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Hoisting Systems
—New designs ensure safety, productivity and depth of wind

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Today's Hoists Reveal Tomorrow's Priorities

Recent projects leverage solutions that ensure future safety, productivity and depth of wind

By Jesse Morton, Technical Writer

An overhead crane moves equipment and parts during installation of possibly the largest production friction hoist in the world, at Oyu Tolgoi. (Photo: The Redpath Group)

Like a beacon flash parting the midnight horizon and warning of the shallows, the future announces its arrival beforehand.

In mining, in the hoist space, such was as much the case in the Witwatersrand Goldfields of the 1950s as it is in the Sudbury Basin and the Gobi Desert today. The projects and innovations of then and there, and here and now, shed light on the challenges and opportunities to come. Summaries of some major headline-grabbing hoist and hoist infrastructure engineering projects illustrate.

Deep Made Possible

Start with when Blair multi-rope (BMR) hoists were first deployed to deep South African mines in the late 1950s and early 1960s. The BMR features two independent, two-compartment drums and two ropes per drum, each of which attaches to a skip via its own head sheave. Coverage from back then reported "continuous equalization of rope tension is effected either by a simultaneous coiling or uncoiling of the ropes on a compensating drum attached to the conveyance or by movable headgear sheaves supported on interconnected hydraulic cylinders, which permit the sheaves to move in vertical guides."[1]

Compared to a single-rope drum hoist, the BMR featured at least double the rope. Compared to double drum hoists, "smaller ropes could be used," and the drums were of a smaller diameter.

The smaller ropes, drum and, in turn, motor, allowed for easier installation underground. With the skip load "distributed equally on two ropes, ... payloads can be increased, and deeper hoisting is possible."

By 1961, BMR hoists were deployed to South African mines operated by Anglo American Corp., Zandpan Gold Mining and Buffelsfontein. Anglo American installed one at President Brand

[1] "Blair Hoist Reaches Lower, Lifts More With Smaller Ropes." (1961, November). The *Engineering and Mining Journal*, 162 (11), 112.

that was "the first permanent-service hoist, ... able to lift a 10-metric ton (mt) payload from a depth of 5,250 ft at a maximum speed of 3,000 ft per minute (ft/min.)."

It was a glimpse of the future. Hoisting that tonnage, at that depth, at that rate, makes the BMR an increasingly attractive solution to head offices brainstorming on expansion projects today, according to Todd Kennedy, business development and general sales manager, FLSmidth.

"Although there is a large number of BMRs installed in Africa and put into service, other parts of the mining world are starting to realize not only the merits for BMR, but also the need for BMR," Kennedy said.

The uptick in interest and demand, he said, is due to "depth of wind and required payloads ruling out friction hoists or Koepes, and they are ruling out single-rope hoists." The BMR could help a miner "avoid a winze or a subvertical machine," he said.

Greater depths and payloads were among the capabilities that sold AngloGold Vaal River Operations, Glencore and others on FLSmidth-made BMR hoists in the recent past. That and the fact the supplier has manufactured the lion's share of the BMRs currently in operation worldwide.

Most recently, FLSmidth fulfilled an engineering, manufacturing and supply contract for four BMRs for the Mopani Deeps Project in Zambia. The hoists were cold commissioned in early 2017 and since have been on care and maintenance.

The hoists could help render the Deeps, as the 30-year-old Mindola and Mufulira copper mines are known, "feasible again," Francois Koekemoer, mechanical design engineer, FLSmidth, said.

A glance over the numbers reveals why.

The two rock hoists, one for each mine, each feature a 27.5 mt payload and a length of wind of 2,010 m. Conveyance speed is 3,600 ft/min. (or 18 m per second [m/s]), for a projected 20.27 skips per hour.

The two personnel hoists, one for each mine, each feature an 11 mt (135-person) payload and a length of wind of 1,940 m. Conveyance speed is 2,940 ft/min. (or 15 m/s), for a total of 5.5 trips per hour.

For all four, drum diameter is 5.7 m, the rope compartment width is 1.8 m, and the rope diameter is 51 mm.

The hoists are designed to be used 18 hours per day, 25 days per month.

They were selected because, of the types considered, the BMR best resolved the depth-of-wind and fleeting angle challenges. With the existing shafts at between 1,700 and 1,800 m deep and approximately 6.1 m in diameter, other hoist types theoretically could have been designed to suffice but would have come with potentially prohibitive tradeoffs and concerns.

The double drum hoist presented "handling problems of ropes in excess of 70 mm in diameter," the minimum legal size for that type of hoist at that depth of wind, FLSmidth reported in a white paper.

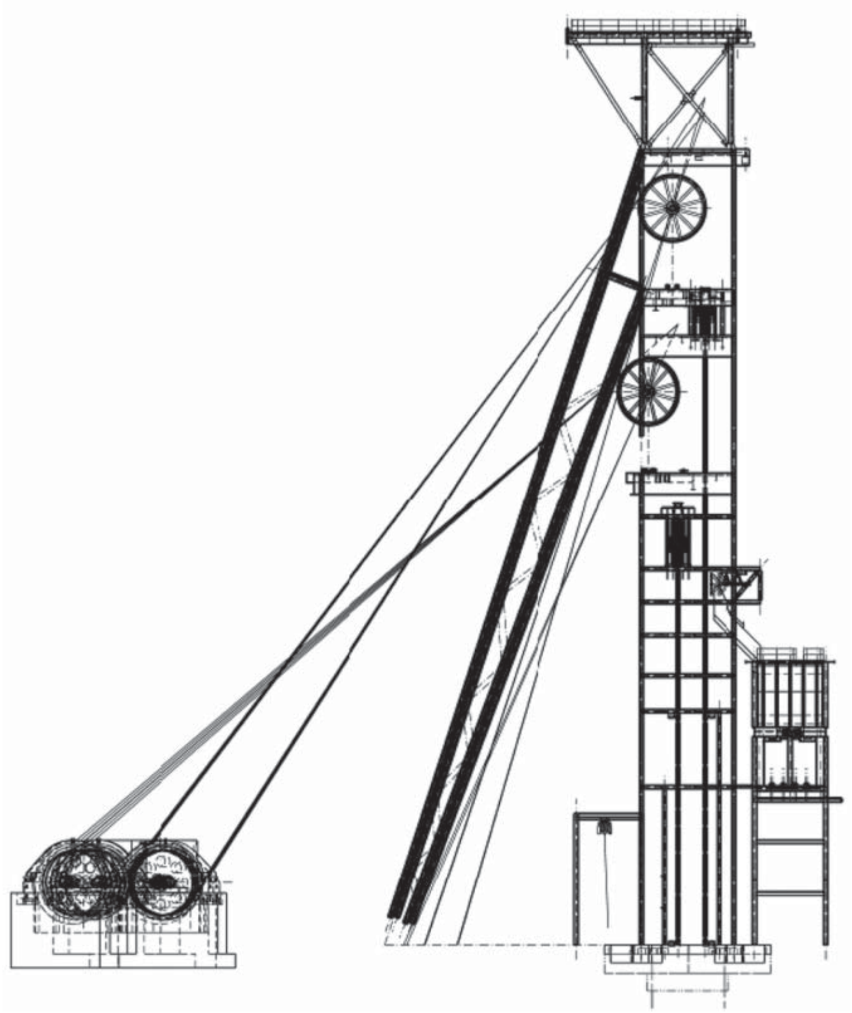
A multi-level Koepe (friction hoist) solution would mean longer and more complex rope change-outs, shorter rope life, more expensive headgear, and, importantly, at that depth of wind was without precedent in Southern Africa.

"One of the advantages of Koepe is it is multi-rope, and therefore very heavy payloads," Kennedy said. "But rope-life limits the depth of wind, so it gets ruled out below 1,500 m or thereabouts."

The BMR solution introduced compensating sheave requirements, higher capital costs, and higher peak power requirements.

In the end, it was the main challenge of depth of wind that forced the selection of machine into the BMR category.

FLSmidth offers four types of BMR: a geared, an inline configuration, a Hooke's joint, or an electrically coupled



A sketch of an FLSmidth BMR hoist installed at the Mopani Deeps Project in Zambia. (Image: FLSmidth)

BMR, like the one selected by AngloGold for Moab Khotsong.

For the Deeps, each was considered. The geared configuration was ruled out due to the large drum and expensive components. The in-line configuration was eliminated due to drum width. The electrically coupled BMR had a higher capital cost, heavier components, and would use more energy. "Due to the head gear layout, the head frame layout and the hoist house arrangement, a Hooke's joint-type BMR was required to solve the fleeting angle challenges," Koekemoer said.

The typical Hooke's joint solution is comprised of three parts, two yokes and a center block, or spider, FLSmidth reported. "The Hooke's joint used as a single joint will transmit nonuniform motion between input and output shaft," the company reported. "The variation in angular velocity at the output shaft is a function of the angle between both shafts; a method to mitigate this attribute is to make use of a double joint."

The design allowed the drums to be positioned asymmetrically, which saved space.

Installation of the hoists required overcoming significant logistical challenges, Koekemoer said. "All service assemblies are trial-assembled in the manufacturing shop in the Vienna-Johannesburg area of South Africa but then taken apart and shipped piece by piece, and then assembled on site as the machine progresses," he said.

Road conditions were less than ideal. "The drum shafts for these machines weighed in excess of 61 mt," Koekemoer said. "Transporting those by road was quite a challenge" and not entirely without incident.

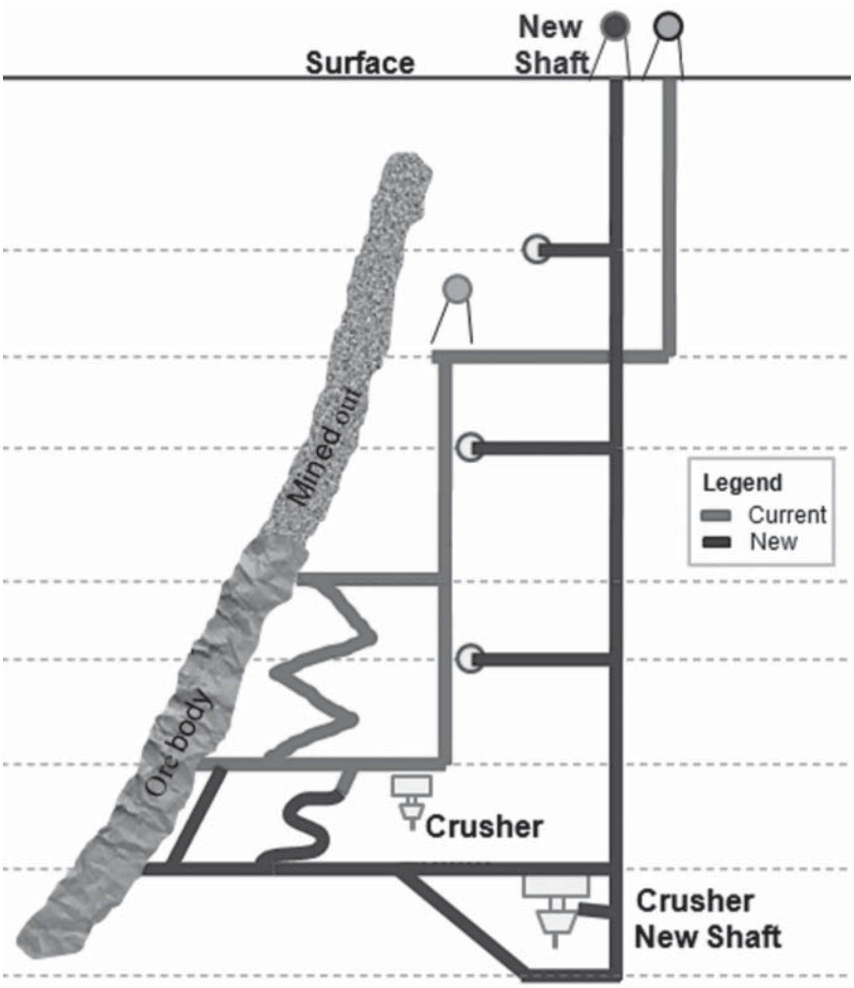
During the staged assembly that followed, the FLSmidth team was limited to use of a single overhead crane. "Since the pieces of the drum, the drum shaft, the motor rotor, the motor stator are all considered the heavy-lift components, the timing had to be well-planned," Koekemoer said.

Which it was, with the result that the hoists were installed on time, within the budget, and with the miner "all happy," amounting to "quite an achievement," Koekemoer said.

Annual production at Mindola and Mufulira will eventually target 3 million mt per year, a goal the hoists enable the miner to attain, Kennedy said. "These are impressive machines in terms of speed and connected power and that sort of thing," he said.

They are also harbingers of the future of deep underground mining, Kennedy said. "There is a marked increase in feasibility studies going on for BMR applications," he said. "Five or ten years ago, you'd seldom see a request for a BMR; these days they occur several times per year."

Ultimately, that work at some point flows back to where BMR hoisting began. "It is a solution that has been developed by FLS over many years, and South Africa was the first country to go to those levels and to have such a number of machines installed," Koekemoer said. "The solution is there," he said. "The problems of deep shaft mining just need to start in those other areas."



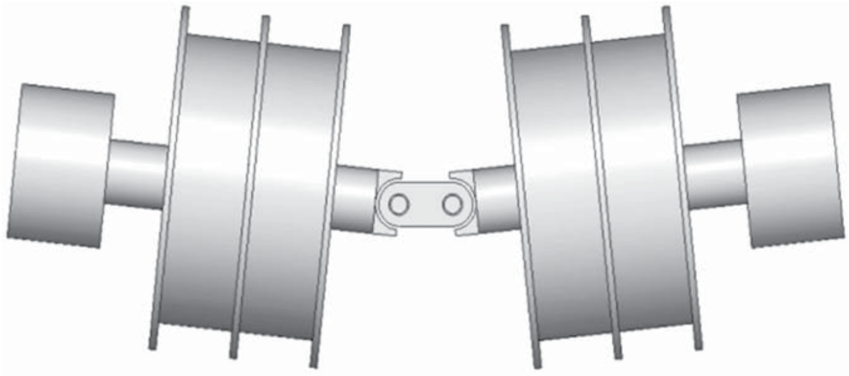
A mining flow diagram for both mines at the Mopani Deeps Project in Zambia. (Image: FLSmidth)

Enabling Safety and Savings

Another brownfield project reportedly launched by a miner seeking to counter the effects of dwindling reserves is the Onaping Depth nickel-copper project in the Sudbury Basin. There, Glencore is investing $700 million into developing a precedent-setting all-electric mine, accessible from a pre-existing mine's infrastructure and targeting 14 million mt of nickel ore situated roughly 2,500 m down.

The project has received heavy press coverage, with a focus both on the projected depth and the hypermodern technologies expected to be deployed there.

Most recently, Nordic Minesteel Technologies Inc. (NMT) was contracted to "provide all of the shaft equipment, to include skips, cages, safety arrestors, catch gear, as well as all of the required wire rope sheaves for sinking produc-



A FLSmidth Hooke's joint BMR hoist solved fleeting angle challenges at the Deeps. (Image: FLSmidth)

tion and service," Jim Brownlee, P.Eng., sales and product manager, shaft equipment, NMT, said.

NMT's compensating sheaves, a relatively recent addition to the company's equipment portfolio, are designed to answer BMR-type application design challenges related to safety, performance and maintenance costs, the company reported. "It is normal for the wire ropes to stretch over time and they may stretch at very different rates," Brownlee said. "Our sheaves compensate for this hydraulically by maintaining a common pressure between the two supporting cylinders," he said. "The system includes features which adjust the sheave levels and also interlock with the hoist controls."

At Onaping Depth, NMT will face challenges now proving common to deep mine expansion projects. Adhering to a strict order of operations will be key.

The new subvertical shaft, or winze, will be accessed via the existing shaft starting at roughly the 1,200-m level. The winze will be raisebored down 700 m and then extended further to roughly the 2,700 m level with conventional shaft sinking.

"This means all of our equipment must be modular for disassembly and transport to the winze," Brownlee said.

Additionally, the mine is widely reported to feature relatively small openings. "The necessary openings are reduced due to a lower ventilation demand for electric mobile equipment," Brownlee said. That means less space for both NMT's equipment and the transportation of it, he said.

"This creates an additional level of complexity as the pieces must all be re-assembled underground and some of this equipment is very large," Brownlee said. To accommodate the NMT team, Glencore will "excavate a shop for assembly and maintenance," he said.

The adoption of a BMR solution at Onaping points to a future wherein, among other things, greater safety is prioritized, Brownlee said.

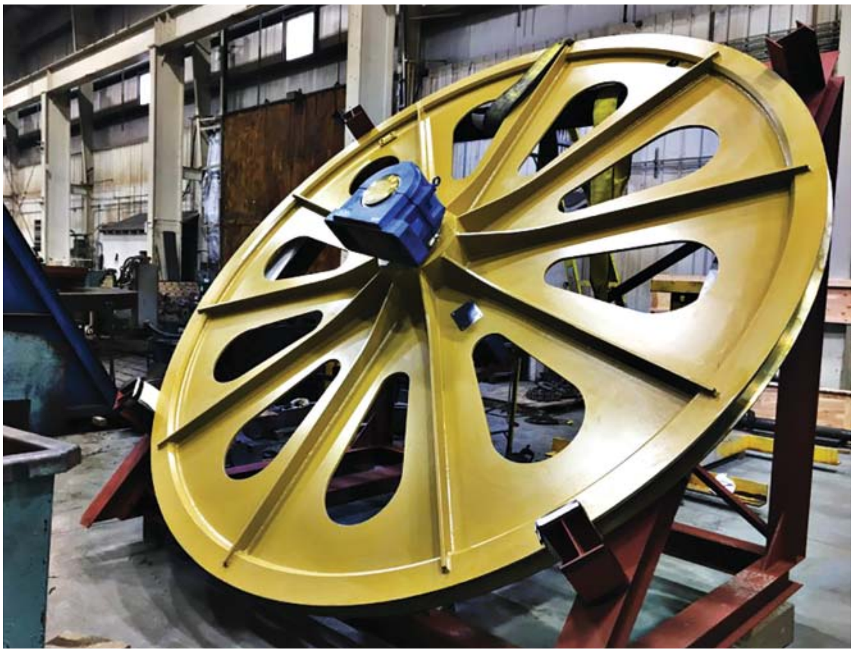
"In Canada, we must provide a safety mechanism that will stop a free-falling conveyance with an acceleration between 0.9 and 2 gravities," he said. To date, the requisite solutions are only available for wood guides, Brownlee said. Wood guides "are expensive and require continual maintenance" and regular replacement, he said. "By using the BMR arrangement with two ropes, if there is a failure of a rope or attachments, the second rope satisfies our Ministry of Labour, and we are allowed to use steel guides, which require minimal maintenance and typically last the life of the mine," Brownlee said. "Which amounts to a great savings for the mine long term."

Possible savings and increased safety are part of the reason why Kirkland Lake Gold recently tapped NMT to supply sinking sheaves, service sheaves and production sheaves for the mine's planned Macassa Shaft No. 4.

The miner reported the four-compartment shaft will be 21.5 ft in diameter and concrete lined. It will initially sink to a depth of roughly 5,500 ft, and from there will be extended to reach 7,000 ft. Projected hoisting capacity is reported to be in the 4,000 mt/day (mt/d)-range.

The service sheaves NMT will supply for Macassa Shaft No. 4 "are a compensating-type sheave very similar to that supplied for the Glencore ODP Mine," Brownlee said. The production sheaves are "larger than typical" for mines in the Abitibi gold belt. "They are just under 18-ft in diameter." Anything over 16 ft is considered large, he said. "We can produce sheaves up to 26 ft in diameter."

Helping bring BMR-solutions to North America and partaking in the development of precedent-setting mines is par for the course for NMT, Brownlee said. "These projects are demonstrations of Canadian leadership in this in-



NMT's gold head sheave, above, can be designed split for ease of transportation and installation. (Photo: NMT) dustry," he said. "We are proud to play our small part in this project."

Ensuring World Class Ops

In 1957, the year the BMR was invented, two production friction hoist systems were delivered to two Canadian mines, Madsen Red Lake Gold's Austin shaft and Falconbridge Nickel's No. 9 shaft.

The Austin shaft hoist, using 32 mm ropes, would operate two skips, each with a rated capacity of 8.2 mt. The No. 9 shaft, using 29 mm ropes, would operate one skip with a rated capacity of 7.7 mt.[2] At the time, that was state of the art and those were heavy loads.

Fast forward to today, where perhaps the largest production friction hoist in the world, with a rated capacity of a whopping 60 mt, is being installed by Dayan Contract Mining (DCM) for the No. 2 Production Shaft at the Oyu Tolgoi copper mine in the Gobi Desert in Mongolia. DCM is a joint venture comprised of Redpath Canada Limited and Mongolia's Hasu Megawatt. Oyu Tolgoi is operated by a joint venture that includes primarily Rio Tinto and the Mongolian government.

In mid-January, Redpath announced the completion of Shaft No. 2 sinking operations. The shaft is 10 m in diameter and 1,284 m deep. It will be used for both skip and service hoisting and will support the South Hugo Dummett block cave mine.

The shaft was sunk blind by a surface-nested, ground-mounted 8-boom jumbo drill. A three-stage sinking Galloway supported the equipment and personnel, and a conventional 15-ft-diameter double-drum hoist operated 16-mt muck buckets. Digging up almost 135,000 m³, it was Redpath's "largest excavation by volume" and for it, DCM "employed approximately 200 Mongolians," who comprised 75% of the shaft sinking workforce, Redpath reported.

From there, DCM "eagerly" began "the task of installing the largest friction hoist in the world," which will be completed by

[2] "ASEA Friction-Drive Hoists Delivered or Under Manufacture for Mines in the U.S. and Canada." (1957, Mid-June). The *Engineering and Mining Journal*, 158 (6a), 38, 39.

The Dayan Contract Mining team leveraged a three-stage Galloway during the sinking of the No. 2 shaft at Oyu Tolgoi. (Photo: The Redpath Group)


An 8-boom jumbo drill penetrates rock in the bottom of the developing No. 2 shaft at Oyu Tolgoi. (Photo: The Redpath Group)

a workforce of 156, including 139 Mongolian nationals, Scott Hayne, vice president, Redpath Canada Limited, said.

Both the production hoist and its sibling service hoist are ABB technology, tower-mounted, and feature a nominal drum groove diameter of 7.2 m and 6.75 m, repsectively.

The production hoist features a rated motor output of 9.9 megawatts (MW), a rated speed of 46.3 rotations per minute (rpm), and is designed for a production rate of up to 30,000 mt/d.

The service hoist features a rated motor output of 2.875 MW, a rated speed of 28.3 rpm, and a 24.3-m^2 service cage with a capacity of 300 men, for a possible conveyance output of up to 1,800 men per day, plus materials and equipment.

Agnico Gets ABB Hoists for Kittilä

Agnico Eagle's Kittilä gold mine, in the far north of Finland, contracted ABB for a 2.5-megawatt (MW) friction hoist, a 1.2-MW single drum service hoist, and real-time hoist condition monitoring for a new shaft.

The hoists and the shaft will enable the miner to "utilize the deeper parts of the deposit in an economically viable way," ABB reported.

Leadership at the mine described ABB's solutions as indispensable. "The hoisting machine is a new critical factor in the mine production chain," Seppo Voutilainen, project manager, Agnico Eagle, Finland Oy, said.

The hoists will be the first deployed to the mine, which is undergoing a $186 million expansion project. The project will result in greater energy efficiency at the mine, which is eliminating truck- and off-road-vehicle-transport of ore and personnel, ABB reported. The processing capacity of the mine's concentrating plant will increase from 1.6 million to 2 million metric tons per year.

The Kittilä mine is the largest gold mine in Europe.

ABB has delivered over 700 mine hoisting systems all over the world.

Each remaining project milestone represents a significant amount of work. The equipment must first be moved from the yard to the headframe, hoisted up the headframe and then moved to the required levels. Next is the alignment of the stator and bearing sole plates. The bearings, stators and hoist drums are then installed, followed by the alignment of sheave tools, the installation of the sheaves, final alignments and commissioning.

The primary challenges arise from logistics and synching multiple teams, Redpath reported. Added to the mix is a young workforce hungry for experience, which they are getting, Hayne said. For example, "this is the first time we've used a 70-mt flatbed transporter," which incorporates mutli directional tramming functionality, he said.

Secondary challenges were related to climate, geology and the remoteness of the site, Hayne said, citing seasonal swings of from -40°C to 40°C. "This summer we had record rain falls, which is highly unusual, bringing washed out roads, strong winds and dust storms."

To answer, DCM tapped lessons from Redpath's history, allowing it to "anticipate potential issues and provide solutions in a timely manner," Morgan Aspin, project manager, Redpath said. DCM developed "specialized work teams and internal task forces," worked "closely with suppliers," and honed plans to ensure the alignment of the efforts of the separate teams and stakeholders, he said.

The result is a mine site that, despite its location, "is actually world class with world class equipment," Aspin said. "It is an extremely safe project." That achievement he attributes to "teamwork from all parties working as a unit, rather than separate, towards a common goal."

The goal of commissioning the hoisting plant will be symbolic of a possibly brighter future for the locals, Hayne said. History could one day reveal the increase in overall mine production, with the inclusion of Shaft 2, to be "Mongolia's economic turning point," a testament to emergent and spreading modernity that could one day "improve the quality of life of the people," and give "them the opportunity to grow at an international level."