Successful shafts

Hoisting remains the most efficient means for transporting crushed ore to the surface from below ground, in many applications. And, mine hoists are often the only way of conveying staff and equipment up and down.

Technology in mine hoisting is advancing to address a combination of higher capacity requirements, deeper hoisting depths and faster winding rates. New records in shaft sinking are being set in Mongolia at the Oyu Tolgoi copper mine. Ivanhoe Mines established a new national record in the country with a 6.7 m diameter shaft over 1 km deep at the Oyu Tolgoi project. JS Redpath’s shaft sinking team worked 24 hours a day for 18 months to reach the 1,000 m mark. The completion depth of 1,311 m for that shaft was achieved in September 2007. This made Shaft #1 the deepest in the country, but Shaft #2, at 10 m, will be one of the largest diameter shafts in the world.

“It takes a highly skilled team working at peak performance to achieve such an objective,” John Macken, Ivanhoe Mines President and CEO said at the time. “Shaft sinking is one of the most demanding jobs in mining and I congratulate the team for the excellent job it is doing. Mongolian miners, most of them trained at Oyu Tolgoi, are opening the door to a new era of development.”

Hepburn Engineering has supplied four 50 t rope-pull shaft sinking stage winches to sink Shaft #2 at Oyu Tolgoi. Hepburn also supplied a 4,475 kW DC drive and control system for the production hoist in Shaft #1. Hepburn designs and builds mine hoists and electrical controls for applications from shaft sinking up to the largest production capacities. It is one of the only hoist suppliers providing fully mechanically and electrically integrated drum and friction hoisting plants from a single source. With mechanical, hydraulic and electrical components, controls and operating software, all coming from a single design office, Hepburn provides complete design integration and system responsibility.

Just over a year ago, Cementation achieved a significant milestone in North America. Without incident, first aid, medical aid, or lost time injury the mine contracting and engineering firm completed work on the longest and largest diameter raise ever bored in the Canadian Shield. The project, a contract for Goldcorp’s Red Lake gold mines in Ontario, resulted in a bored raise that is 694 m long and 5.52 m in diameter.

“Delivering the potential of larger diameter bored raises to clients provides them with new options for mine access and ventilation systems.” Cementation President Roy Slack said at the time.

Cementation completed the second raise directly over its first record setting raise completed early in 2007, making the...
Esterhazy’s hoist control system is based on ABB’s industry-leading AC800M industrial controller, itself a key component of ABB’s flagship automation platform, System 800xA. Also the ABB Hydraulic Disc Brake System with controlled retardation ensures the same safe braking force in all operating situations (direction, speed, load and friction). The result is a mine hoist system that is the recognised benchmark in the global industry.

combined length of the 5.52 m diameter vent raise 1,010 m long.
A good technical paper on the design of mine shafts is one produced last year by Dr Isadore Irvin Matunhire, previously of the Department of Mining Engineering at the University of Pretoria, South Africa, and now working for TWP Consulting (see the table on the next page).

Hoist systems

Speed, reliability and safety are essential in the demanding round-the-clock process of shaft operations. The efficiency of the hoist system determines the mine’s productivity and eventual profitability. ABB’s showcase hoist systems include installations at Kiruna iron ore mine in Sweden, operated by LKAB, and a Mosaic potash mine in Saskatchewan, Canada.

The Kiruna mine is the world’s largest underground iron ore mine and its 11 ABB mine hoists make it the largest hoisting plant in the world, ABB says. ABB is currently upgrading the four underground hoists and has supplied a seventh surface hoist to enable LKAB to boost production capacity by 25% to 33 Mt/y of crushed ore.

Mosaic’s Esterhazy mine is one of the largest potash mines in the world. ABB recently upgraded one of two production shafts to increase skip capacity by 50% and boost mine production by 1.1 Mt/y. The 8.6 MW motor and drive solution - the most powerful hoist system in the world - has improved energy efficiency at the Esterhazy mine by an estimated 5-8%. Despite its huge size and power requirements, it maintains grid stability.
without the need for additional power correcting equipment.

At the heart of the ABB mine hoist system are three powerful ABB technologies. First is the ACS6000 AC drive system, which controls the torque and speed of the giant AC motors. Even though hoists require huge amounts of electricity, the drive system has negligible impact on the surrounding power network and does not affect power quality for other consumers.

ABB also has an impressive track record in

---

**Shaft selection criteria**

<table>
<thead>
<tr>
<th>Shaft type</th>
<th>Selection criteria</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
<td>Steep dipping orebody, Deep orebody</td>
<td>Quick access to deep orebody, Efficient at depths exceeding 500 m, Cheaper per metre as depth rises, Early return on investment</td>
<td>Highly skilled labour, High labour cost, High initial capital cost, High maintenance cost, Require headgear, Limited hoisting capacity, Require constant power supply</td>
</tr>
<tr>
<td>Decline</td>
<td>Flat dipping orebody, Shallow orebody</td>
<td>Can be mined in the strike or dip direction of choice, Easy access to shallow orebody, Low initial capital costs (no headgear), Low operating costs, Construction skills and equipment readily available, High hoisting capacity with conveyor belts</td>
<td>Longer distance to orebody, Only economical to 500 m vertically, Excessive travel time to orebody, Trackless hauling is slow and congested, Heat pickup from rock over length, Slower return on capital invested, Water handling can be problematic</td>
</tr>
<tr>
<td>Inclined</td>
<td>Flat dipping orebody, Shallow orebody</td>
<td>Limited development to orebody, Short ore pass system required</td>
<td>Derailments, Shaft maintenance &amp; repairs time consuming, Spillage cleaning is time consuming, Limited hoisting capacity</td>
</tr>
</tbody>
</table>

From: *Design of Mine Shafts* by Dr Isadore Irvin Matunhire

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Canada’s Sudbury Basin and is currently involved in significant projects for the two mining majors operating there: Xstrata and Vale Inco. Xstrata’s Nickel Rim South mine is scheduled to achieve full annual production capacity of 1.25 Mt/y of crushed ore (containing nickel, copper, palladium and platinum) in 2009. ABB has supplied four mine hoist systems for the main production shaft, service shaft and two auxiliary hoists.

ABB is Vale Inco’s electrification, hoisting and automation partner for the Totten mine project. Vale Inco’s reopening of Totten is a $400 million project on which work began in 2007, with production scheduled to commence in 2010.

ABB Canada’s scope of supply for Totten mine includes a full suite of power and automation solutions, starting at the surface 69 kV substation with high voltage breakers, relay protection and control; medium voltage switchgear; a microSCADA system; a remote control connection to the Vale Inco Power Department; two mine hoists — one medium voltage and one low voltage; and all motors, drives, motor control centres and instrumentation throughout the mine surface plants and underground. Underground airflow and quality will be controlled with a state-of-the-art ventilation on-demand system (VODs). Also supplied are underground mobile substations and underground field bus connected devices and controllers.

The entire scope of supply is seamlessly integrated together with ABB’s Industrial IT - 800xA automation system. The VODs under the scope of ABB will use advanced real time asset tracking technology and intelligent airflow systems for optimal performance. The system is designed to dilute and remove hazardous substances, control the thermal environment, and provide oxygen for humans and mobile equipment engine combustion. The VODs will optimise energy management of the entire mine through automation.

“ABB has enabled innovation in our core business on the Totten project,” said John Sagman, Vale Inco Senior Project Manager.

In 2006 a consortium consisting of the Siemens Industrial Solutions and Services Group (I&S) and Siemens modernised the mine winder at K+S Kali’s Werra mine. The winder was fitted with a new friction drum with an integrated motor, including a cycloconverter, transformers, cooling systems and a power supply system. Control and safety systems, the shaft signalling system and a new brake with control unit were also part of the order, valued at about €5 million.
“ABB has brought the latest technology and expertise forward as their contribution to our unified project team.”

Siemens International recently received an order from the Shandong Yuncheng coal mine to supply the drives, automation systems and braking systems for three new shaft hoisting installations. The project is worth more than €10 million. These hoists are scheduled to start production in spring 2010.

For the new winding machines, Siemens is supplying the drives, the automation equipment, including a safety system as well as the braking systems. Each of the winding machines will be fitted with a 3,500 kW synchronous motor and, for the power supply, DC link voltage converters of the type Sinamics SM150, each with an output of 10 MVA, will be used. Simatic S7-400 programmable logic controllers will form the heart of the automation system. The drives will be controlled by means of the FM458 Simatic application module. For safety reasons, the control and monitoring system will have a two-channel design. The signals of the two channels will be compared with each other continuously. An error will trigger the safety circuit, which will then immediately stop the drives and apply the safety brakes. The braking system will be sub-supplied by Siemag M-Tec, the winder machines by Citic Heavy Machinery. Siemens is also responsible for system integration, supervision of the assembly work, commissioning and customer training for the complete electrical equipment and braking system.

Located in the east Chinese province of Shandong, the mine is set to produce 2.4 Mt/y of coal. There will be two shafts, one for production and the other one a service shaft.

Hepburn has also developed a DC thyristor drive system capable of up to 4,500 kW, with 12 pulse design for low harmonics. These drives are ideal for upgrading existing large DC hoisting systems, without having to buy new motors. The DC product line, including very large 12 pulse drives up to 10,000 AC, is a reliable workhorse in many applications around the world.

Hepburn continues to provide the full range of drive and control systems for all hoisting drives, including custom designed MG set controls, for hoisting applications where existing MG sets are upgraded to the most modern digital drive system. Hepburn’s DDRK retrofit for DC thyristor drives is an ideal ‘bolt-on’ replacement for older thyristor control systems.

The company’s integrated approach to hoist design allows for both a control system upgrade and hydraulic braking system upgrade to be done at the same time, allowing complete modernisation of an existing hoisting plant. Hepburn can offer a control system to suit the owner’s choice of automation platform, thus ensuring user familiarity with both the hardware and software platforms. In recent times Hepburn has successfully completed more than 50 upgrades, comprising drive systems, control systems, and braking systems - providing a cost effective, reliable and safe hoisting plant.

Hepburn Engineering offers a hoist management system, in the form of a graphical interface package and relational database which effectively packages available knowledge of the designer, manufacturer and operator of hoisting plants into a software operating system. Careful design and integration of the hoisting plant, instrumentation and software-based operating system, allows this to be easily accessed online to improve hoist safety and productivity.

Hepburn says “the powerful software that underlies the graphical interface has allowed [it] to integrate substantial diagnostic, operating and maintenance support systems into the Hoist Manager. Open software connectivity permits direct data exchange with...
common spreadsheet and word processor software. Linking of the graphical interface to a relational database allows for further development of diagnostic and historical analysis, and for the integration of hoist maintenance into mine-wide stores or maintenance systems."

The fault diagnostics system provides comprehensive information for component replacement and allows maintenance staff to retrieve information using graphical and picture-driven selections. Access to both
text and CAD documents allows for on-line linking to information traditionally supplied in separate maintenance manuals. Combining remote connectivity (internet or direct line) with the comprehensive database fault logging, allows on-line diagnostic technical support from remote locations. The system is extremely user-

Twiflex brakes are just one example of shaft technologies from Altra Industrial

The Hepburn Hoist Manager provides increased levels of automation for hoist operations, including automatic brake testing, over travel testing and hoist start-up. It also provides a simple way to control one or more hoists from a central or remote location.
friendly for operators and maintenance personnel.

Hoist operation is carried out from the main operating screen. It provides information on the position of the skips or cages, hoist speed, armature current and voltage, field current and brake pressures.

The brake system screen incorporates a hydraulic schematic identifying all components in the system. Information such as brake pressure and condition of brakes is shown together with animation of valves, pumps, levels and filters. Brake faults are identified to component level and identification is linked to database and associated maintenance records. Pop-up functions provide brake valve testing, dynamic brake testing, and real time recording of valve operation, brake pressure and hoist speed.

The electrical system screen provides a schematic with pushbuttons for each starter and circuit breaker; animated for power flow. Faulty components are highlighted, and each component is linked to data sheets and maintenance records.

The control system screen provides a layout of the control and communication system and displays the status of each communication network. The status or value of every input and output to the control PLC is displayed. The PLC input is linked to the component providing the input with its associated data sheet.

This powerful, user friendly, operating and management system can be retrofitted to existing hoisting systems, as well as incorporated in new hoists. VoIP shaft communications are becoming an important tool. Mine Site Technologies (MST) ImPact WLAN System for underground mining applications is one such system. For instance, Konkola Copper Mines (KCM) in Zambia has undertaken a major upgrade of its underground communication infrastructure by introducing MST’s digital backbone and tracking applications at the Konkola mine. The mine was looking to introduce advanced communication technology to support productivity goals through improved access to information for the management of underground equipment and processes.

Apart from two-way voice communications using VoIP phones, Konkola is introducing a tracking system to allow better management of equipment underground. To achieve communication along the main roadways underground, and track equipment & vehicles, Konkola is installing:

- 59 ImPact Wireless Network Switches (WNS). Each of MST’s WNS units consist of a four-port, single mode gigabit fibre switch with one or two wireless radio cards, as well as four PoE external ports
- Eight ImPact PoE Access Points. These are MST’s basic single Access Points that form minor spurs off the main WNS based backbone, to provide Wi-Fi coverage at specific locations
- 12,000 m of ImPact Composite Fibre/Power cable to link the ImPact WNSs and form the main digital backbone
- 100 Wi-Fi RFID Tags are being installed to begin tracking key assets. The Tags are AeroScout’s advanced T3 Wi-Fi Tags. AeroScout’s Mobile View and Positioning Engine will be used as tracking software. Ten Spectralink VoIP phones are being installed initially to begin the introduction of two-way digital voice communications in the mine. This will complement the existing fixed phones and overcome the limited coverage from the mine’s existing leaky feeder radio system.

The core hardware in the digital backbone is based on MST’s ImPact WNSs. These provide the wireless link to various Wi-Fi enabled devices, such as the VoIP phones. Importantly, they also act as the readers for the Wi-Fi enabled RFID Tags. These WNSs are configured with single or twin radio cards; twin radios being used where immediate determination of direction of travel is required.

Operations experience can change theoretical solutions into practical and profitable outcomes. A simple change to a client’s mining method turned a theoretical loss into a very profitable outcome.

Mines don’t just happen… they are made.
Finding drives and controls
Altra Industrial Motion has launched a new website providing a comprehensive resource for motion control solutions in a wide variety of operating applications. It offers convenient, 24-hour access to the Altra brands. It is organised by 13 mining application categories ranging from shovels and draglines to conveyors, crushers, winders and hoists, and more.

Within these categories are products, photos, features and benefits of each Altra brand solution that can be applied to improve efficiency, productivity and safety. Each product contains a web link to one of the 12 Altra brands that support the mining industry where engineers can access detailed product specifications.

The website also contains a mining solutions video, case studies, a literature page and information on Altra's Replacement Program for clutches and brakes from Industrial Clutch, Wichita Clutch and Twiflex as well as its rebuild program for backstops from Formsprag Clutch and Marland Clutch.

Caliper brakes and sheaves are used on a variety of mine winders and hoists. For instance the Marland BC-MA Series Holdback provides positive protection against reverse torque runaways of elevators. Twiflex Model VKSD modular disk brakes provide up to 800 kN braking force with on-site torque adjustment.

SHAFTS & EQUIPMENT
Rope diameter selection (see following page for details)

<table>
<thead>
<tr>
<th>Rope details:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>TURBOPLAST</td>
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<tr>
<td>Tensile grade (MPa)</td>
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<tr>
<td>MBL factor</td>
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<tr>
<td>Mass factor</td>
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</table>

<table>
<thead>
<tr>
<th>Shaft and winder details:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Max suspended length (m)</td>
<td>1500</td>
</tr>
<tr>
<td>Skip mass (kg)</td>
<td>10000</td>
</tr>
<tr>
<td>Payload (kg)</td>
<td>18000</td>
</tr>
<tr>
<td>Number of ropes per drum</td>
<td>1</td>
</tr>
<tr>
<td>Required factor of safety</td>
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</tr>
</tbody>
</table>

Solve for optimum rope diameter based on data given above:
Resulting rope diameter (mm) : 55.6 calculated, exact

Resulting rope properties from exact calculated rope diameter:
Rope diameter (mm) : 55.6 calculated
Rope MBL (kN) : 2399.2 calculated
Rope mass (kg/m) : 13.94 calculated
Factor of safety check : 5 calculated

Next 1 mm up rope size based on calculated rope diameter:
Rope diameter (mm) : 56.0 calculated
Rope MBL (kN) : 2430.1 calculated
Rope mass (kg/m) : 14.12 calculated
Factor of safety : 5.04 calculated, i.e. better than 5.0

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The Twiflex VM53 SP is a spring applied, hydraulic released modular safety brake with up to 230 kN braking force. Bibby's G-Flex Series grid couplings are all-metal couplings that provide positive protection against the damaging effects of shock loads and vibration. Aluminum horizontal cover (T10) and all-steel vertical cover (T20) designs are available. G-Flex tapered grid couplings are an excellent choice where torsional flexibility/vibration damping are primary concerns.

All this and more, like TB Wood's full line of sheaves and drives to meet specific application requirements, can be found on www.AltraMining.com.

Hoist ropes
Wolfgang Oswald, Managing Director of Casar, explains the key attributes required of mine winder or hoist ropes are:
- Koepe friction winders
- Corrosion resistance
- Good tension and bending fatigue performance
- Non-spin characteristics in deeper shafts
- Drum winders (with multi-layer spooling)
- Corrosion resistance
- Ability to withstand crushing on the drum
- Ability to withstand relatively large changes in lay length in deeper shafts.

Typical vertical shaft depths in, for example, gold and platinum mining, are in the range 500 m to 3,000 m with steel wire rope based single lift hoisting used exclusively in these shafts. Koepe friction winders and multi-layer drum winders can be used in installations up to about 2,000 m shaft depth. Beyond this depth, multi-layer drum winders and Blair winders (a type of multi-layer drum winder with two ropes per conveyance) are used.

"Typical rope diameters used for hoisting in vertical shafts are 30 to 60 mm," he explains. "Typical rope diameter to drum and sheave diameter ratio is 100:1. The rope diameter selection is driven by the required economical attached mass (payload and conveyance mass) and the given factor of safety (FoS) required in the particular country. So, for example, for a FoS of 5.0, we would have the following scenario with a 1770 MPa CASAR TURBOLAST rope on a multi-layer drum winder" (see table page 38):

One focus of Bridon is developing opportunities in China, with a focus on the recently acquired operation in Hangzhou. Bridon Hangzhou has a good manufacturing base to serve core strategic markets in mining. Investment is being made in the operation in Hangzhou with equipment being upgraded and the facility being placed to meet the growing demand for high quality rope across Asia.

Bridon acquired an 80% shareholding in Hangzhou Super Strength Wire Ropes in May 2008, with the business trading as Bridon Hangzhou Co. Ltd.

Regular testing of hoist ropes is of course vital. At DMT, an important in-house development for testing wire ropes for broken strands, corrosion and wear is the company's magneto inductive wire rope testing technique, an effective combination of measuring the flux leakage and cross-section. By carrying out destructive testing on new and discarded wire ropes in its testing facilities DMT consolidates and updates its wire rope know-how. IM

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