of over 21 tons of carbon dioxide into the atmosphere. This approximate calculation does not take into account the additional costs of transporting additional coal to power plants. In addition to vibration diagnostics, the possibility of thermal monitoring can be used to estimate energy losses, and, accordingly, the environmental load on the environment.

The thermal control of roller bearings and other conveyor elements with the help of infrared thermography allows more accurate installation of defective components. For example, to detect local overheating of one bearing, malfunction of the cooling system, defects in the lubrication system. The power used to overcome friction in the bearing[5].

Formula 7
P friction = M friction · ω, W

Where:
M friction – is the frictional moment in the bearing (N · m);
ω – angular velocity of the bearing (rad / s).

Friction in rolling bearings is a complex physical process caused by the contact and the General deformations Caprica-related bodies, macro – and microgeometry of a rolling surface, the grease, etc. by Calculating the frictional moment in the bearing 180306 roller Ø159×600 mounted on a conveyor belt 3LL1600 technical capacity of 3,500 t/h and belt speed of 4 m/s has received *M* friction = 6.8 N·m. Angular speed of the roller bearing will be:

Formula 8
$\omega = 2 \cdot v$ / Dp = 2 · 4 / 0.159 = 50.3 *rad* / *s*

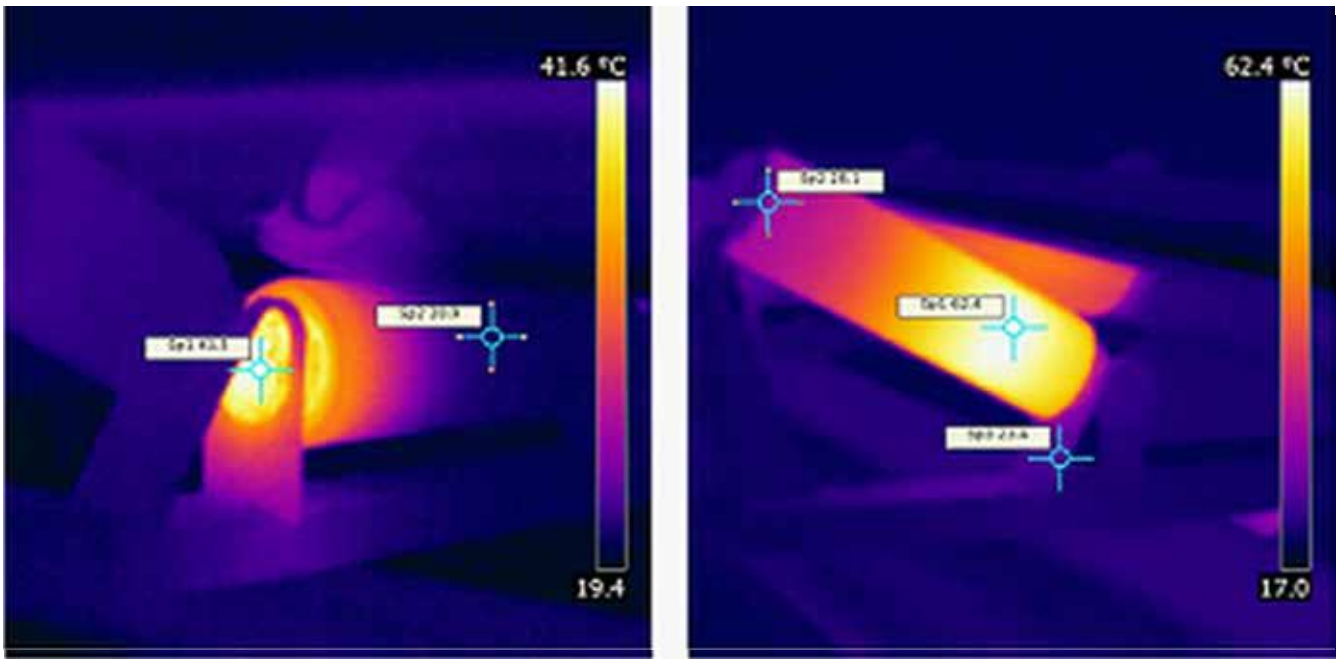
Bearing features deep groove ball 180306: • The inside diameter *d* = 30 mm. • Outside diameter *D* = 72 mm. • The diameter of the rolling elements *Dw* = 12.3 mm. • Number of rolling elements – 8. • Static load rating *C* = 15100 N. Calculate the power consumed for heating the roller in the working roller bearing without defects:

Formula 9
P friction = *M* friction · ω = 6.8 · 50.3 = 342 W

The specified heat output, resulted in heating the body bearing-Nika roller exceeding the ambient temperature by 0,8÷1,0 Degrees (see **Figure 3a**). In **Figure 3, 4** shows the thermograms roller belt conveyor.

After was built the dependence of the temperature of the roller surface from heat loss (**Figure 5**).

The dependence of the power of friction from roller temperature. Analysing losses on non-productive friction, can make the that, for example, for heating the outer surface of the roller 48 degrees Celsius, you need to spend about 10 kW (see **Figure 5**). Belt conveyor type 3LL1600 rollers 420 are installed at every 100 meters of pipeline, survey results show the temperature anomalies at 10÷15 °C for 5÷10% of the rollers. Take the averages and calculate power loss for a pipeline length of 1000 m. Get the following value for:



a b

Figure 4: The thermograms of the defective rollers: a) temperature anomaly zones *C*; b) temperature anomaly zone *D*.

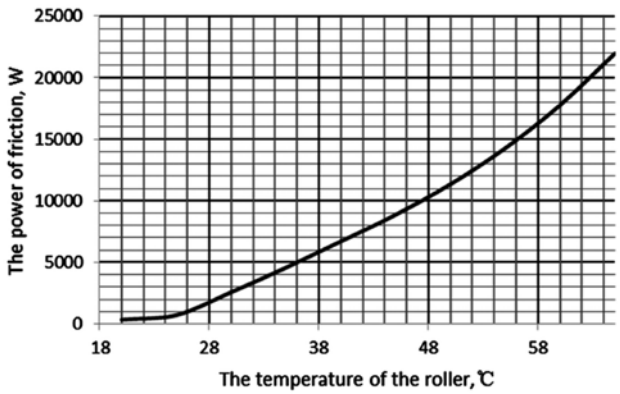


Figure 5:

Formula 10

$\Delta P = 4200 \cdot 0.07\ 2.5 = 735$ kW

This capacity exceeds the capacity of the drive motor by 1.5 times. Of the four drive motors, one certainly consumes energy for the rotation of the roller with worn-governmental bearings. Like the example with the vibro-diagnostics calculate energy losses for the month by the formula 5:

Formula 11

$\Delta W = (P2 - P1) \cdot n = 735 \cdot 630 = 463050$ kWh

It is about 175 tons of additional coal for electricity generation leads to emissions of more than 615 tons of carbon dioxide per month.

CONCLUSIONS

Thus, periodic monitoring of technical condition of mining equipment, and adequate maintenance significantly reduces the environmental burden on the environment.

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Fundamental principles of an effective reinforcing roof bolting strategy in horizontally layered roof strata and areas of potential improvement

It is arguable that the development of reinforcing roof bolting systems has largely stagnated in recent times, primarily due to the prevailing industry view that few, if any, further improvements can be made to what currently exists. However, this paper contends that reinforcing roof bolting systems can be further refined by considering both the specific manner by which horizontally bedded roof strata loses its natural self-supporting ability and the specific means by which reinforcing roof bolts act to promote or retain this natural self-supporting ability. The Australian coal industry has insisted on minimising bolt-hole diameter to maximise load transfer and on targeting full-encapsulation by any means necessary for many years. This has led to a significant, albeit unintended, consequence in terms of overall roof bolting effectiveness, namely increased resin pressures during bolt installation and the associated potential for opening bedding planes that may have, otherwise, remained closed during the bolt installation process. Given that the natural self-supporting ability of roof strata is strongly linked to whether bedding planes are open or closed, logically, minimising resin pressures should be a significant benefit. This paper focuses primarily on three key issues that relate directly to the function of the roof bolting system itself: (1) the importance of proper resin mixing in the context of maximising load transfer strength and stiffness, (2) the importance of minimising resin pressures developed during bolt installation, and (3) the importance of maximising the effectiveness of the available bolt pre-tension. All mine operators should be invested in improving the individual

effectiveness of each installed roof bolt, even by relatively small incremental amounts, so this is an important topic for discussion within the mining community.

INTRODUCTION

The installation of primary roof bolting as part of the roadway development operation is the most obvious pro-active strata control process that is available to mining operations. The way the primary roof support is installed suitably close to the development face and the extent to which it is geotechnically fit for purpose sets in place the future conditions. The installation of the primary roof support ultimately determines operational outcomes, such as the trigger action response plan (TARP), subsequent roof deterioration or instability, and whether or not expensive, high-density, secondary support measures will be needed. However, in an overall industry context, the effectiveness of primary roof support has received far less attention in more recent times compared to such areas as geotechnical characterisation, geotechnical design, and operational strata management. This paper revisits the subject area by examining several technical areas where substantial improvements can potentially be made based on the published findings of a range of research studies and specific testing data.

The development of reinforcing roof bolting in underground coal mining, which is the mainstay of safe and efficient mining, has reached a point where the design and setup of the bolting system can be further refined by considering the manner by which the roof strata loses its own self-supporting ability. Reinforcement is the promotion or retention of the natural self-supporting ability within the host rock mass. By understanding both the de-stabilising mechanisms within the roof strata and the various influences that primary roof bolts have on those mechanisms, the setup of each installed roof bolt can be optimised to achieve the highest level of individual roof bolt effectiveness.

Without digressing into a detailed history of roof bolting development over the past 40–50 years, an optimum roof bolting system needs to incorporate measures that address at least eight fundamental principles of roof reinforcement: (1) position of bolt installation with respect to the development face (i.e., cut-out distance), (2) use of an appropriate bolt length and a geotechnically suitable bolt pattern, (3) minimum resin pressure during bolt installation to reduce the adverse effects on the roof strata within the bolted interval, (4) proper resin mixing when generating the bond between the bolt and surrounding strata, (5) use of resin system properties that act to promote increased load transfer strength and load transfer stiffness, (6) maximum effectiveness of the bolt pre-tension generated via nut tightening at bolt installation, (7) protection of mine personnel from any roof material that may detach between bolts, and (8) application of an ongoing operational process to both correctly install ground support, as well as manage and control the inherent uncertainties in the stabilisation of a naturally formed engineering material.

Applying these eight fundamental principles leads to various insights as to how a reinforcing roof bolting strategy can be best optimised. This paper considers, in varying detail, several issues that relate directly to the setup of the roof bolting system itself: (1) proper resin mixing in the context of maximising load transfer strength and stiffness, (2) the importance of minimising resin pressures developed during bolt installation, and (3) maximum magnitude and effectiveness of the bolt pre-tension developed at installation.

The discussion around each of these aspects is based on an analysis of how the primary source of self-supporting ability in layered roof strata is retained, how such natural roof stability is lost, and the various interactions between installed roof bolts and the occurrence of de-stabilising mechanisms.

SELF-SUPPORTING ABILITY IN LAYERED ROOF STRATA

Figure 1 illustrates a simplified representation of the three fundamental sources of roadway roof stability in a layered and jointed rock mass under the action of some level of horizontal stress[1]. The three stabilising mechanisms are (1) cohesion between bedding planes, (2) horizontal stress acting to prevent shear slip along sub-vertical jointing within the roof strata, and (3) some form of suspension-type support to hold up a roof mass that does not contain the natural stabilising benefits of (1) and (2). Without at least one of these mechanisms in place, a major roadway roof fall is an inevitable consequence.

On the assumption that using a suspension roof control strategy is not a preferred approach in high-production underground coal mining, preventing horizontal separations occurring within the roof strata becomes critically important. First, the opening of bedding planes directly causes the loss of bedding plane cohesion (stabilising mechanism). If closely spaced bedding planes open up, it can lead to

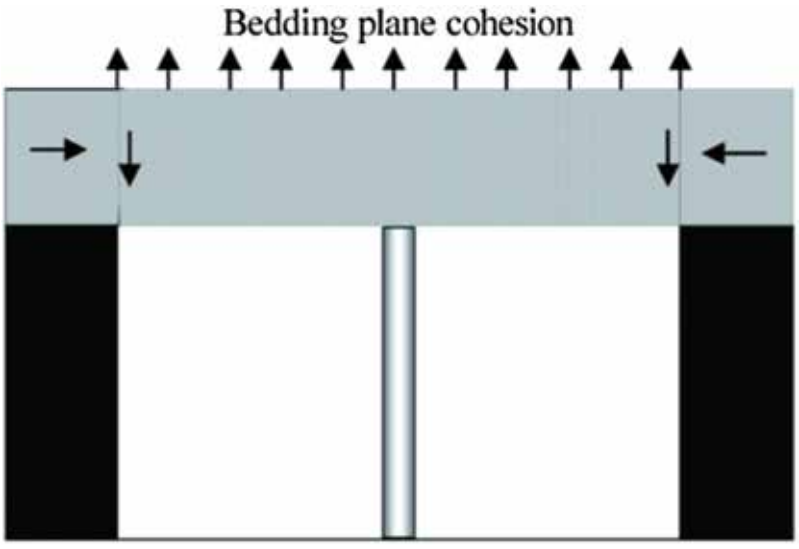

Figure 1: Schematic representation of the three sources of roadway roof stability[1].

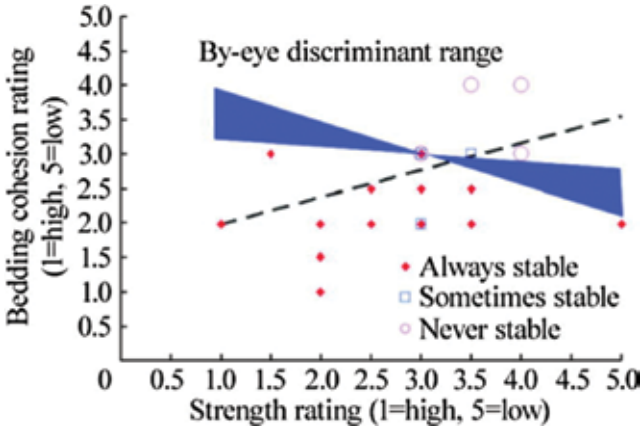

Figure 2: US extended cut stability database assessed for both UCS and bedding cohesion[4].

the en masse buckling of the roof strata and an associated reduction in horizontal stress levels (stabilising mechanism (2)), as explained in detail in Colwell and Frith[2,3].

A real-world demonstration of the significance of the bedding plane condition to the self-supporting ability of layered roof strata is found in **Figure 2**, which is derived from the US extended cut database used to evaluate roadway roof stability without roof bolts installed[4]. The two axes represent the varying compressive strength (UCS) of the roof material (x-axis) and bedding cohesion within the roof (y-axis) for each of the database case histories. The estimation of the latter is part of the underground method for determining the coal mine roof rating (CMRR) as it is used in the Mark study[4].

The key feature of **Figure 2** is the line or boundary that best separates the "always stable" from the "never stable" cases because this provides an indication of the relative importance of the UCS of the roof material, as compared to bedding plane cohesion within the roof, to either the retention or loss of natural roof stability (self-supporting ability).

A "by-eye" discriminant zone (in blue) is shown in **Figure 2**, and it is clear that it only discriminates between stable and unstable cases according to varying bedding plane cohesion, i.e., lower cohesion (greater than ≈3) is linked to "never stable" cases, and higher cohesion (less than ≈3) to "always stable" cases. Furthermore, the "always stable" cases cover the full UCS range from low to high, meaning that UCS is not a reliable predictor of natural roof stability[5].

The point of **Figure 2** is that the roof almost certainly loses its natural stability or self-supporting ability in line with the opening of bedding planes, termed "delamination." It logically follows that the higher the level of delamination within the bolted interval, the higher the level of installed roof support required to maintain adequate levels of roof stability (all other factors being equal). Bolted roof reinforcement should, therefore, be primarily focused on preventing bedding planes from opening within the bolted interval. Minimising the degree of bedding separation once they are open should be a secondary, albeit still relevant, consideration.

The setup of a reinforcing roof bolting system is further considered based on the concept that retaining the self-supporting ability of the roof strata prevents the bedding planes from opening within the bolted interval, while accepting that, if they do open, it is beneficial to minimise the level of separation that occurs.

RESIN MIXING AND MAXIMISING LOAD TRANSFER PROPERTIES

The entire subject of maximising the load transfer properties of resin-encapsulated roof bolts has been widely researched based largely on both in situ short encapsulation pull-tests and laboratory pull or push tests. The general outcome of this work, in Australia, is that, in order to maximise load-transfer strength and stiffness, the roof bolting system should be fully encapsulated, and the annulus between the bolt and surrounding strata should be as small as possible. When considered in isolation, the logic behind maximising load transfer makes sense and remains the current norm in the Australian coal mining industry.

However, works from New Zealand, published by Campbell and Mould, as well as Pastars and McGregor, find that there is a fundamental problem with the 15:1 ratio (mastic-to-catalyst) resins systems that were almost universally used in the Australian coal industry both prior to and at that time of this work and remain so today[6,7]. They are prone to poor resin-mixing towards the top end of the bolt. The load-transfer was further reduced by "gloving," which is when large pieces of plastic film corrupt the integrity of the resin bond between the bolt and the surrounding strata. A combination of both poor resin mixing and gloving was found to give very low load-transfer properties, the existence of which is hidden from view during normal mining operations and cannot be easily audited or directly monitored. No practical solution is offered in these works to overcome these problems using an industry standard 15:1 resin system.

The idea that load transfer is maximised via minimising the annulus between the bolt and surrounding strata is brought into question by the work of Hagan and Weckert[8]. Lab-based pull testing using a "mix-and-pour" resin system rather than a "spun-through" resin, used in actual bolt installations, shows no discernible difference in load transfer properties, neither strength nor stiffness, for hole diameter variations between 28 and 30 mm (**Figure 3**). This finding is directly contrary to what had been published in the past (see **Figure 4**)[9]. In hindsight, this has almost certainly driven the industry practice of using the smallest possible bolt hole diameter (as low as 26.5 mm).

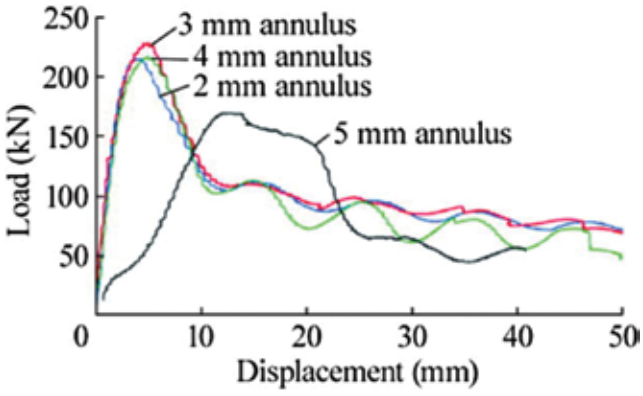

Figure 3: Load vs displacement data for roof bolt pull-testing using mix and pour resin[8].

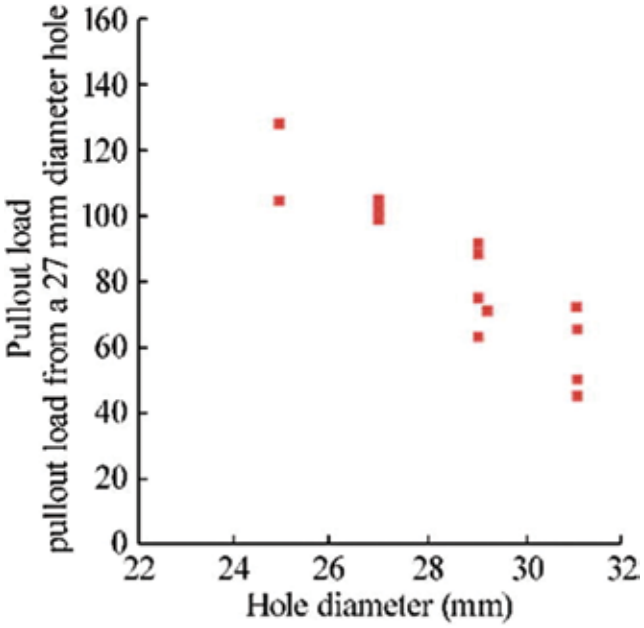

Figure 4: Effect of hole diameter on load transfer[9].

As noted in **Figure 4**, rebar with nominal diameter of 22 m is used in each test.

The logical conclusion is that the effectiveness of resin mixing within a 15:1 resin system is highly dependent upon minimising the hole diameter, leading to the common finding with in situ short encapsulation pull test studies that load transfer increases as the hole diameter decreases.

This theory was put to the test as part of ACARP Project C21023. McTyer conclusively shows that resin mixing effectiveness for 15:1 resins substantially reduces with an increasing hole diameter from 28 to 30 mm, whereas little or no reduction is seen when using a US-style 2:1 resin system[10]. **Figure 5** illustrates why this is likely to be the case via a simple cross-section of the bolt hole and relative cross-section areas and locations of the bolt, mastic, and catalyst sections.

From this, it is concluded that the Australian coal industry bases the practice of minimising bolt hole diameter to maximise load transfer on the resin mixing limitations of 15:1 resin systems according to increasing hole diameter. The use of the smallest possible roof bolt hole has a significant, albeit unintended, consequence in terms of overall roof bolting effectiveness. This practice promotes increased resin pressures during bolt installation, associated potential

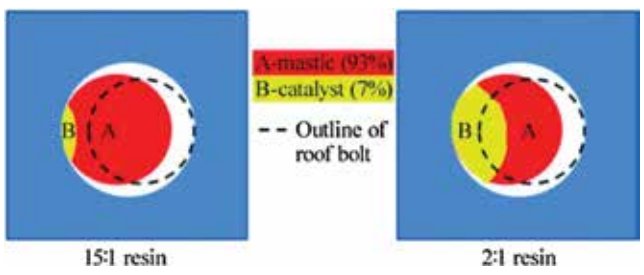

Figure 5: Schematic illustration of the various roof bolting system components during bolt installation and resin mixing.

for opening the bedding planes near the bolt hole, and resin losses into the roof strata as a direct consequence.

RESIN PRESSURE DEVELOPMENT DURING BOLT INSTALLATION

Resin pressure development during bolt installation and the significance to roof reinforcement can be considered based on a combination of the following: resin pressure measurements made during bolt installations by several researchers, theoretical treatment of the key parameters that logically influence the development of resin pressures, common fracture patterns observed within the bolted interval, Griffith Crack Theory, and published test data showing the clear links between less-than-theoretical bolt encapsulation achieved with various changes made to the bolting setup (e.g., resin volume used and varying hole diameter).

Comments are also included pertaining to a recently published technical paper which purports to significantly diminish the significance of resin pressures generated during bolt installation to roadway roof stability using a series of technical arguments and roof bolt installation testing results that contain several fundamental oversights[11].

An early indication of the significance of resin pressures developed during roof bolt installation is found in Pettibone, where the fracturing of 31 MPa concrete blocks is reported as a direct result of roof bolt installation[12]. The significance to roadway roof stability is not directly considered in this publication, but the link is made between roof bolt installation and potential fracturing of the host material.

Compton and Oyler reports resin pressure measurements during installation (**Figure 6**)[13]. However, without spinning during installation, a 1.2-m-long × 15.9 mm diameter roof bolt in a 25.4-mm diameter steel pipe results in a 4.7-mm-thick annulus, which is equivalent to a 21.7-mm core diameter roof bolt being installed in a 31.1-mm diameter hole. At an insertion rate of 128 mm/s, which is equivalent to a 1.2 m-bolt being fully inserted to the back of the hole in 9.5 s (**Figure 6**), the maximum pressure measured is 41.4 MPa at the top of the hole. This is a greater magnitude than the setting pressure for longwall shields.

While the bolt installation method used is fundamentally different than what is used in Australia, where spinning the resin starts at the base rather than the top of the hole, Compton and

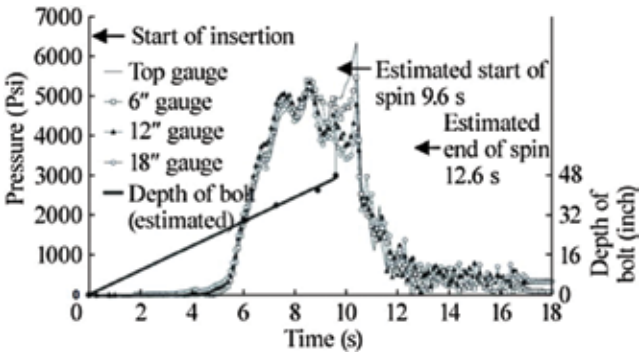

Figure 6: Hydraulic pressures generated at four locations in a 25.4 mm diameter pipe during roof bolt installation (15.9 mm diameter bolt)[13].

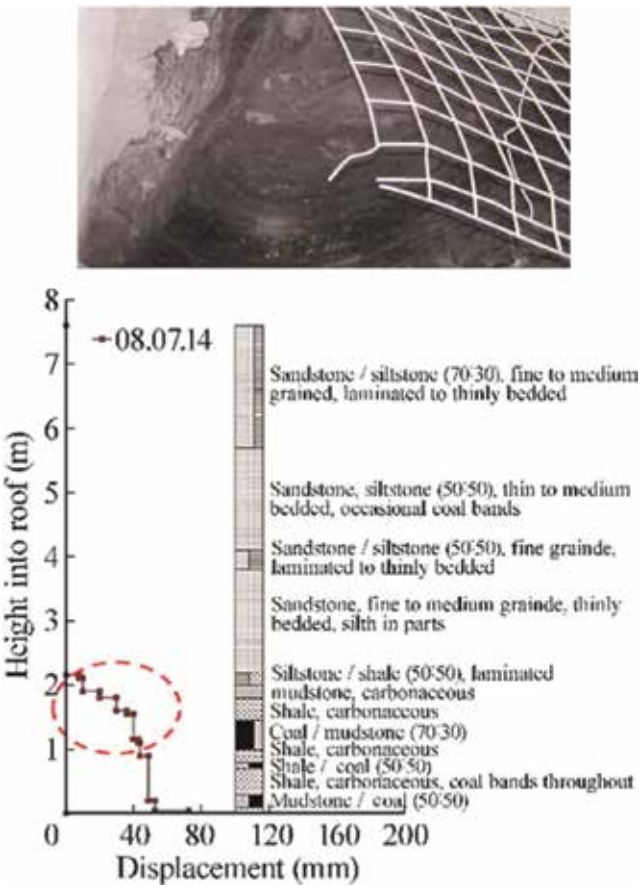

Figure 7: Roof fall cavity and bolted interval fracture pattern from an adjacent borescope hole.

Oyler provided an indication of the potential resin pressure magnitudes that can be generated[13]. They report a maximum measured pressure of 68 MPa using the available power of a hydraulic roof-bolting rig.

A combination of exceedingly high resin pressures being measured during roof bolt installation and the observation of blocks of strong host material being fractured as a direct consequence leads to the conclusion that resin pressures are, indeed, significant. They have the potential ability to hydro-fracture the roof strata, particularly in the upper portion of the bolt where the highest pressures are generated during bolt installation. The logical questions that follow from this recognition are (1) does the action of resin pressures potentially detract from overall roof stability? (2) if the answer to (1) is yes, which roof types are most affected by this action? and (3) how can resin pressure be controlled? Can these controls be implemented to minimise or even eliminate any negative impact on roof stability while not compromising other key reinforcing aspects of the bolting system?

The answer to (1) can be found in observed or inferred fracture patterns within the bolted interval of mine roadways and in the statement that the self-supporting ability of roof strata is primarily retained by preventing or minimising the loss of bedding plane cohesion within the roof strata.

Figure 7 shows a roof fall cavity (with extruded resin "pancakes" clearly evident at the top of the fall profile) and an associated borescope observation plot of the location and distribution of open fractures in the roof strata. The installed roof bolts were 2.1 m long and were designed to be fully encapsulated using 1200 mm long resin cartridges in a hole drilled with a 27 mm bit. The presence of more intense roof fracturing in the upper section of the bolted interval is clearly evident in the borescope data. The geotechnical reasoning for such fracturing is not obvious. However, the action of resin pressures forcing resin into the roof strata, thus opening the bedding planes can be reasonably inferred from the available evidence.

Figure 8 shows a series of sonic-probe roof extensometers from an ACARP Project field trial at Tower Colliery with the condition of the upper section of the bolted interval being consistently fractured compared to the overlying strata. The fracture is to the extent that the bolt length in use can be identified from the extensometer plots.

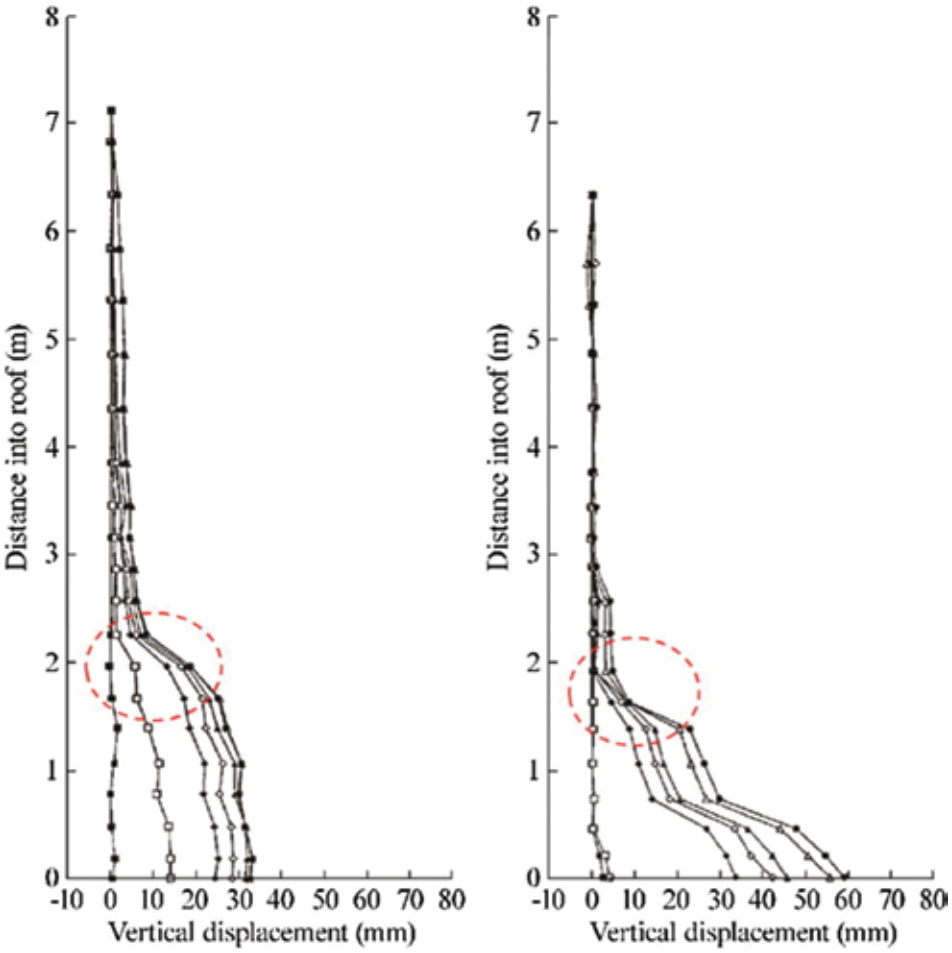

Figure 8:. Sonic probe extensometer data from ACARP Project C3032 (ACIRL 1995)[14].

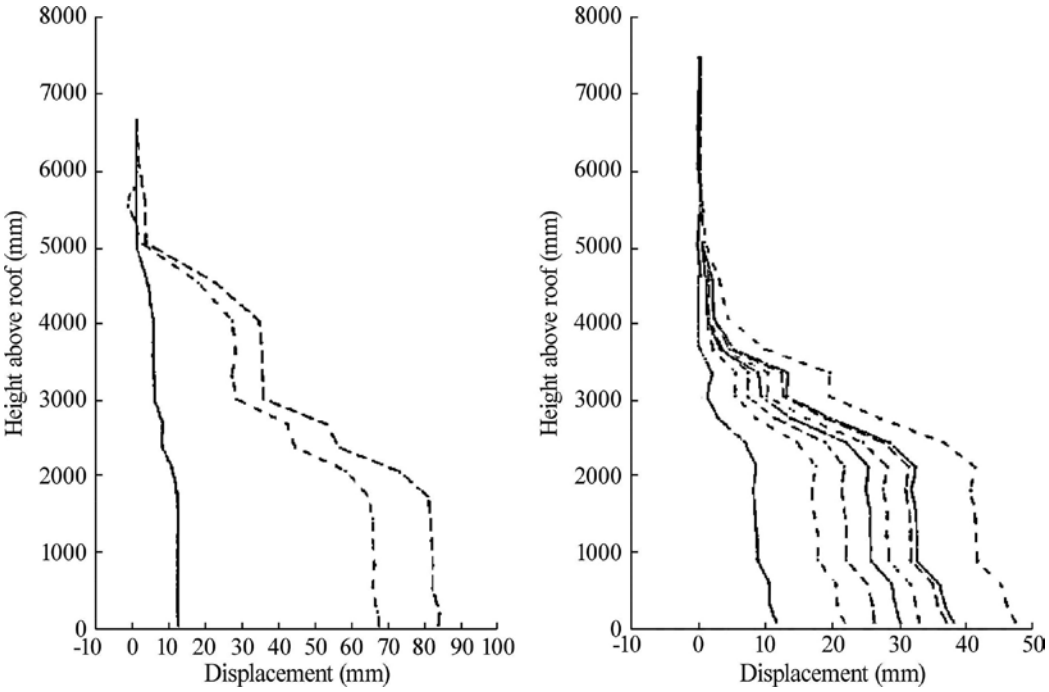

Figure 9: Sonic probe extensometer data related to hand-held pneumatic roof bolters.

In contrast, **Figure 9** contains a series of aged sonic probe roof extensometer plots linked to roof bolt installations via hand-held compressed air roof bolters, which have a far lower ability to generate high resin pressures during bolt installation. The change in roof fracturing in the upper section of the bolted interval, compared to **Figure 8**, is evident. The potential implication is that far less roof fracturing is present in the section of the bolted interval where maximum resin pressures are generated.

With regard to question (1), the natural self-supporting ability of the roof strata is strongly linked to whether bedding planes remain open or closed (**Figure 2**). Resin pressures during bolt installation initiate or aggravate the propagation of open fractures within the upper section of the bolted interval via pumping resin along such fractures. Therefore, the roadway roof stability is negatively impacted.

In terms of which roof or strata types are most likely to be affected by the influence of resin pressures can be considered by applying the various principles of hydro-fracturing, as used by Purcell *et al*.[11].

Fracture development from a borehole is based on the applied hydraulic pressure overcoming two distinct resistant forces to fracture development: the stress acting across the fracture plane and the cohesion (intact tensile strength) of the rock mass across the fracture plane. As a result of the first force, fracture development from a vertical borehole typically propagates perpendicular to the lower of the two relevant horizontal stress magnitudes because this represents the lowest possible resistance of the in situ stresses. The relevant equation governing fracture propagation, as quoted by Purcell *et al*. from Amadei and Stephansson is as follows[11,15]:

Equation 1

$\partial 1=3\partial 2+S-P1-P0=3\partial 2-$ Pr

where $\sigma 1$ is the major principal stress; $\sigma 2$ the intermediate principal stress; S the tensile strength of the rock perpendicular to the fracture direction; P_i the crack initiation pressure; P_o the pore pressure; and P_r the crack re-opening pressure.

Equation 1 was specifically developed for predicting crack initiation and re-opening pressures for vertical cracks in a vertical borehole as part of hydro-fracturing stress measurement. However, Purcell *et al*. combines a basic model for the in situ major and minor horizontal stresses in underground coal mines with what they state to be a moderate tensile strength for coal measures rock (5 MPa)[11]. This results in the required crack initiation and re-opening pressures for a range of cover depths, as shown in **Figure 10**.

Crack initiation pressures ranging from almost nothing to 50 MPa are predicted. Purcell et al. uses these to conclude that crack initiation pressures in coal measures strata are both highly variable and also require site-specific consideration in terms of stress conditions and rock parameters before applying roof bolting systems that include resin pressure reduction measures[11].

The analysis conducted and presented by Purcell et al. is correct in terms of crack initiation pressures required to fracture solid rock material around a vertical borehole in virgin conditions where the in situ major and minor horizontal stresses act across the borehole plane[11]. However, the analysis is flawed and significantly over-

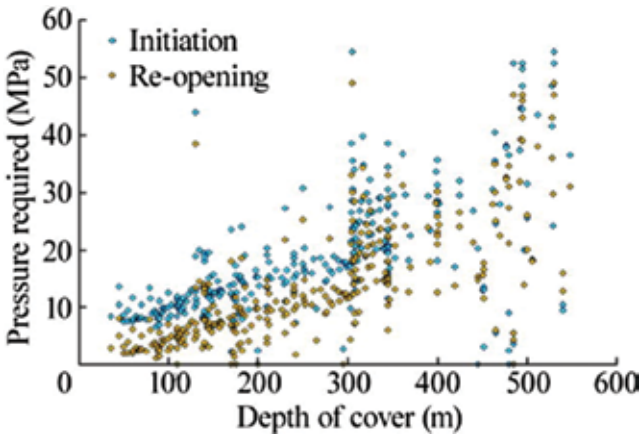

Figure 10: Pressures required for crack initiation and crack re-opening in moderate strength (5 MPa tensile) rock for Australian real mine virgin stress conditions[11].

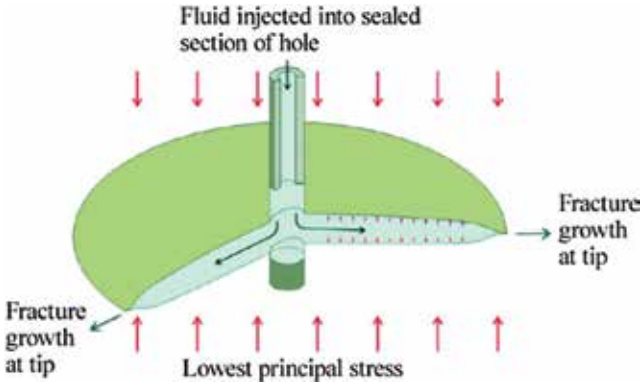

Figure 11: Concept of hydraulic fracture growth in rock[16].

predicts crack initiation pressures in the immediate roof of a mine roadway on the basis of the following:

1. Crack initiation develops perpendicular to the minimum applied stress. In the case of the bolted interval above a mine roadway, the minimum stress is inevitably vertical due to the presence of the underlying roadway void; hence, the fracture propagation is likely to be horizontal, as illustrated in **Figure 11**[16].

2. The magnitude of the vertical stress within the bolted interval of a mine roadway is substantially less than the in situ vertical stress or either of the principal horizontal stresses due to the existence of the underlying roadway void, which acts as a very efficient vertical stress reliever. Therefore, the confining stress (σ_2 in **Equation 1**) to be overcome during roof bolt installation is likely to be far lower than indicated by the analyses of Purcell *et al*.[11]. The same logic is applied by Mills and Jeffrey in their analysis of hydro-fracturing the spanning conglomerate unit above longwall panels at Moonee Colliery for the purpose of windblast mitigation and control[16].

3. The weakest horizontal planes in the roof of a mine roadway are bedding planes and contacts, which have a tensile strength in the vertical direction substantially less than 5 MPa (as assumed in **Figure 10**). Frith reports the tensile strength of bedding planes in both sandstone and carbonaceous material as found from direct tensile testing of core samples[17]. In all cases, average values are less than 0.5 MPa. Even for solid sandstone, the tensile strength is found to be just over 2 MPa. Therefore, the assumption in the Purcell et al. analysis that a 5 MPa tensile strength represents "moderate" strength rock is significantly over-stated[11]. It is an order of magnitude higher than the tensile strength across horizontal bedding planes, this being the more relevant consideration in terms of the stability of a bolted mine roof.

For weak bedding planes and contacts within the bolted interval, typical crack initiation pressures of 3 MPa and less are estimated to be far more realistic. These values are depth independent due to the very low vertical stresses acting within the bolted interval being almost entirely determined by the formation of the underlying roadway void. They are also at the low end of resin pressures that have been measured in surface and in situ bolt installation testing, including those reported by Purcell *et al*.[11].

Another consideration in regard to resin pressures driving the development of bedding plane separations in the roof needs to be considered, namely the short time period (of only a few seconds) that high resin pressures are able to act. Griffith Crack Theory states that the highest stress is required to start the propagation of a crack, but once initiated, the stress required to further propagate the crack decreases as a function of the length of the crack. Therefore, in the example of resin pressures causing bedding plane separations in the roof of a roadway, the main significance of resin pressure could be to commence the propagation of a fracture that, otherwise, would not have started under the action of horizontal stress alone. Once the resin pressure starts the crack, however, the horizontal stress is then able to drive its further propagation unassisted.

In terms of the controls on resin pressure development, if the problem is considered as a piston being pushed into a closed void space full of resin, resin pressure will develop if the rate of resin volume escaping back past the piston is less than the volumetric compression of the resin ahead of the piston. Therefore, it is necessary to consider both the rate of piston insertion (roof bolt insertion rate) and the various factors that act to restrict the escaping of resin back past the piston (roof bolt).

It is evident that slowing down the rate of roof bolt insertion into the bolt hole will tend to reduce the development of resin pressures ahead of the bolt because this allows more time for resin to escape past the bolt. The data in **Figure 6** relates to an insertion rate of 128 mm/s, and the test data shown in **Figure 12**, developed in conjunction with Dywidag-Systems International (DSI), is typically associated with a bolt insertion rate of 150 mm/s.

Rate of bolt insertion is also a relevant consideration in terms of resin mixing. If the rate of insertion is too slow (e.g., 100 mm/s), for a 1200-mm- or 1400-mm-long resin

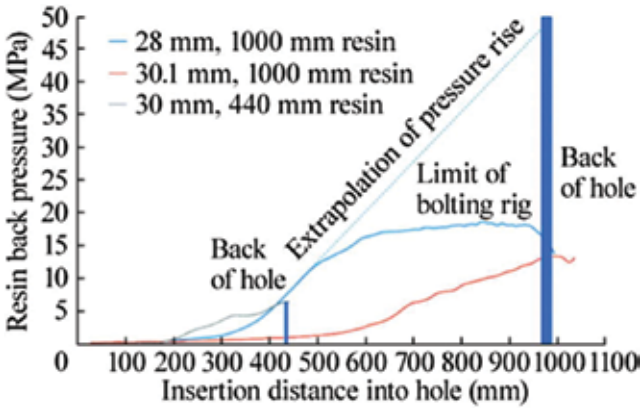

Figure 12: Resin pressure measurements for varying hole diameters and resin volumes.

	Resin length	Drill bit			
		27mm spade	27mm angel	26.5mm twin-wing	28mm twin-wing
Theoretical	1200	2017	1918	2205	1509
Actual		1480	1420	1370	1530
% resin loss		27%	26%	28%	Nil
Theoretical	1400	2353	2238	2572	1761
Actual		1700 + excess	1700 + excess	1700 + excess	1700 + excess

Figure 13: Resin loss by drill bit diameter[18].

cartridge (commonly used for fully encapsulating a 1.8-m- or 2.1-m-long bolt), the bolt will not reach the back of the bolt hole or be spun sufficiently to ensure adequate mixing in the top section of the bolt without over-spinning the resin in the bottom section of the bolt.

Reducing the rate of bolt insertion is an obvious method for lowering resin pressures developed during bolt installation, as implied in the test work reported by Purcell *et al*.[11]. They conduct their testing at an insertion rate of 100 mm/s and report lower resin pressures than other published test data, including **Figure 12**. However, it is almost certainly inconsistent with resin-mixing needs along the full length of the roof bolt. Therefore, other remedies are required to reduce resin pressure development, which leads to the various reasons why resin is restricted from flowing along the annulus around the roof bolt during insertion.

Figure 12: contains typical results from a series of roof bolt installations under controlled conditions conducted by the authors and DSI. With regard to this type of testing, it is vital to use a closed system so that resin cannot escape by any means other than back past the bolt being inserted. This ensures that the maximum possible resin pressure is measured. Similar testing conducted in situ, for example, is prone to resin bleed-off through openings in the roof strata, particularly in friable roof types, such as coal and claystone sequences. In situ testing inevitably returns lower resin pressures than a closed system does. Such testing is meaningless if the roof bolting system design objective is to minimise resin pressures to prevent the development of open fractures in the roof. This is an oversight in the in situ testing reported by Purcell et al. and explains the very low measures of resin pressures, which are used in isolation to then discredit the significance of resin pressures and their potential detrimental influence on roof instability[11].

Figure 12 demonstrates the significance of two key drivers of resin pressure development during bolt installation: (1) resin pressure decreases as the bolt hole diameter increases (i.e., annulus thickness around the bolt), and (2) resin pressure decreases when using less resin, as evidenced by the pressure development curve associated with the use of a 440-mm-long resin cartridge compared to 1000 mm.

Two further logical drivers of resin pressure during roof bolt installation are the viscosity of the resin and the extent to which the rotation of the roof bolt during installation acts to pump the resin back up the hole, thereby further restricting its flow past the bolt.

With regard to any pumping action of the spinning roof bolt, it is noted that the early roof bolt patents included a specific innovation, where the deformed profile was designed to push resin back up the hole during spinning in, as opposed to having it pump resin out of the hole. Therefore, the idea that a spinning roof bolt acts to prevent resin flowing along the annulus during installation has been a roof bolt design characteristic since their first use in the mining industry. This pumping action can be readily eliminated by either the use of a smooth bar or, preferably, a neutral deformed profile, such as a herringbone pattern which neither pushes resin back up the hole or pumps it out of the hole.

The general relationship between the efficiency of a pump and minimising the clearance between the impellor (roof bolt) and casing (bolt hole wall) is also noted in the context of the annulus thickness around the bolt.

There is a link between increasing resin pressure and increased roof fracturing via resin being forced into the surrounding roof strata, seen in the various changes in bolt encapsulation according to either increasing the bolt hole diameter or the volume of resin used, both influence resin pressure development.

Figure 13 is taken from Craig [18]. It is clear that, for a 1200-mm resin length, the lower bolt hole diameters result in the achieved encapsulation being less than 100% of the theoretical value, and this is only achieved at a hole diameter of 28 mm. Other published research studies mirror this general outcome.

Figure 14 shows variations in what is termed as the "encapsulation ratio" for varying resin cartridge lengths from 1.8-m-long bolt installations in a friable coal roof. For a 28-mm diameter hole, a 21.7-mm diameter bar, and a 25-mm diameter resin cartridge, for every 1 mm of resin cartridge length, 1.8 mm of bolt encapsulation should theoretically be achieved if no resin is lost from the hole and the hole diameter is accurate. In other words, if there is no resin loss, the encapsulation ratio should be 1.8.

The data in **Figure 14** shows that, for resin lengths up to 700 mm, the measured encapsulation ratio is just below the theoretical maximum of 1.8, the likely reason for this being that the actual hole diameter is slightly greater than

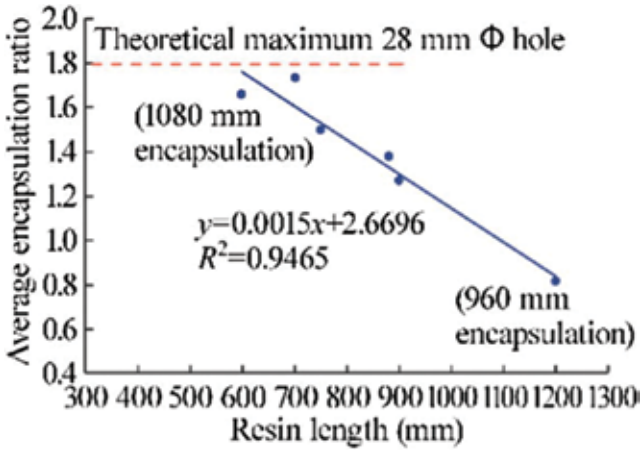

Figure 14: Measured encapsulation ratio as a function of resin cartridge length–friable coal roof.

the assumed hole diameter (drill bit diameter) of 28 mm. However, for resin lengths >700 mm, the encapsulation ratio incrementally reduces. For a resin length of 1200 mm, the encapsulation length achieved (960 mm) is actually less than that achieved with 600 mm of resin (1080 mm). Logically, this effect is being driven by ever-increasing resin pressures during installation due to increasing resin volumes, thereby driving ever-greater resin losses into the surrounding strata.

The data and arguments presented in this section of the paper lead to the conclusion that resin pressures developed during roof bolt installation are sufficiently high in the top section of the bolted interval to both initiate and further propagate roof fracturing and associated resin loss. In bedded roof conditions, preventing such fracturing from occurring is a primary objective of reinforcing roof bolts. This is a real and legitimate stability concern. Industry focus on achieving full encapsulation for long bolts (>1.8 m long) in the smallest possible hole is aggravating this effect, which is largely hidden from view during operations. Fortunately, there are some controls for resin pressure development that can be modified to substantially reduce this potentially hazardous effect.

ROOF BOLT PRE-TENSIONING

Pre-tensioning generates an axial tensile force in the bolt and a compressive force against the roof at the plate, without the need for roof movement or bedding plane separation, the latter being the principal driver of roof beam breakdown. This is why it is referred to as an “active” force, as compared to the “reactive” force generated by load transfer. A tensile axial load due to pre-tensioning develops along whatever bolt length is able to be freely stretch at the time of nut tightening.

The effectiveness of the applied pre-tension in reinforcing the initial approximately 0.5 m of roof is clearly illustrated in Fig. 15, Fig. 16. Fig. 15, Fig. 16 show the sonic probe extensometer data from Teralba Colliery in the mid-1990s when increasing roof bolt pre-tension was first being operationally evaluated in industry.

Figure 15 shows data related to low levels of applied pre-tension, the salient points being (a) the presence of delamination throughout the entire bolted interval (2 m for 2.1-m-long bolts) and (b) the associated time dependent roof behaviour where equilibrium is not easily being achieved. The displacement levels would undoubtedly trigger a development TARP today.

Comparing **Figure 15**, **Figure 16**, which is related to a significantly higher level of applied pre-tension, it is clear that the initial approximately 0.5 m of roof strata contains no obvious delamination. The total roof displacement is substantially reduced, and the time-dependent trend is far more stable. It is also noted that the height of roof fracturing in both instances is identical. In neither case are the 2.1-m roof bolts anchored securely into more stable overlying strata. The significant stabilising effect of the generating

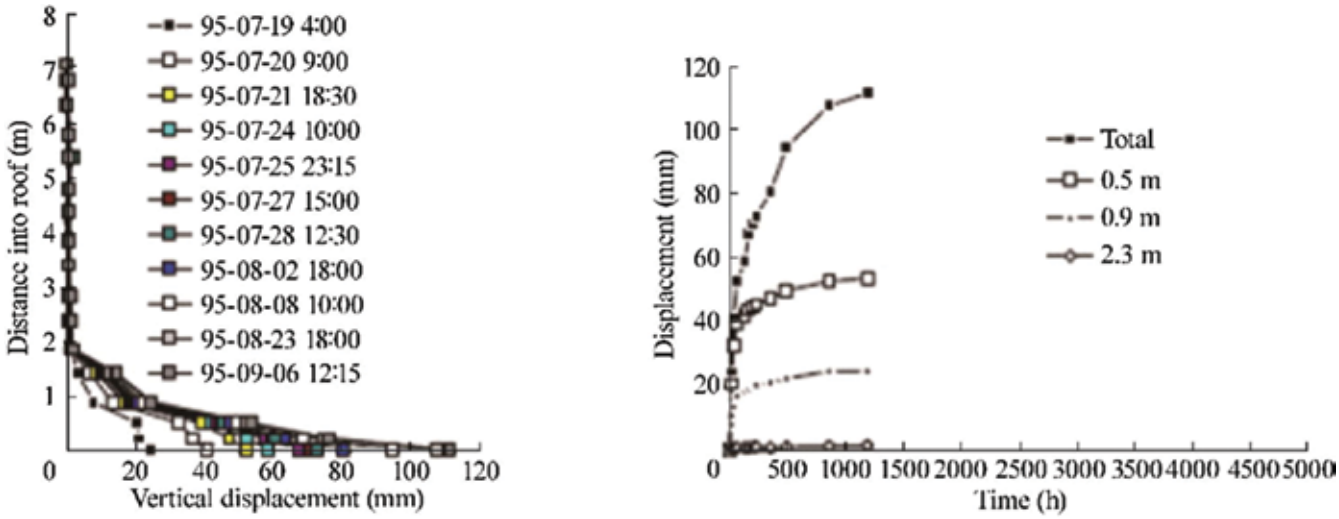

Figure 15: Roof extensometer data-applied roof bolt pre-tension 2-3 tonnes.

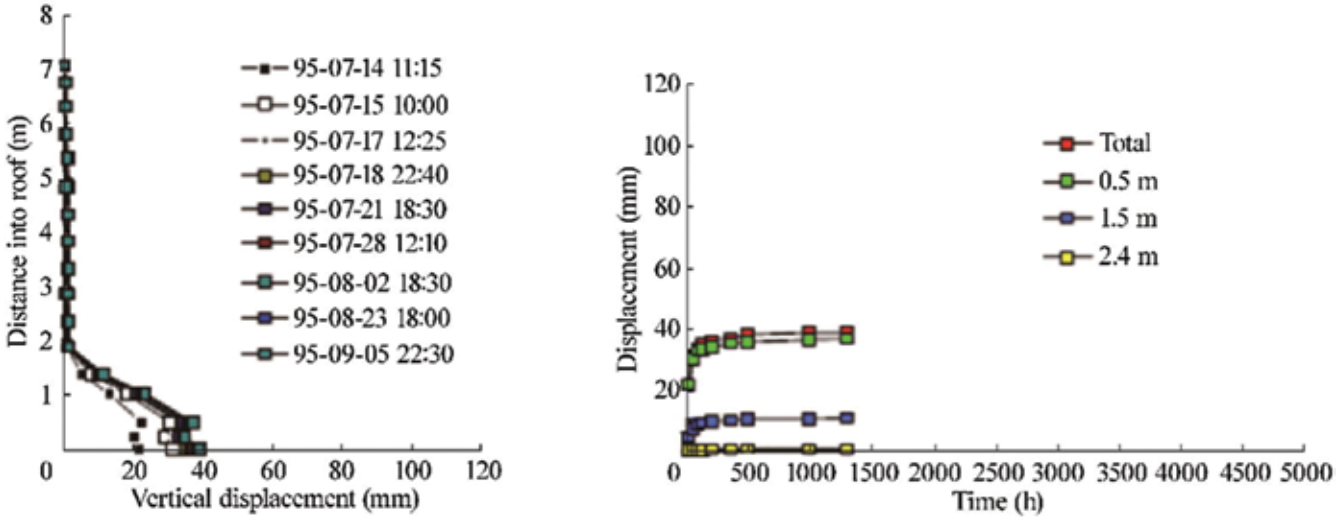

Figure 16: Roof extensometer data–applied roof bolt pre-tension 8-10 tonnes.

beam acts in the initial approximately 0.5 m of roof to prevent delamination using the action of the applied pre-tension.

If the condition of the initial approximately 0.5 m of roof strata is a key roof reinforcement consideration, it raises the question as to whether it is best reinforced via pre-tension or load transfer. By definition, load transfer requires full encapsulation, whereas pre-tensioning can potentially be achieved without the roof bolt necessarily being fully encapsulated.

The critical aspect of using roof bolt pre-tensioning for roof reinforcement purposes is that it modifies the end condition of the roof strata between roof bolts from "pinned" to "clamped". Clamped-end beams are 4 times as stable as pinned-end beams (all other factors being equal). This is potentially highly relevant in friable roof types, where the dominant mechanism driving roof instability is roof deterioration between bolts (guttering and buckling), eventually leading to instability across the full roadway width if not adequately controlled.

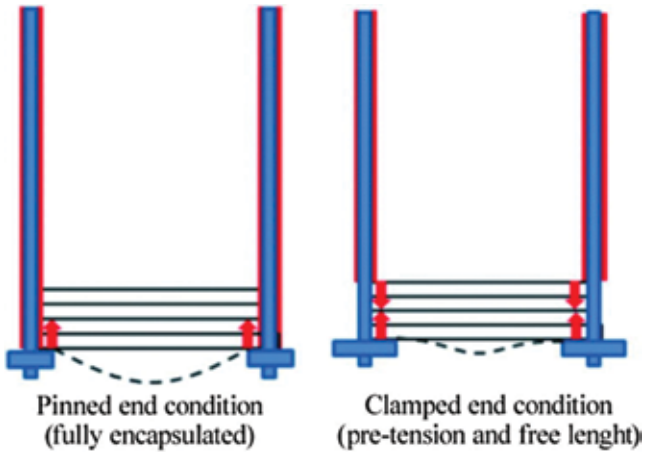

Figure 17: Schematic illustration of pinned and clamped-end roof beams between roof bolts due to load transfer and pre-tension, respectively.

The concept of different roof beam end conditions is schematically illustrated in **Figure 17**. A pinned-roof beam via full encapsulation and minimal pre-tensioning effect are compared to a clamped beam, developed using pre-tensioning and a bolt free-length that is equivalent to a beam thickness that can stabilise the full width roof span. The different roof displacement profiles shown between bolts (u-curve for pinned and double s-curve for clamped) are dictated by the end condition of the beam, as defined by the installed roof bolts.

Effectively using the applied pre-tension requires three requirements to be met:

1. The pre-tension generated from nut tightening is as high as possible.

2. The roof bolt plate is able to accommodate the applied pre-tension levels and preferably the yield load of the bolt without itself going into yield.

3. The resin anchor above the intended roof interval of bolt pre-tension is able to allow the pre-tension level to be generated by nut tightening, and allow the yield strength of the bolt to be generated as a result of any subsequent roof delamination below the resin anchor.

Only points (1) and (2) are considered in more detail in this paper.

In terms of the level of pre-tension generated due to nut tightening, the key issues are the applied torque and the thread system, which determines the efficiency of the torque to pre-load conversion. The thread system must also remain stable under the dynamic loading and associated heating during nut tightening.

Current hydraulic bolting rigs commonly use two-speed motors whereby "high rotation per minute-low torque" is used for drilling, and "low rotation per minute-high torque" for nut tightening. This makes the best use of the available hydraulic power for these two significantly different functions.

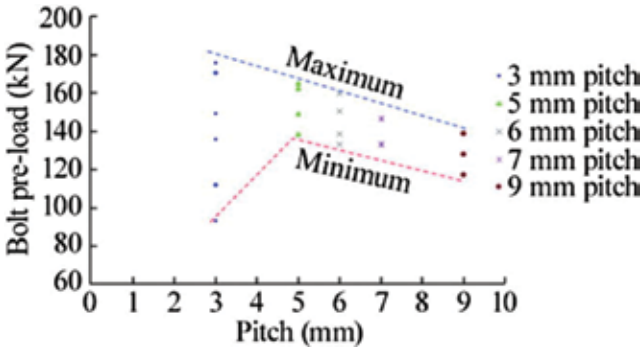

Figure 18: Roof bolt pre-tension level variations as a function of thread pitch.

Attempting to maximise both the efficiency of the torque-to-load conversion and thread stability during tightening is actually counter-productive because the former increases, but the latter decreases as thread pitch reduces. Roof bolts generally use a 3 mm thread pitch (standard M24 thread), which is about as low as pitch can go without thread stripping during nut tightening.

Test work evaluating pre-tension as a function of thread pitch (Fig. 18) for a hydraulic rig generating in the order of 400 N·m of torque indicate that the combination of a 3-mm pitch and a 1.25D nut do not always allow the maximum possible pre-tension level to be achieved. At 5 mm and above, it does. The solution to this, without decreasing the applied torque, is to either increase the nut length to reduce thread contact pressures making the thread more stable or increase the pitch to at least 5 mm.

With a suitably designed thread system, modern hydraulic roof bolting rigs that stall at around 400 N·m should be able to reliably generate 12-15 tonnes of pre-tension due to nut tightening. This is a significant roof-bolting attribute that has yet to be fully implemented by industry.

The strength of the head plate is a roof bolt system component that has received little attention following the industry move to full encapsulation. The plate is seen as a relatively unimportant part of the bolting system as a direct consequence. However, in any roof-bolting system that uses pre-tensioning for reinforcement but may not always achieve full encapsulation, the head plate is, in fact, a vital component of the system.

The British Standard on strata reinforcement support system components used in coal mines states that a roof bolt plate "shall flatten under a load of 50%-70% of the nominal breaking load of the bar[19]". It should "allow pull-through of the rock bolt, nut, and conical seat assembly under a load of 70%-95% of the nominal breaking load of the bar." In other words, the plate should be yield at an applied load as low as 17 tonnes (50%) for a 34 tonne bar (X grade steel) and allow system failure at an applied load as low as 24 tonnes (70%) for a 34-tonne bar. The underlying intent is presumably to protect the rock bolt from tensile failure by limiting the strength of the plate. The direct consequence of this is that the plate loses its elastic

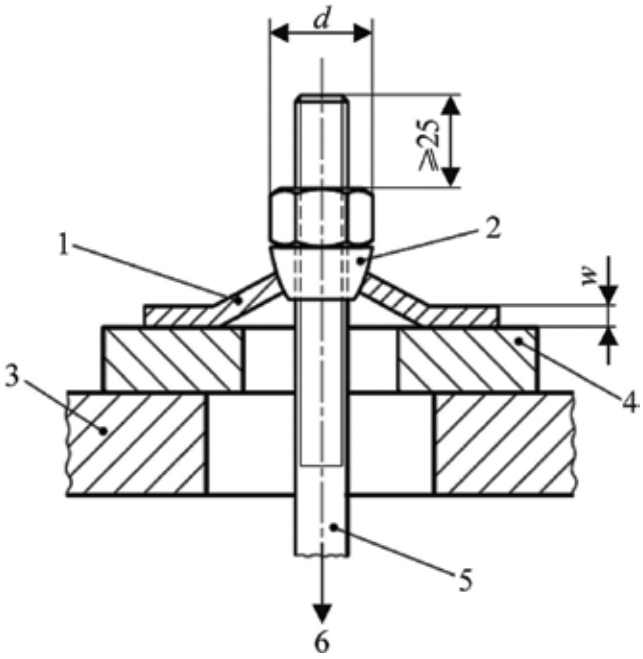

Figure 19: Load test arrangement for testing of steel domed washer plate[19].

stiffness, a key reinforcement consideration, at quite low levels of applied load, which is less than ideal.

The other major problem is that plate testing, as defined in the same British Standard, is undertaken per the arrangement shown in **Figure 19**. This is a highly idealised test setup using a flat surface against the plate. While this could allow representative comparisons between different plate designs, it provides optimistic plate strength values compared to those used in undulating and uneven roof environments. Therefore, the stated plate design criteria listed previously that are based on the test arrangement shown in **Figure 19** perform in situ at even lower levels than those specified.

Current standard roof bolt plates are understood to have an ultimate strength rating (or collapse loading) of 24 tonnes, which is exactly 70% of the ultimate strength of an X grade bar. Whether this is directly linked to the British Standard is not known. However, it confirms that there is potential, via a stronger head plate, to generate and use higher bolt

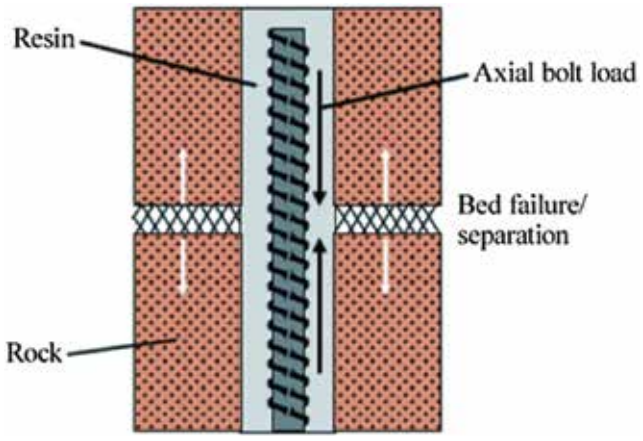

Figure 20: Basic load transfer reinforcing mechanism.

loads within the immediate roof strata as compared to the current situation.

In contrast, the basic load transfer mechanism is shown in **Figure 20**. The main point is that, for an axial bolt load to be generated due to bed separation, stable resin anchorages are required both above and below the bed separation. It is, therefore, constructive to consider the extent by which this reinforcing mechanism is able to work within the initial 600 mm of roof because this will provide further guidance as to the true imperative of achieving full encapsulation to the head of the bolt.

Ignoring any contribution from the roof bolt plate, the preferred requirement of the resin anchorage system, is to allow, at least, the yield strength (24 tonnes for an X grade bolt) and, ideally, the full axial strength of the bolt to be developed via bedding separation effects. For a 600-mm-thick immediate roof beam, if bedding separation occurs at the mid-point of the beam, the resin anchorage above the separation is the majority of the bolt length. However, below the anchor, it can be no more than 300 mm in length. Therefore, the relevant question to consider is whether a 300-mm-long resin anchor, particularly in weak roof strata, has the ability to develop 24-30 tonnes of axial bolt load.

A 300-m-long resin anchor is the same as what is used for short encapsulation pull testing. The objective of using a short anchorage is to evaluate the resin bond rather than the strength of the bolt. This is indicative that a 300-mm-long resin anchor is unlikely to allow the yield strength of an X grade roof bolt to be developed. Short-encapsulation pull test results in weak types roof commonly indicate pull-out strengths in the range of 10-12 tonnes, depending on the resin type and associated characteristics.

Therefore, load-transfer reinforcement within the immediate 600 mm of roof is unlikely to be able to develop more than about half of the yield strength of an X grade bolt. Further illustrations of this are provided in **Figure 21**, **Figure 22**[20,21]. It is clear that the axial loads being developed incrementally reduce towards the top and bottom of the bolt. More importantly, in **Figure 22**, the roof displacement profile is also shown (based on sonic probe extensometry), which indicates that, even though axial bolt load reduces towards the bottom of the bolt, the roof strata nonetheless contains a significant amount of delamination as low as the as-cut roof line. In other words, while the driver of axial bolt load generation via load transfer is present throughout the entire bolted interval, the load magnitude being developed in the initial approximately 1 m of roof is clearly being limited by some influence.

Other points of note with regard to the use of load transfer for reinforcing the immediate roof strata are as follows:

(a) By definition, load transfer requires bedding planes to open in order to develop axial bolt load. However, the opening of bedding planes is also the main driver for beam breakdown and associated roof instability. The required mechanism of load transfer is directly contrary

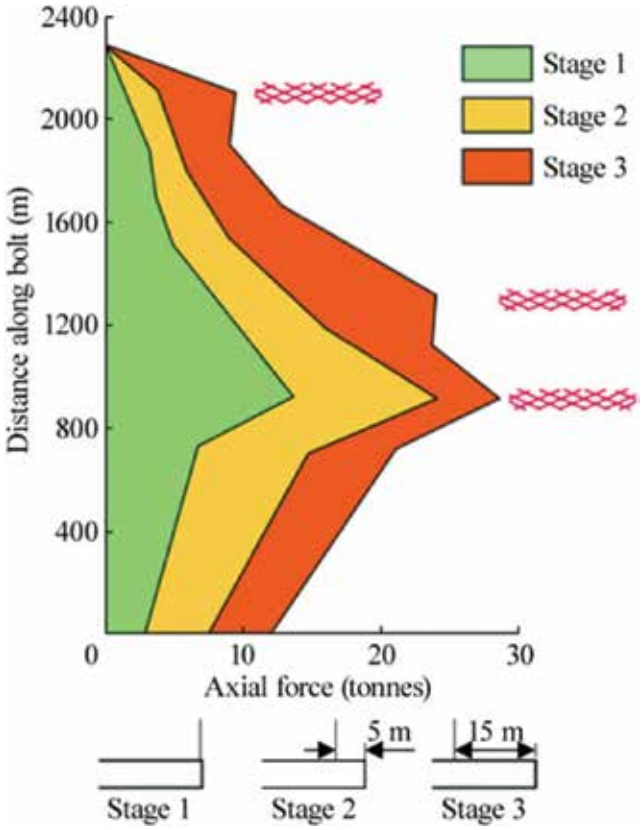

Figure 21: Typical axial load distributions measured in a fully encapsulated bolt[20].

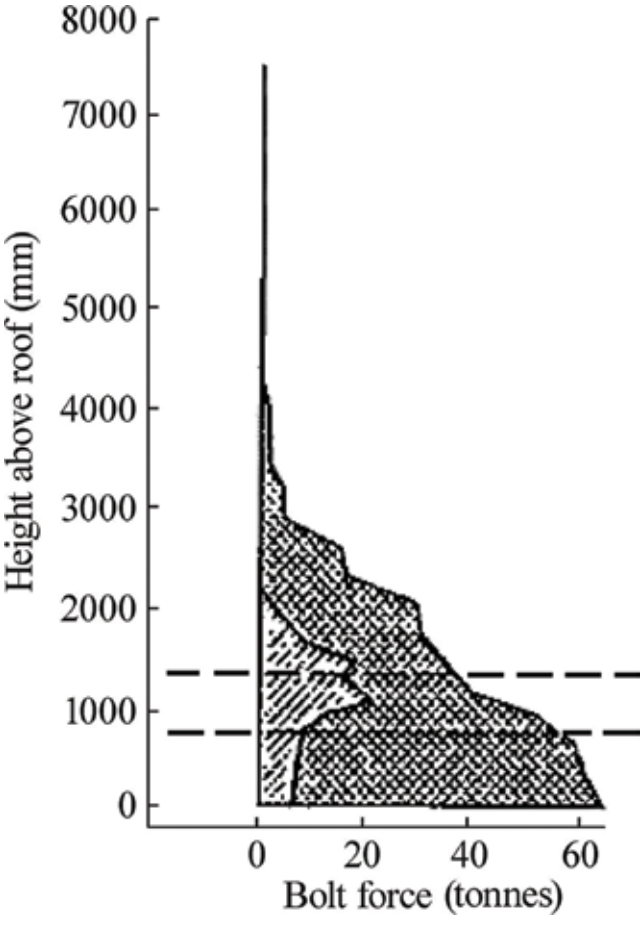

Figure 22: Combined axial bolt load v roof displacement profile measurements[21].

to primary roof reinforcement, preventing the opening of bedding planes in the first instance.

(b) While this has never been researched, the role of the plate in supplementing load transfer in the immediate roof is not clear-cut. The loading mechanism for the plate largely relies on relative movement between the strata and the bolt, whereas load transfer attempts to minimise such relative movement. The second graph in **Figure 22** clearly shows the bolt in yield above 1 m into the roof, but zero axial bolt load at the plate, meaning that the plate is presumably providing no direct contribution to overall load transfer.

(c) The base of the bolt is the most likely location for "sliming" the hole wall due to drilling through any overlying clay bands along the bolt length. This effect is rarely captured in short encapsulation pull testing but is known to significantly reduce load transfer strengths from those generated without hole sliming.

While load transfer has the proven ability to develop the full axial strength of an X grade bolt in the mid-section, it is significantly limited in the lower section, which is where the first potentially stabilising roof beam is located. Given the importance of this beam to overall roof stability, this is a less than optimum reinforcing outcome.

The maximum potential axial loading of a roof bolt via load transfer is typically limited to the middle portion of the bolt length. It is also at odds with the known stepwise progression of roof movement and associated softening starting at the roof line and incrementally moving up into the roof. **Figure 23** illustrates this data. **Figure 24** shows roof softening progression with displacement[22]. The logic here is that, if the immediate roof can be reinforced as a stabilising beam so that vertical movement is restricted, it will limit the upwards progression of roof softening. The higher into the roof that roof softening progresses, the less stable the roof is overall. Therefore, a higher level (length and density) of long tendon roof support is required to control the roof.

With a suitably designed nut and appropriately rated roof bolt plate, reinforcement of the immediate roof beam is best facilitated by bolt pre-tensioning to prevent bed separations, rather than load transfer, which relies upon bed separations opening. Furthermore, the inclusion of a defined bolt free-length to ensure that pre-tensioning is applied over a requisite roof beam thickness is beneficial when there is potential for increased roof fracturing in the upper section of the bolted interval due to the use of larger resin volumes to achieve full encapsulation.

SUMMARY

The paper demonstrates in select technical areas that the general beliefs of the Australian coal industry that current primary roof bolting systems are fully optimised are flawed. Furthermore, substantial improvements in reinforcing effectiveness can potentially be realised to benefit mining operations if geotechnical engineers and mine operators are prepared to embrace such a possibility.

To summarise, roof reinforcement improves when the reliability of resin mixing with varying hole diameters is substantially improved, gloving of the resin cartridge film is minimized, resin pressures generated during bolt installation are substantially reduced, the length of the bolted interval directly influenced by high resin pressures generated during bolt, installation is substantially reduced, roof bolt pre-tension levels are increased, roof bolt pre-tension is reliably applied across a section of immediate roof strata that is thick enough to be able to substantially and positively influence overall roof stability, load-capacity of the head plate is increased so that a greater proportion of the available roof bolt strength is mobilized, load transfer stiffness is substantially improved via the use of a modified resin system.

Mine Advice, in conjunction with DSI, has taken the view that there is substantial benefit to be realised if roof bolting systems are improved in each of these technical areas. The DSI-PEAK Resin Bolting System uses a partially rather than fully encapsulated bolt[23]. It is the first significant industry

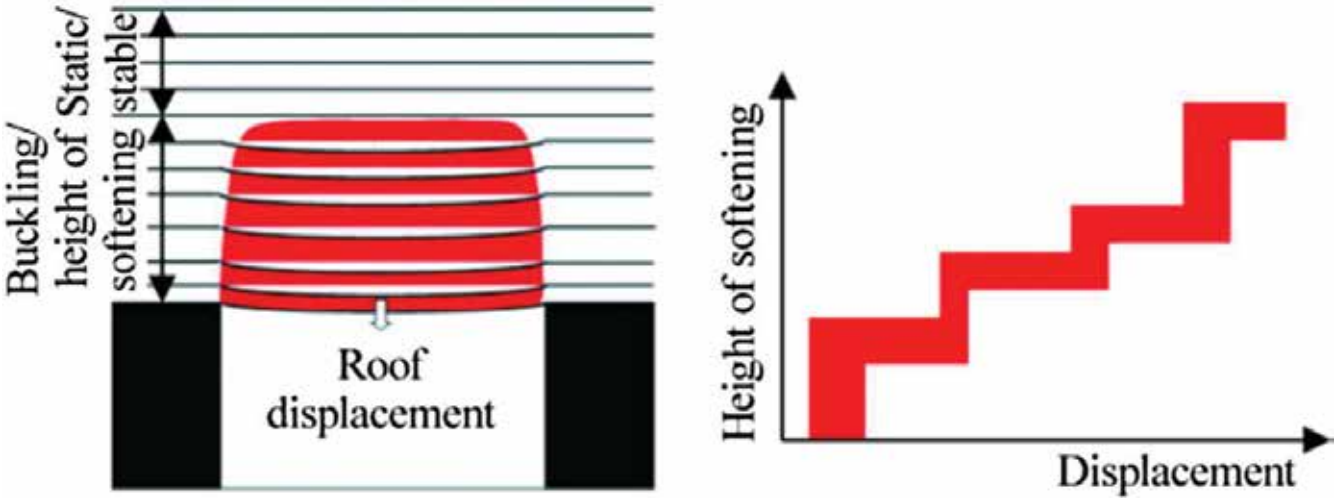

Figure 23: Schematic illustration of stepwise development of roof softening with increasing roof displacement.

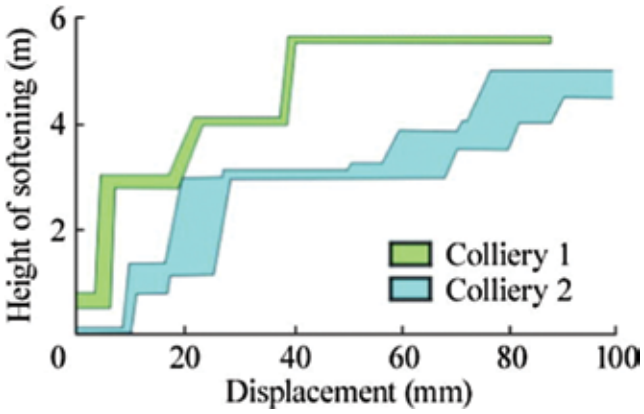

Figure 24: Field data–roof softening progression with Displacement[22].

initiative that has incorporated all of these various research findings into a more balanced bolt setup. The PEAK Resin Bolting System is being used commercially at several mines and has allowed a number of substantial operational improvements to be realised without any negative strata control implications. However, that is another story for another time[24].

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Remote mine waste storage facility oversight

Safety audits of operational waste rock dumps and tailings storage facilities (TSF) account for a significant proportion of the workload in the SRK UK and SRK Kazakhstan Mine Waste Engineering teams.

Mine operations have found ways to continue production despite the disruptions caused by COVID-19, which begs the question; ”How can the safety and integrity of mine waste storage facilities be maintained during lockdown?”. The human, environmental, and business-continuity consequences of waste storage facility failure are so significant, operators and stakeholders need to know: 1) if the facilities are safe; and 2) what the potential consequences of failure could be, so that preventative measures can be put in place.

In normal times, our engineers spend significant amounts of time travelling to mine sites, working with the Clients to understand the waste facility designs, construction/operational practices, constraints, performance and risks, so that we can provide appropriate advice or raise concerns where required. In response to the current travel restrictions, visualisation technology has enabled us to undertake remote inspections utilising satellite and drone image data to identify ‘areas of interest’, supported by local site based teams with survey equipment and high-resolution video cameras. The survey equipment is used to measure key metrics such as slope and beach geometry, which can be compared with the latest designs and monitoring data to assess performance of the facility. We subsequently collectively review the data via group video conferencing and can determine features requiring further investigation or areas of divergence in performance.

We have formed integrated teams with the Clients and Contractors where everyone is working constructively to overcome challenges rather than delay progress. Through the use of regular video/teleconference meetings, we have built up effective lines of regular communication which is allowing review of data as it is generated and modifications to the program based upon findings/progress.

Despite significant restrictions to travel, we have remotely provided TSF inspection and design review services to our Clients in Central Asia. We plan to use ‘real-time’ observations utilising live network-linked cameras on remote site locations once network coverage becomes available, and Qualified professional engineers will subsequently follow up these remote inspections with full Dam Safety and Operational Reviews (DSOR) in person.

In addition to TSF inspections, we are also undertaking remote supervision of waste rock dump foundation investigation works which are currently underway at remote sites with difficult ground conditions. Inspection of high-quality core photographs (with high pixel density) allows us to gain understanding of ground conditions as they are encountered and to modify drilling/sampling/testing/monitoring-installation as required.

Our Clients understand that these remote services cannot fully replace a site inspection or site supervision, but they see value in continued expert input during these difficult times.

A loud siren warning of a tailings dam breach should be the last line of defense. We should not rely on it alone, but if all goes wrong it may be the difference between life and death. Accordingly, and in conjunction with RST Instruments from Maple Ridge, BC, Canada, SRK has developed a new,

cost-effective system to trigger an alarm at the onset of an earthen dam breach.

Leading practice in tailings dam surveillance focuses on verifying whether performance and risk management objectives are being met. This practice is based on the premise that the early identification of deviations to expected dam performance will mitigate dam safety risks by allowing adequate time for the implementation of effective remedial actions. However, while putting effort into monitoring performance and identifying early signs of dam failures is recommended, some of the latest catastrophic tailings dam failures have demonstrated that in many cases information related to the root cause of the dam failure was available, but was either not understood or not interpreted in a manner leading to early warning alarms being raised. Many owners are therefore looking for a “last line of defense” – a system that can trigger an alarm and warn downstream populations of an occurring dam failure in hopes of preventing loss of life.

Unfortunately, many tailings dams are currently at unacceptable risk of failure and the associated risks must be mitigated and managed. The most effective means of alleviating a potential for loss of life is to relocate the population at risk. A supplementary strategy, if relocation is not possible or feasible, is to implement a siren system that will warn the population within the flood area that a dam has breached.

Nowadays, the majority of dam emergency siren systems are activated by a dam operator upon visual confirmation of a dam breach. Reliance on human intervention alone can result in a delay in triggering the alarm or, in the worst case, the alarm may not be triggered at all. SRK, together with RST Instruments, has designed and developed a simple and practical system that will set off a siren. The system comprises of several wire circuits buried in the dam crest that are connected to a datalogger, which is installed outside the dam embankment on natural ground. The datalogger verifies, at a very high frequency, whether the circuit remains uninterrupted and the wire is installed such that it will break immediately if the dam crest is mobilized due to a dam failure, causing the signal to the datalogger to be interrupted and the siren, in turn, to be triggered.

Our dam breach detection system is currently being installed in several high-risk tailings dams. The owner of these dams has relocated the populations most at risk and agreed with surrounding communities to implement the system as a last line of defense while the dams are being stabilised.

Richard Martindale (*SRK):Principal Geotechnical Engineer*
Jamie Spears (*SRK) Senior Tailings Consultant:, Remote Mine Waste Storage Facility Oversight*
Ignacio García *Schmidt(SRK) Senior Geotechnical Engineer*

Last line of defence – A dam breach detection system

Flender opens state-of-the-art testing and workshop facility in Perth, Western Australia

One of the biggest names in industrial drivetrain services, Flender, has opened its new state-of-the-art testing and workshop facility at the Tonkin Highway Industrial Estate in the Perth suburb of Bayswater. The 3,500 square metre facility enables Flender to combine sales, project delivery, engineering and training in one location in the first of its kind for Flender in Australia. It will also enable the company to expand its operations in Western Australia.

The facility is one of only a few in the world capable of servicing all makes and types of gearboxes and drive train components and is the only OEM facility on the west coast with a 1.5 MW load test bench capable of testing complete drive systems up to a voltage of 6.6KV.

Flender, a leading global supplier of mechanical drives, continues to grow in the region to meet increasing customer demand, especially in the wind energy and mining sectors. Kareem Emara, CEO and Managing Director at Flender Australia, said that the new facility in Tonkin Highway Industrial Estate enables Flender to centralise operations and offer more to customers in Western Australia. "It is also a vote of confidence in the Western Australian economy," he said.

"Our recent growth in Western Australia has been great and a testament to the quality of our products, service and technical know-how. As we continue to grow, we want to reinvest in this key market and be where our customers are to offer them the combined brains trust of over 50 facilities worldwide through this new state-of-the-art centre," Mr. Emara said.

Flender has the largest installed base of industrial drives in Western Australia. Some installations have been in operation since the 1970s and are still in service today in mine and port locations across the Pilbara and other regions of WA. The facility will also be designed to cater for projected growth in 'geared' wind turbines over the coming decades.

"Having been in WA for over 40 years, our view is and always has been long-term. Whilst COVID-19 has presented challenges to the economy, we have taken a long-term view and are confident in our expansion plans to help set up the right support structure for the nation's critical energy infrastructure and industries. We are supporting critical industries such as mining now and are preparing for future growth in other industries," added Mr. Emara.

This announcement follows the $5 million investment into Rockhampton service centre in 2017.

Anglo American contracts Ventia at Bowen Basin projects

CIMIC Group company Ventia has secured a contract with Anglo American to provide facility and asset management services at the company's Central Queensland metallurgical coal projects.

The four-year contract will see Ventia deliver services at Anglo American's Capcoal complex and the Moranbah North, Grosvenor and Dawson mines in the Bowen Basin region.

Ventia plans to provide services associated with the sites' accommodation villages and company housing, as well as the nearby Middlemount Aerodrome.

The company will employ more than 250 people across areas including town and site maintenance, property management, grounds and gardens, pest control, aerodrome management, security and safety services, industrial cleaning services, village catering and housekeeping.

Ventia group executive of defence and social infrastructure Derek Osborn said the company aimed to support Anglo American's employees' safety, health and wellbeing on site through its services.

"We are proud to have been awarded this facility and asset management services contract with Anglo American," Osborn said.

"We will provide a strong focus on asset lifecycle management and our technology platform will help us achieve this.

"This will be enabled by our ability to harness technology and provide a tailor-made solution to support Anglo American's facilities and assets."

The contract comes with an option to extend for an additional year at Anglo American's discretion.

It is expected to generate a total revenue of about $216 million for Ventia.

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Jobs set to be created on former site of Kellingley Colliery

Harworth Group has sold the first plot of development land at the former Kellingley Colliery to CRT Property Developments Ltd, a subsidiary of The Coalfields Regeneration Trust, as part of the site's long-term regeneration programme.

CRT Property Investments Ltd has acquired 3.04 acres that forms part of the main entrance to the site.

It plans to build small industrial units totalling 39,000 sq. ft to support the growth of small and medium sized businesses. Completion of the units is scheduled for September this year.

The deal forms part of Harworth's transformation of the 151-acre former colliery site into a new development called Konect, which will offer 1.45m square feet of manufacturing and distribution space.

Kellingley's closure in 2015 marked the end of deep coal mining in Britain. At its peak, the colliery employed more than 2,000 workers. Harworth took over the ownership of the site in March 2016.

The company has demolished all the redundant industrial structures including the site's two former pitheads. It received planning consent from Selby District Council for the re-development of the site in 2017 and intends to develop the site's remaining land over the next decade to create several hundred jobs.

Shaun O'Brien, Property Investment and Development Director at the Coalfields Regeneration Trust, said: "We are committed to providing high quality industrial accommodation for SMEs in coalfield communities. These areas are often overlooked by traditional developers, yet we understand the importance of these neighbourhoods and the positive contribution they can make to the local and national economy.

"With the right support and assistance, we are happy to

play our part in stimulating new industrial development at Kellingley.

"The development will provide much needed floor space to support the creation and safeguarding of much needed jobs and opportunities.

"We hope to replicate this development in many other coalfield areas. We are pleased that the land purchase has completed and we hope to work with Harworth again to secure further opportunities."

Chris Davidson, Associate Director of Harworth's Yorkshire and Central team, added: "This deal is excellent news for all parties, acting as the springboard to open up the site in both providing quality new jobs for local people in quality new spaces while creating a welcoming entrance to show that employment is coming back to Kellingley.

"The Konect re-development has enormous potential to support the rebalancing and decarbonisation of the UK economy and this deal will act as the catalyst to bring hundreds of new jobs back to site."

Imports at major ports fall 16% to 55 MT in Apr-Dec

Disruptions caused by the COVID-19 pandemic continued to impact cargo movement in India with thermal coal imports at 12 major ports declining 16.43% year-on-year to 55.16 million tonnes in April-December 2020 period, according to ports' body IPA.

Coking coal handling dropped by 12.13% to 36.96 MT during the April-December period of the current fiscal.

Coal volumes at the 12 major ports declined for the ninth straight month in December 2020, as per the Indian Ports Association (IPA).

These ports had handled 66 MT of thermal coal and 42 MT of coking coal in April-December period of the previous financial year.

Thermal coal is the mainstay of India's energy programme as 70% of power generation is dependent on the dry fuel while coking coal is used mainly for making steel.

India is the third-largest producer of coal after China and the US. It has 299 billion tonnes of resources and 123 billion tonnes of proven reserves, which may last for over 100 years.

In the wake of the pandemic, sharp declines were also witnessed in handling of containers, coal and POL (Petroleum, Oil and Lubricant), among other commodities.

India has 12 major ports under the control of the central government – Deendayal (erstwhile Kandla), Mumbai, JNPT, Mormugao, New Mangalore, Cochin, Chennai, Kamarajar (earlier Ennore), V O Chidambarnar, Visakhapatnam, Paradip and Kolkata (including Haldia).

These ports handle about 61% of the country's total cargo traffic. They handled 705 MT of cargo last fiscal.

Adversely impacted by the pandemic, these 12 ports witnessed a considerable decline in cargo traffic for the eighth straight month in November 2020.

Recently, Shipping Minister Mansukh Mandaviya said the cargo traffic at 12 major ports declined considerably from March 2020 onwards due to the adverse impact of the pandemic.

Hargreaves inventory sold to German joint venture

Hargreaves Services plc, a diversified group delivering services to the industrial and property sectors, has announced the sale of its entire inventory of specialty coal to its German joint venture (JV), Hargreaves Raw Material Services GmbH (HRMS), ending its material direct business interests in coal.

Hargreaves has sold all of the speciality coal held at its two UK stockholding sites to HRMS for a cash consideration of approximately £24 m. Hargreaves' remaining coal stocks comprise heavy industrial coal, which is expected to be sold to third parties over the remainder of the current financial year. The group expects to have no material coal inventory by 31 May 2021, the end of the current financial year.

Following the sale to HRMS, Hargreaves has entered into a sales agency agreement whereby Hargreaves will market and arrange for the sale of the speciality coal inventory on behalf of HRMS on a commission basis. Hargreaves will no longer produce or import coal and all material direct revenue streams relating to coal production or trading will cease, with HRMS taking over the trading in the UK. Hargreaves ceased all coal mining operations as of July 2020, as announced on 2 June 2020.

Hargreaves owns 49.9% of the voting shares in HRMS but retains an 86% economic interest. Building upon its existing expertise in coal and other bulk commodity trading activities in continental Europe, HRMS expects the purchase of Hargreaves' speciality coal inventory to provide a springboard from which to establish enduring trading relationships with major UK purchasers.

The transaction results in a £3 million impairment to goodwill relating to Hargreaves' coal trading business. The cessation of coal trading will reduce the group's projected revenue by £25 m and £30 m in the years ending 31 May 2021 and 2022 respectively, and by £20 m for subsequent years. However, the impact on underlying PBT is expected to be neutral as Hargreaves will benefit from a combination of reduced interest charges and a projected increase in its share of profits from the HRMS JV.

Following the receipt of the proceeds of the transaction, the group expects net debt at 31 May 2021 to be £15 m lower than its previous expectations, reflecting the fact that a proportion of the speciality coal stocks was projected to be sold before the financial year end in any event. Forecast period-end net debt is expected to comprise only leasing commitments with no net bank debt.

The transaction reduces Hargreaves' projected borrowing requirements materially and, by selling off all coal inventory, is expected to assist Hargreaves in establishing banking facilities which will be more appropriate for its future business needs. HRMS is independently funded without recourse to Hargreaves, other than a long-standing guarantee in respect of the borrowings of HRMS, which is capped at €5 m.

As Hilmar Eller, the Managing Director of HRMS, and other members of the HRMS management team hold in aggregate 50.1% of the voting shares and an effective aggregate 14% economic interest in HRMS, the directors consider that the transaction should be treated as a related party transaction pursuant to AIM Rule 13. Furthermore, in view of his position as a director of HRMS and although he has no direct economic interest in the transaction, Gordon Banham, the company's CEO, has chosen not to involve himself in the board's deliberations on the transaction. The Directors, other than Gordon Banham, having consulted with the company's Nominated Adviser, Nplus1 Singer Advisory LLP, consider the terms of the transaction to be fair and reasonable in so far as the company's shareholders are concerned.

Roger McDowell, the Chairman of Hargreaves, said: "The board is delighted to have unlocked the capital from its coal business, which was a key strategic goal, whilst supporting the growth of HRMS to deliver future shareholder value. This transaction represents a significant stride away from our legacy in coal as the group looks to build sustainable growth across our remaining revenue streams."

Don't shun coal as of yet

India should not crush its energy aspirations in a quest to follow the West, coal minister Pralhad Joshi said, adding the country should make maximum use of its coal reserves while shifting to cleaner forms of energy.

Joshi said some groups often irresponsibly argue to shun coal, without assessing its implications.

He said the second tranche of commercial coal mining will begin this month, at an event to mark the signing of agreements for pilot commercial coal mining.

According to the International Energy Agency and the US Energy Information Administration coal will continue to meet most of the world's increasing energy needs over the next two decades. The demand for coal is projected to increase substantially over the next several decades, he said.

"Ours is a growing country in terms of population and GDP. Still, it is noteworthy that our per capita CO2 emission is only 1.9 tonnes, contributing only 6.8% of global emissions. Since coal is the cheapest source to generate electricity and light up the homes of over 130 crore Indians, it provides the opportunity for achieving continual economic growth, increased incomes, higher living standards and poverty reduction," Joshi said.

Home minister Amit Shah said coal will be the biggest contributor to India becoming $5 trillion economy.

Joshi said presently about 19 major approval or clearances are required before starting a coal mine in the country. Single Window Clearance Portal is in the spirit of minimum government and maximum governance and would be a milestone for ease of doing business in the Indian coal sector.

In the absence of a unified platform for grant of clearances, the companies were required to approach different departments leading to delay in operationalisation of coal mines. Now, the complete process shall be facilitated through Single Window Clearance Portal in a phased way," Joshi said.

How China is fighting to survive in a greener world

The future of coal looks like an ice cream truck parked half a kilometer down a mine shaft in China's Shanxi province. The yellow and white vehicle is equipped with a 5G router from Huawei Technologies Co. to gather data for the mine's control center, where technicians monitor high-definition feeds on a screen the size of a two-story house. They're tracking temperature and methane concentrations while keeping watch over the black lumps zipping along conveyor belts on the way up to waiting trucks.

The data collection would previously have been done by workers down in the pit, but Yangquan Coal Industry Group has managed to eliminate some of those workers and virtualize the least appealing aspect of mine labour. "It will take time, but in the future, miners will wear suits and white shirts," says Han Weihai, manager of Huawei's mine projects in Shanxi. "People no longer want to work in a mine, especially young people with college degrees."

When President Xi Jinping announced in September that China would be carbon-neutral by 2060, he gave coal a four-decade transition period. Or even longer, perhaps, if China's vast and politically powerful coal industry can find a way to capture the planet-warming pollution generated by burning the fuel, or find other ways around the national policy.

The long transition buys China time to use up its vast coal resources and figure out how to gradually shut down an industry that still employs, directly and indirectly, tens of millions of people. Nowhere shows this high-tech trajectory for China's coal sector better than the Xinyuan mine.

Next-generation mining jobs there pay as much as 100,000 yuan ($15,000) a year. That's more than miners of previous generations could have dreamed of making, and for some workers, that's for sitting behind a desk in a college campus-like facility with a basketball court, pingpong tables and a library. The company organizes outdoor movie nights in the summer and running races in the spring and autumn.

The operation produces about 2.4 million tons of coal a year, less than a tenth of a percent of China's current demand. That much coal could generate as much as

5 million metric tons of carbon dioxide when it's burned, even as Xinyuan employs emissions-reducing techniques such as using methane instead of coal in its boilers.

Coal's long exit is part of a two-speed approach proposed by climate scientists at Tsinghua University. Citing the inertia of energy and economic systems, they proposed allowing coal power plants to continue being built until around 2030, when China will be richer and replacement technologies will have advanced. Then the plan calls for the ongoing transition to solar and nuclear to accelerate sharply.

Easing off coal slowly would reduce abrupt shocks that risk bringing unrest, the Communist Party's biggest nightmare, by dulling the inevitable pain to China's army of coal workers. "The industry will cut jobs, but it should be slow and gradual," says Wang Haigang, Xinyuan's deputy general manager. His mine had 3,000 workers in 2012, and by 2025 plans to have fewer than 1,000. "It may take a long time, but we're aiming for a future in which no workers need to work underground."

Keeping coal alive while reducing the number of miners may also solve a further headache for China, where climate policies governing 1.4 billion people are planned in Beijing but have to be implemented by dozens of local governments. The central government has long struggled with the question of how to get local officials to embrace plans for restructuring industries that many of those officials rely on for income.

New mining technology will allow provincial governments to keep earning money that could be used to develop post-coal industries. That's happening in Jinzhong, the city above the Xinyuan mine, which in 2018 invested 11.5 billion yuan ($1.8 billion) in a medical research center, an industrial park for logistics companies, and other major projects.

Chinese state-owned utilities are betting on coal's longevity by building new coal-fired power plants, with their fleets set to expand about 10% by 2025. Just last year, China opened the $30 billion Haoji Railway line, a 2,000-kilometer (1,243-mile) conduit to haul 200 million tons of coal a year directly from central mining basins to energy-hungry regions in the southeast.

But the coal industry and local governments that support it may be too optimistic about the remaining timeline. China needs to stop building coal power plants immediately if it wants to meet the 2060 pledge, according to the Draworld Environment Research Center and the Centre for Research on Energy and Clean Air. That goal would require whittling China's coal fleet down to 680 gigawatts by 2030, a reversal of the 1,300-gigawatt expansion currently planned.

The Shanghai Waigaoqiao Power Generator Company coal power plant | AFP-JIJI.

Before long, an uncomfortable truth could push to the forefront: China's national target of reaching net-zero emissions might not be compatible with another generation of coal.

The climate researchers and the coal industry envision two parallel universes. In one, the use of fossil fuels is drastically reduced and China pivots quickly to renewable energy. In the other, coal is phased out slowly as new technologies are used to reduce their environmental impact.

China's coal bosses know their regions may struggle to recover if the first scenario comes to pass. In the northeastern city of Fuxin, locals have been extracting coal since the 1700s. When the Communist Party took over in 1949, leader Mao Zedong made Fuxin central to his efforts to modernize the nation. Working the mines was an economic necessity but also a source of patriotic pride.

Coal owned the city. At its peak, more than 500,000 of the city's 700,000 residents either worked for the mining bureau or were family members. The bureau ran hospitals, schools, and sports facilities. Everything revolved around the Haizhou mine, the largest open-pit coal resource in Asia.

By 2005, easy-to-reach fuel was tapped out and the mine declared bankruptcy. Thousands of workers were dismissed with little money. For three days, they protested in the streets, lining the road that led to the city's administration, says Zhu Yu, who had been working at the mine for eight years at the time.

He eventually received severance equal to about three month's wages. After the mine went through a restructuring he managed to get a job there, with a severe pay cut. Older workers and those who couldn't pass a health check weren't so lucky.

"They had no other skills, no education, and no preparation. If the mine that they worked for all their life won't hire them, how could they expect other companies to?'' he says, gazing at the defunct mine, which has been turned into a museum. "We sacrificed our health and our youth for a job that's supposed to last our whole lives, but suddenly we're told the promise is no longer valid?"

Fuxin is still struggling to adapt. From the rim of the Haizhou pit, you can see wind turbines on a distant hill, sounding both a note of hope for the future and a death knell for the resource that built the city. Manufacturing and technological advances, driven largely by Chinese factories, have lowered the cost of wind and solar power to a point where they're competitive or even cheaper than coal without subsidies.

But assembling solar panels and wind turbine parts isn't generating as many jobs as mining did.

Sacks of coal at the closed Muchengjian coal mine in Mentougou.

Coal is loaded onto a truck at a port in Yichang, China, in 2001.

From Shanxi, where the high-tech mine is located, to such other heavyweight coal regions as Inner Mongolia, Shaanxi, and Xinjiang, local officials are trying to figure out how to avoid Fuxin's fate for as long as possible. In China, it isn't corporate dynasties like Koch Industries that are lobbying for fossil fuels, it's provincial party leaders and heads of state-owned enterprises. These local figures rely on the industry to generate jobs and economic growth, and to maintain their power and personal wealth.

They are people such as Chen Jinxing, the former chairman of China Datang Group, one of the country's biggest coal power generators. He started out as a worker at a coal plant in Shandong province and spent 40 years rising through the ranks at various state-owned power companies before becoming a top government adviser. In May, he told China Electric Power News, a trade publication, that coal should play a "foundational role" in stabilizing China's power supply to help "make sure China is self-sufficient and will never be controlled by others."

That's an argument the industry has used for years to lobby for more government support, and one that's gained credence as China becomes increasingly isolated on the global stage. At the party's annual legislative meeting in May, delegates from China's coal industry submitted proposals that centered on the fuel's role in providing "energy security," a term gaining popularity amid growing nationalism.

There's good reason for the coal industry to think it can find a way to coexist with the 2060 pledge. It's done it before. When Xi began pursuing more progressive climate policies five years ago, companies began upgrading their plants to trap more of the small particulates that generate smog, and to produce more electricity from every ton of coal they burn. Chinese power companies now brag that their best coal power plants are on the same environmental level as some gas-fired units.

They are also banking on technology breakthroughs in areas such as carbon capture and sequestration, which traps and stores the greenhouse gases emitted when coal is burned, to help achieve carbon neutrality. China is running demonstration projects using the expensive technology, and top researchers say they want scale up to offer an alternative to clean-energy storage as a reliable around-the-clock power source.

Climate experts are wary of both those approaches, which seek to mitigate carbon emissions instead of actually eliminating them. But it might be the best China can do in the foreseeable future. At least that's what Wang, the mine supervisor at Xinyuan, is hoping. Coal "cannot be replaced in a short period of time," he says, "even if it will one day disappear from our society."

Weak US thermal coal export recovery projected in 2021

In the Atlantic thermal coal export market, S&P Global Platts Analytics forecast a weak US recovery in 2021 as European import demand remains low and Russia looks to import more into Asia.

"The end-of-year rally in [Amsterdam-Rotterdam-Antwerp] prices dissipated early January, which does not bode well for a recovery in US thermal coal exports to Europe," Platts Analytics said in its forecast 7 January.

Platts CIF ARA hit a 21-month high of $70.25/mt at the end of December, following a jump of nearly $20/mt since the start of November. Since the December high, CIF ARA reversed its climb, experiencing some volatility as it dropped about $8/mt in the first week, before rising slightly to $67.70/mt, down 10 cents on the week, on 8 January.

Prices in the Atlantic thermal coal market are expected to correct slightly downward following the strong gains last month.

Through October 2020, US thermal coal exports to Europe total 2.5 million mt, down 65% year on year, while exports to Asia are down approximately 20% over 10 months at 11.2 million mt.

In 2021, Asia is expected to be the largest regional destination for US thermal exports, importing about 12 million mt-15 million mt. European imports, however, are forecast to "rebound only slightly in 2021 to around 4.5 million mt," Platts Analytics said.

However, Platts Analytics added, the projection has significant downside risk, similar to those for the US domestic thermal market, driven by cheaper alternate fuels and increasing coal generation retirements.

Elsewhere in the Americas, Colombian exports and production are expected to have a slow recovery, reliant on continued improving demand from the Mediterranean and Turkey markets.

Platts Analytics forecast 2020 coal exports of approximately 53 million mt with a recovery to nearly 59 million mt in 2021.

Russia, the other major coal exporter in the Atlantic market, is forecast to continue increasing its exports in 2021 to 174 million mt, up 16 million mt year on year, and to 184 million mt in 2022.

Platts Analytics "expect Russian producers will look to Asian countries to try and increase export volumes, particularly with the trade dispute between China and Australia."

India sees $55 billion investment in clean coal over next decade

India expects to invest 4 trillion rupees ($54.5 billion) in clean coal projects over the next decade as it seeks to tap domestic energy sources and curb imports, federal home minister Amit Shah said.

The investment will be made in clean coal facilities, including coal gasification and coal-bed methane, Shah said at a signing ceremony to develop new mines. He said coal power will be key to achieving India's ambition of becoming a $5 trillion economy, a goal he said would be reached despite setbacks due to Covid-19. Emissions from burning coal can be made cleaner but not totally erased.

India, the world's third-biggest emitter of greenhouse gases, expects coal to remain its dominant energy source for decades, even as large parts of the world shun the dirtiest fossil fuel, which is blamed for contributing to global warming and air pollution. The South Asian nation has defended its use of the fuel while also embracing large-scale renewable energy projects to transition to clean energy.

"We have to meet a target to become a $5-trillion economy, and for that, we have to exploit our coal reserves," Shah said to the winning bidders of India's first auction of coal blocks for commercial mining. "We should look at exploiting our coal reserves under the ground in the next thirty years to speed up economic growth. Looking at the rapid growth in alternative energy sources, the sooner we exploit these reserves, the better for us."

The investment in clean coal from state-run companies will be 2.5 trillion rupees, Shah said, accounting for almost 63% of the total. He said a roadmap has been prepared and 100 million tons of coal gasification capacity is planned by 2030.

Coal helped produce about 64% of India's electricity in the first half of the fiscal year ending March, although its share has been sliding with the growth in renewable energy.

"It is impossible to operate an industry or even grow crops without using some form of energy. And energy will continue to mean coal for several decades," coal minister Pralhad Joshi said at the same event.

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Fading, but not fast enough

The announcements at the end of last year came like a drumbeat: the Philippines declared a moratorium on new coal plants; at the Climate Ambition Summit, Pakistan's Prime Minister Imran Khan vowed his country would turn its back on coal; Bangladesh, Kenya and Egypt have all torn up plans for major coal projects.

These are only the latest blows for a thermal coal industry that is in terminal decline in Europe and North America. The sector has long looked to fast-developing Asian economies as a source of near-term growth, even as climate concerns make its longer-term outlook dismal. However, analysis of the ten countries with the largest pipelines of new coal-fired power plants (all of which, bar South Africa, are in Asia) shows a rapidly darkening picture for coal bugs.

Since 2014, the pipeline of planned coal projects in these countries has shrunk by around two-thirds, according to Global Energy Monitor, a US-based NGO that tracks coal, oil and gas projects.

"When it comes to policy decisions [and] the economics of power generation, it seems every day that the outlook for the coal industry gets worse," says Toby Hassall, lead analyst for coal market research at financial data provider Refinitiv. "It comes as no surprise to me that planned coal power stations that have been in pipeline for a number of years, in places like Vietnam, Indonesia, and India, are increasingly being cancelled."

This has contributed to a landmark for the coal-fired power sector; in 2020, the global capacity of operating coal-fired power stations shrank for the first time on record, from 2,055GW in 2019 to 2,048GW.

The proximate reason for this is the retirement of coal-fired power plants in Europe and the US. However, the more interesting story is in Asia, where key to the reversal of fortune for the coal sector (outside China, at least) has been the drying up of concessional, low-cost finance from South Korea, Japan and China.

"[Approximately] 90% of all coal-fired power plants built in Asia in the last five years were underpinned by export credit agency [ECA] finance," says Tim Buckley, director of energy finance studies at the Institute for Energy Economics and Financial Analysis (IEEFA). These agencies provide government-backed loans, guarantees and insurance to companies exporting to developing countries – in this case, underwriting billions of dollars of exports of turbines and other electrical engineering equipment.

As pressure has built on governments to address climate change, these spigots have been turned off. In July, Japan's government tightened state-backed financing of overseas coal-fired plants. South Korea is mulling legislation banning state-backed financiers and utilities from backing overseas coal projects. In October, state-controlled utility Korea Electric Power Corp. said it would no longer promote new coal-fired plants overseas.

And the biggest financier, China, is backing away from the sector. Most of its support to overseas coal projects was directed through its Belt & Road Initiative (B&RI), a trillion-dollar programme of investment in infrastructure across Asia and into Europe. However, faced with growing international unease about the programme – over, for example, overburdening developing countries with unsustainable levels of Chinese debt – Beijing has applied the brakes.

Lending from the China Development Bank and the Export-Import Bank of China, the two key conduits for B&RI funding, fell from a peak of $75bn in 2016 to just $4bn in 2019, shows a Boston University database.

Chinese exceptionalism

However, while China may be pulling back from overseas projects, it is expanding its own fleet. This is despite President Xi's historic announcement in September than the country would be become carbon neutral by 2060, and its earlier commitment to peak carbon emissions by 2030.

Global Energy Monitor tracked an increase in China's pipeline from 206GW in 2019 to 254GW in 2020.

Within China, a powerful coal lobby has allies in local government, where officials striving to hit GDP targets favour the quick wins possible from building large-scale infrastructure. However, the economic prospects for this new capacity are not good. Researchers at the University of Maryland forecast that, over the next five years, Chinese coal-fired capacity will grow 15% to more than 1,200GW. Given over-capacity in China's power system, coal-plant utilisation will decline from below 50% to below 45%.

"As over half of China's existing coal plants are already operating at a loss, lower utilisation will further undermine the performance and financial viability of the entire coal industry," according to the study from the university's Center for Global Sustainability.

These economic realities provide tailwinds for efforts to transition China's power sector. Dave Jones, senior electricity analyst at Ember, a climate and energy think tank, notes that the central government is promoting financial transition mechanisms by which the banking sector is encouraged to provide funding to coal-dependent utilities to instead build-out renewable energy.

"They are paying coal companies to transition," he says.

Jones is also anticipating the publication of China's next Five-Year Plan, covering 2021–25 and due to be unveiled in March, which is likely to further elaborate how the country will begin to move away from coal. "They are in the process of rewriting their Five-Year Plan and developing the policies to incorporate a net-zero pathway," he says.

A plateau in India

India, Asia's other coal giant, appears to have turned a corner. After years of growth, its coal fleet shrank slightly in 2020, while its pipeline is dramatically smaller than in 2014.

The immediate reason is a combination of over-investment in coal capacity ahead of the 2008–09 financial crisis, and low power demand growth subsequently, says Thomas Spencer, a fellow in the electricity and fuels division at the Energy and Resources Institute (TERI) in Mumbai. And, supported by falling technology costs and strong policy and regulatory support, rapid growth in renewables has met demand growth, and will continue to do so.

Equally, the structure of India's economy, which is dominated by agriculture and services rather than heavy industry and manufacturing, means it lacks China's powerful coal-based industrial complex, he says.

Now the hard part

There are certainly grounds to be optimistic that the pipeline of new coal-fired power plants in Asia will shrink further in the years to come. However, to stand any chance of meeting international climate targets, existing coal-fired generation will have to close, and rapidly. "Coal use needs to collapse 80% by 2030 to hit the 1.5°C target," says Jones at Ember, based on Intergovernmental Panel on Climate Change scenarios.

There are two elements to the transition: the first is shutting down coal; the second is replacing generating capacity with cleaner alternatives in the context of fast-growing demand, especially if countries are also going to electrify transport and heating. Energy markets consultancy Wood Mackenzie estimates that if China is to meet its carbon-neutral target and achieve this electrification, electricity demand will have to be 71% higher in 2060 than under its base case. That demand will require around 6,800GW of additional capacity.

This growth will require massive investment in renewables. If China is to decarbonise its power sector by 2060, it will have to begin closing down 40GW of coal-fired capacity, or fitting it with carbon capture technology, every year from 2030, says Trevor Sikorski, head of global gas and energy transition at Energy Aspects. "That is a big number," he comments.

Given the lower load factor of most renewable energy sources, replacing those plants would require four times the nameplate capacity, he says. As a point of comparison, China installed 56GW of wind and solar in 2019. "It is easy to close down three or four gigawatts of coal-fired power plants with the stroke of a pen, but it is much harder to get the 12–16GW of renewables that will be needed to get the same amount of power," Sikorski says.

Moreover, closing down coal-fired generation would imperil other sustainable development priorities, such as economic growth and electrification, argues Deborah Adams of the International Energy Agency's Clean Coal Centre. "We have to get to zero carbon, but it doesn't have to be zero coal," she says. The inability of renewables to provide baseload power, and the additional costs involved in integrating large volumes of renewables into electricity grids, means there is a place for high-efficiency coal power fitted with carbon capture and storage, she argues.

International investment

Buckley at the IEEFA believes that arguments about the costs of clean-energy related grid improvements miss the point for emerging economies. Unlike countries such as Australia or Germany, which face issues with outdated infrastructure built for incumbents, many countries in Asia are starting with a cleaner slate and are planning for huge growth. "If demand [for power] is doubling, they will need to rebuild their grids anyway. They might as well build grids that are fit for purpose."

Openness to international capital – both for transmission infrastructure and renewables capacity – will be critical to speed the transition. One factor behind India's dramatic growth in renewables has been the willingness of overseas institutional investors to acquire projects once they have a year or two of successful operation under their belts. This significantly reduces the cost of capital for their domestic developers, says Spencer at TERI.

The concern for environmental campaigners is that, rather than being replaced with renewables, coal is instead replaced with natural gas. This would be a disaster for the climate, argues Buckley, noting research showing that, in many cases, leaks in the extraction and transportation of natural gas makes it more carbon-intensive than coal.

Despite planned increases in gas demand in some countries, notably China and Japan, those concerns may be overdone, says Sikorski. Gas will grow in China, "but they are not going to replace 1,000GW of coal with 1,000GW of gas-fired power," he says. On energy security grounds, it will make more sense to use renewable energy resources than imported and potentially expensive liquified natural gas.

Analysts at Wood Mackenzie, meanwhile, predict nuclear will play a big role in closing the gap. In China, the company forecasts that the country's nuclear capacity will need to rise from 50GW at present to around 620GW by 2060. "This level of growth in nuclear reactor builds will be exceptionally challenging," writes Wood Mackenzie's Asia-Pacific vice-chair Gavin Thompson, "and will require comprehensive planning and decades of continuous resource commitment."

Nearer-term, there is an urgent need for policy frameworks that support renewables and discourage coal – or at least make it pay its way. Demand for Chinese-backed coal plants in India, Indonesia, Vietnam and Bangladesh is driven by domestic policy as much as it is enabled by Chinese finance, shows analysis from Tufts University and Fulbright University.

"In every case, there are explicit, preferential domestic policies for coal, and in at least one case renewables are disallowed by regulation from competing with coal on a level playing field," the researchers found. "It is crucial for recipient countries to put in place the enabling policy conditions for an energy transition to a low-carbon future."

There are clear lessons for Asia from experience in other parts of the world, says Christine Shearer, Global Energy Monitor's coal programme director. "In the EU, they are making coal plant operators internalise their external costs; not only pollution but, increasingly, their climate effects. If you just make that part of the equation for coal plants, then coal power, as we saw in the EU, disappears pretty quickly."

Russia deepens China ties with expanded energy exports

Eyeing an opportunity to strengthen energy exports to China, Russia has launched new ventures and pipelines that will deliver coal, natural gas and petrochemicals to the world's largest energy consumer.

One of these projects envisions doubling Russia's coal exports to China – enough to replace imports from Australia, with which China's relations have deteriorated.

Chinese President Xi Jinping and Russian President Vladimir Putin agreed to pursue greater cooperation across a range of fields, including large-scale energy and industrial projects.

Describing 2020 as an "extraordinary year," Xi said that "true gold can stand the test of fire, and the difficult period has given more prominence to the unique strength and great value of the China-Russia relationship," according to China's official Xinhua News Agency.

"By strengthening strategic cooperation, China and Russia can effectively resist any attempt to suppress and divide the two countries, and meanwhile forge a solid shield to safeguard international fairness and justice," he said, suggesting that the two countries form a united front against headwinds from the US and Europe.

Elgaugol, the company behind the Elga coal project in the Russian Far East, agreed on 15 December to launch a joint venture with China's Fujian Guohang Ocean Shipping (Group) that will export metallurgical coal to China. The Elga project is expected to ship 30 million tons of coal to China in 2023, which would almost double Russia's total coal exports to China from about 33 million tons in 2019.

The countries' co-operation on coal is partly intended to deliver a blow to Australia. China has imposed restrictions on several Australian exports, including coal, after Canberra called for an independent inquiry into the origins of the coronavirus outbreak.

About a quarter of China's coal imports came from Australia in 2019. Elgaugol Director-General Aleksandr Isaev said his company will replace most of the shipments to China from the US and Australia.

Russian petrochemical company Sibur Holding on 28 December also announced a joint venture at the Amur Gas Chemical Complex with China Petroleum & Chemical Corp., or Sinopec. Construction of the plant is

A compressor station for Gazprom's Power of Siberia gas pipeline in Svobodny, Russia: the state-run company is extending the pipeline to boost exports to China. © Reuters

expected to begin in earnest now that the companies have received the relevant approvals, and is slated for completion in 2024. Sinopec will own 40% of the facility.

The trend extends to natural gas as well. State-backed Gazprom has kicked off an 800 km extension of the so-called Power of Siberia pipeline, which began transporting natural gas from Russia to China in December 2019. The extension will connect the pipeline to the Kovykta gas field in eastern Siberia by the end of 2022, in a step toward Gazprom's goal of boosting flows through the pipeline to 38 billion cu. meters annually by 2025. Flows came to 3.8 billion cu. meters for the first year.

Gazprom, which holds a monopoly on the export of gas through pipelines, transported 200 billion cu. meters of gas to Europe and Turkey in 2019. But the company has been shifting its focus east, and last year began a feasibility study for another pipeline that would deliver 50 billion cu. meters of gas to China via Mongolia.

Russia also began operating a new oil pipeline to northeastern China in 2011.

As the world's top energy consumer, China has long enjoyed a complementary relationship with Russia, a key energy exporter. Their ties have become even stronger in recent months in the face of political pushback from the US, Europe and Australia.

Xi is rushing to diversify his country's energy supply, with the US only expected to increase its pressure on China under President-elect Joe Biden. Russia is a key part of his plan.

"Russia will play an even bigger role in China's energy security, given that tensions with the US are expected to persist over the long term," an industry insider said.

Russia, too, has also had to deal with harsh pushback and sanctions by the US and Europe since it annexed the Crimean Peninsula in 2014. With Europe also planning to significantly increase renewable energy use, the country is under pressure to boost exports to China in order to underpin its oil and gas industry. Xi and Putin aim to double bilateral trade to $200 billion by 2024, largely in natural resources.

But an increased focus on China comes with risks for Russia. Because much of Russia's exports are commodities like crude oil, gas and logs, experts say the country could find itself in a subordinate position to China economically. Russia struggled in price negotiations against China on natural gas exports, and an economic dependence on the Asian superpower could force Moscow to eventually compromise politically as well.

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