SDC 2019

4th international conference on shaft design and construction

PROGRAM

November 18-20, 2019 • Marriott Downtown • Toronto, ON, Canada

CIM ICM

SHAFT2019.CIM.ORG

IOM3 The Institute of Materials, Minerals and Mining

HOIST & HAUL 2020

AUG. 10-13 • MONTREAL, QC

Hoist and Haul is the latest in a series of International Conferences on Mine Hoisting and is held every five years. Hoist and Haul is a peer review conference and will covers systems or technology associated with the handling of ore from the point of extraction in the underground mine to the stockpiling on surface.

We invite you to submit an abstract (**maximum 300 words**) under one of the topics below. The abstract must include: title, objective of the paper, results and its contribution to the development in Hoisting and Haulage.

CALL FOR ABSTRACTS

THESE ARE THE TOPICS COVERED:

Mine hoist plant selection • Hoisting and shaft ropes • Hoist rope attachments • Shaft conveyances • Mine hoist electrical - motors and drives • Head sheaves • Mine hoist braking systems • Loading pockets and dumping systems • Mine shaft conveyance guiding • Mine hoist mechanical – gears, auxiliary drives, couplings, foundations • Hoist plant maintenance and inspections, NDE • Wear materials for shaft conveyances and loading pockets • Innovative mine hoist plant design

IMPORTANT

Authors must register and pay the author/presenter registration fee before **May 31, 2020** in order to guarantee their place in the proceedings and in the program schedule.

Conferences rely on registration fees from all categories of attendees for financial sustainability. A preferential registration fee is set for presenters in recognition of their special contribution to the conference.

KEY DATES

- **January 31, 2020**
  Notification to authors
- **March 20, 2020**
  Full paper submission
- **April 24, 2020**
  Notification to authors
- **May 15, 2020**
  Final revised paper submission
- **May 31, 2020**
  Presenters' registration

Submit your abstract before November 30, 2019 | hoistandhaul2020.cim.org

Table of Contents

This global shaft conference is being held for only the fourth time since its inception in 1959, and for the first time in North America. It is a conference for shaft designers, constructors, equipment suppliers, and mine owners carrying out or contemplating shaft projects. SDC2019 provides a unique opportunity for delegates and presenters to share knowledge, best practices, lessons learned, and to exchange ideas and network.

This conference will showcase the latest technology in shaft design and construction techniques and give us a window into the future of the mine development industry.

HISTORY

- 1959 – **Shaft Sinking and Tunnelling, London, UK**
- 1989 – **Shaft Engineering, Harrogate, UK**
- 2012 – **Shaft Design and Construction, London, UK**
- 2019 – **Shaft Design and Construction, Toronto, Canada**

WELCOME TO TORONTO!

We are delighted to welcome you to Toronto for the 4th International Shaft Design and Construction Conference, SDC2019. This unique conference is the 4th edition since its inception in 1959. The Institute of Materials, Minerals and Mining (IOM3) selected the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) as the host of this conference in Canada and has provided tremendous vision and support.

The quality of the content you will receive this week meets high standards. Our subject matter has evolved significantly over the years and the refinement is evident in the papers received by leading experts in the field. We are confident that you will enjoy and benefit highly from this conference.

In addition to 44 carefully reviewed technical papers being presented, we have the privilege of introducing two highly respected keynote speakers: William (Bill) Shaver and Richard (Dick) McIvor who will share their views on the future of shaft sinking and mine hoisting.

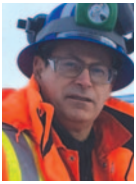
The number of sponsors contributing to this conference is telling and their commitment, impressive. Their generosity allows our organizing committee to put on a world-class international event with you in mind. We thank them warmly.

The authors, their employers, the organizing committee and the CIM staff all worked hard and smart, investing much time and effort to bring you an unequalled conference experience - from learning and knowledge exchange to networking. The collaboration and synergies are impressive.

Delegates of the SDC 2019 will meet the most knowledgeable shaft design and construction experts in the world here this week.

Attend and make the most of the learning, sharing and social opportunities. Deeper, faster, safer is the challenge, we all have a role to play in the future of mine access.

Expand your knowledge and horizons at SDC 2019.



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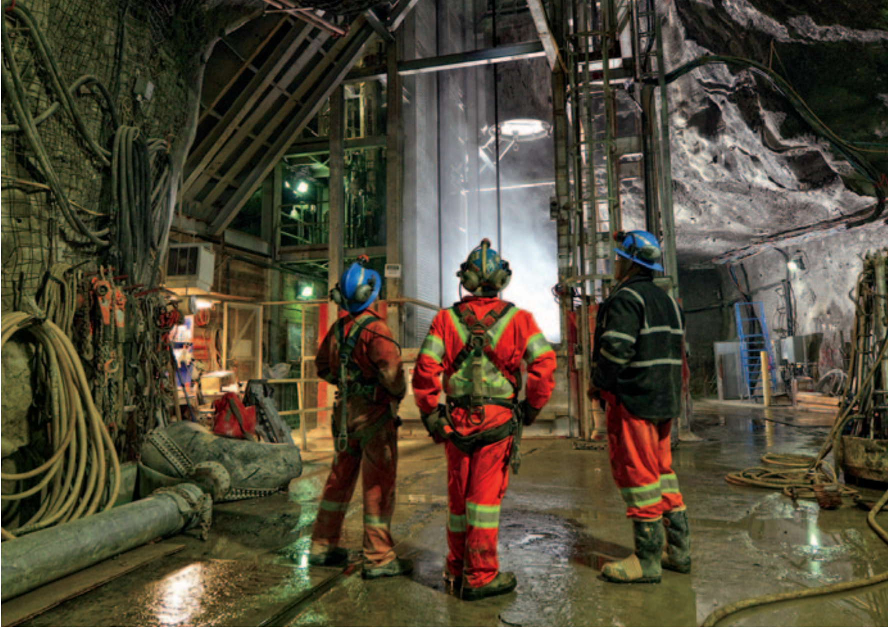
Co-chair



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DAILY SCHEDULE

MONDAY | NOVEMBER 18

08:45 - 09:00	Introduction & Welcome	Grand Ballroom
09:00 - 09:30	Keynote Speaker	Grand Ballroom
09:30 - 10:30	Session 1	Grand Ballroom
10:30 - 10:45	Coffee Break	Ballroom Foyer
10:45 - 12:15	Session 2	Grand Ballroom
12:15 - 13:15	Lunch	Trinity Ballroom
13:15 - 14:45	Session 3	Grand Ballroom
14:45 - 15:00	Coffee Break	Ballroom Foyer
15:00 - 16:30	Session 4	Grand Ballroom
16:30 - 16:45	Closing Remarks	Grand Ballroom

TUESDAY | NOVEMBER 19

08:30 - 08:40	Welcome	Grand Ballroom
08:40 - 09:20	Keynote Speaker	Grand Ballroom
09:20 - 10:20	Session 5	Grand Ballroom
09:20 - 10:20	Stream 2 / Session 1	Trinity Ballroom
10:20 - 10:35	Coffee Break	Ballroom Foyer
10:35 - 12:05	Session 6	Grand Ballroom
10:35 - 12:05	Stream 2 / Session 2	Trinity Ballroom
12:05 - 13:00	Lunch	Trinity Ballroom
13:00 - 14:30	Session 7	Grand Ballroom
13:00 - 14:30	Stream 2 / Session 3	Trinity Ballroom
14:30 - 14:45	Coffee Break	Ballroom Foyer
14:45 - 16:15	Session 8	Grand Ballroom
14:45 - 16:15	Stream 2 / Session 4	Trinity Ballroom
16:15 - 16:30	Closing Remarks	Grand Ballroom
18:30 - 22:30	Social Activity	Berkeley Church

WEDNESDAY | NOVEMBER 20

08:30 - 08:40	Welcome	Grand Ballroom
08:40 - 10:10	Session 9	Grand Ballroom
10:10 - 10:25	Coffee Break	Ballroom Foyer
10:25 - 11:55	Session 10	Grand Ballroom
11:55 - 13:00	Lunch	Trinity Ballroom
13:00 - 14:30	Session 11	Grand Ballroom
14:30 - 14:45	Coffee Break	Ballroom Foyer
14:45 - 16:15	Session 12	Grand Ballroom
16:15 - 16:30	Conference Summary and Conclusion	Grand Ballroom

GENERAL INFORMATION

All activities and events are being held at the Marriott Downtown hotel in Toronto, except for the SDC banquet (Berkeley Church)

Marriott Downtown at CF Toronto Eaton Centre
525 Bay St., Toronto, ON M5G 2L2
1.866.238.4218

Registration

The registration desk is located in the Ballroom Foyer, Lower Convention Centre

Monday, November 18	07:00 to 17:00
Tuesday, November 19	08:00 to 17:00
Wednesday, November 20	08:00 to 17:00

Free WI-FI

Wi-Fi is free for SDC delegates and available in the registration foyer and on the meeting level.

Network: MARRIOTT_CONF

Code: SDC2019

Lunch

Lunch will be served in Trinity Ballroom

Monday, November 18	12:15 to 13:15
Tuesday, November 19	12:05 to 13:00
Wednesday, November 20	11:55 to 13:00

Presenter information

Presenters are invited to upload their presentations in the main computer 15 minutes before the start of their sessions. Please see technician at the back of the room.

SOCIAL EVENT

The SDC 2019 Reception & Banquet is a social and networking event not to be missed! Enjoy a special evening of cocktails and savour a local dinner in the much-acclaimed 1871 Berkeley Church, a unique Toronto event venue. The Shaft Bottom Boys will provide fun entertainment for an unforgettable soirée.

Included with delegate registration. Additional tickets at $120.00

Pre-Banquet Reception: 18:00-19:00 | Dinner: 19:00-21:00 |

Location: Berkeley Church, 315 Queen St E, Toronto

Shuttle: 17:45 to 18:30 / 21:45 to 22:45

Silent auction by

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FIELD TRIP

TWO DAYS
WEDNESDAY NOVEMBER 20 – **THURSDAY** NOVEMBER 21

Onaping Depth Project at Craig Mine

Tour will depart from the foyer of the Marriott Downtown hotel.

Located near Sudbury, Ontario, Onaping Depth is an internal shaft project (winze) that has just commenced sinking. The shaft is accessed via the Craig Mine shaft and the shaft collar is located approximately 1,230 metres below surface. It is a 7.2-metre diameter concrete-lined shaft that will provide access and ventilation to the orebody located approximately 2,500 metres below surface. The site visit will include a safety orientation, an overview of the shaft design and sinking methodology, a trip underground to see the hoisting and headframe arrangement, and the shaft sinking setup and equipment.

WEDNESDAY | NOVEMBER 20

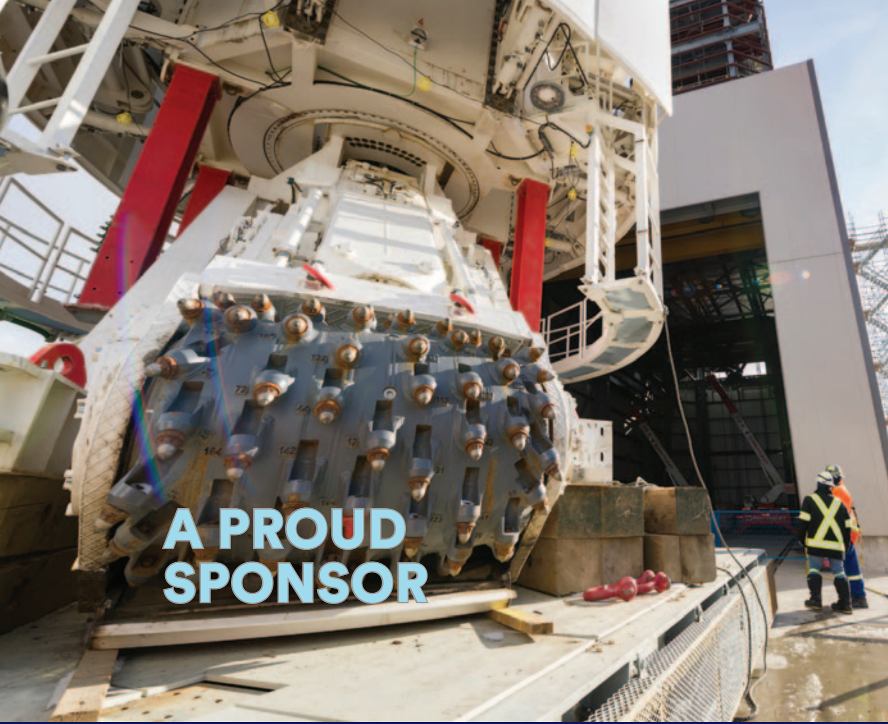
18:00 Depart from the Marriott
22:30 Arrive at Sudbury hotel

THURSDAY | NOVEMBER 21

06:00 Breakfast
06:30 Depart Sudbury hotel
07:00 Arrive at Craig mine
– Orientation (surface)
– Project presentation
– Underground visit
13:00 Lunch & brainstorming
15:00 Depart for Toronto
19:30 Arrive at Marriott in Toronto

Safety requirements: Visitors must report to security prior to entering and exiting the property. All visitors are required to wear steel-toed footwear, hard hats, reflective vests and clear safety glasses (with advanced notice, these can be issued to visitors, to be returned at the conclusion of the tour). Contact lenses are not permitted; prescription eyeglasses, if necessary, must be worn.

Cost: $300 - includes bus transportation, hotel in Sudbury, breakfast and lunch.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MONDAY NOVEMBER 18

08:45 INTRODUCTION & WELCOME | GRAND BALLROOM

KEYNOTE SESSION | GRAND BALLROOM

09:00 Paper 64
Shaft Sinking in the Next Five Decades / 2070

SESSION 1 | 09:30–10:30 | GRAND BALLROOM

09:30 Paper 28
Safety First – Remote Rehabilitation of Underground Excavations

10:00 Paper 22
The Sinking of Nutrien's Scissors Creek Service Shaft

SESSION 2 | 10:45–12:15 | GRAND BALLROOM

10:45 Paper 7
Conventional Shaft Sinking Unconstrained by Equipment Availability

11:15 Paper 48
Sinking Methods and Present Situation of Vertical Wells in China

11:45 Paper 42
Case Study on Drilling and Blasting Full-Face Frozen Shaft

SESSION 3 | 13:15–14:45 | GRAND BALLROOM

13:15 Paper 32
ISO TC 82 – Mining and the Importance of International Standards

13:45 Paper 43
Economics and Long-Term Planning for Shaft Projects in Mexico/South America

14:15 Paper 4
Deep Shaft Sinking Mechanisation Developments

SESSION 4 | 15:00–16:30 | GRAND BALLROOM

15:00 Paper 16
Sinking of Two Freeze Shafts by Using the Mechanized Shaft Boring Roadheader (SBR) Technology for the Slavkaliy Nezhinsky Potash Mine in Belarus

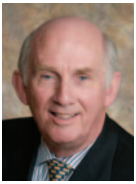
15:30 Paper 53
Design and Application of New Series of Large Shaft Sinking Headframe

16:00 Paper 62
An Innovative Approach to Shaft Sinking Stage (Galloway) Design

16:30 CLOSING REMARKS

KEYNOTE SPEAKER

MONDAY | NOVEMBER 18 | 09:00-09:30



Shaft Sinking: The Next 50 years

By William (Bill) Shaver

Shaft sinking innovation and advances have been incremental over the last 50 years, but recently we have seen some significant innovation in rock cutting and other methods of sinking. This talk will focus on what the next 50 years hold for us, and how lessons learned in shaft sinking and mine and civil development will help to get us there.

Bill Shaver is a professional engineer who has worked extensively in shaft design, construction, rehabilitation, as well as operating and maintaining shafts. He has worked on approximately 40 shaft projects, completing 30,000 metres of shaft sinking work. Many of his years of experience were in the mining contracting business, at Redpath Group, Dynatec Corporation, FNX Mining and DMC Mining Services. Bill is currently chief operating officer at Inv Metals.

TECHNICAL PROGRAM

MONDAY | NOVEMBER 18

08:45 Introduction & Welcome | Grand Ballroom

09:00 **Paper 64**

Keynote Session: Shaft Sinking: The Next 50 years

William Shaver, Chief Operating Officer, Inv Metals

SESSION 1

09:30–10:30 | GRAND BALLROOM

09:30 **Paper 28**

Safety First – Remote Rehabilitation of Underground Excavations

George Pieter van Greunen, General Manager, Royal Bafokeng Platinum

Completion of Silo 4 at Styldrift Mine was key to ramping up the mine to 150 ktpm by the end of 2018 and achieving a steady state of 230 ktpm by Q3 2020. Initial efforts to establish the silo were hampered by very poor ground conditions that made it unsafe to work within 20 m of the excavation. To rehabilitate the site without allowing people near the unsafe area, we contacted other mines to find out how they handled similar situations. It was disheartening to learn many efforts had failed, and the successful solutions had been lengthy (and expensive) to implement. Time was not on our side: we required a cost-effective, time-efficient, safe solution. First, we needed to seal off the bottom of the silo so we could keep people safe while work continued on silo construction. We constructed a steel structure off-site then placed it on site using a remotely operated crane. To ensure people would be safe working under the structure, we sealed it with a 3-m thick layer of concrete. To start rehabilitating the site from the top without introducing people to the site, we remotely released 5.8 m diameter × 1 m deep steel rings one-by-one into the 64 m deep silo around which we could then pour concrete to stabilize the structure. This approach did not go well; we struggled to seal the rings. It took two months to complete the first 10 m of depth. We changed our approach, creating 5.8 x 5 m deep

drums sealed top and bottom and lowering them down the hole one-by-one, pouring concrete around each drum. Working remotely, we completed the remaining 54 m in six weeks. We had gone as far as we could working remotely. To remove the metal sealing that made it possible to pour the concrete, we called on the RBPlat members of Mine Rescue Services to remove the dividing steelwork between each drum. They worked their way down the 64 m, hanging from ropes. Once this work was done, we could complete and commission Silo 4. The team at Styldrift Mine was pleased to report that the entire exercise was injury-free.

10:00 Paper 22

The Sinking of Nutrien's Scissors Creek Service Shaft

Kevin John Melong, Vice President Technical Services and Shafts, Redpath Canada

Redpath Canada Limited and joint venture partner Thyssen Mining and Construction Canada recently completed the sinking of the Scissors Creek service in Saskatchewan through its joint owned company, Associated Mining Construction (AMC). The Scissors Creek service shaft was sunk at Nutrien's Rocanville mine. The paper outlines the shaft sinking plant and the methodology related to sinking and shaft lining.

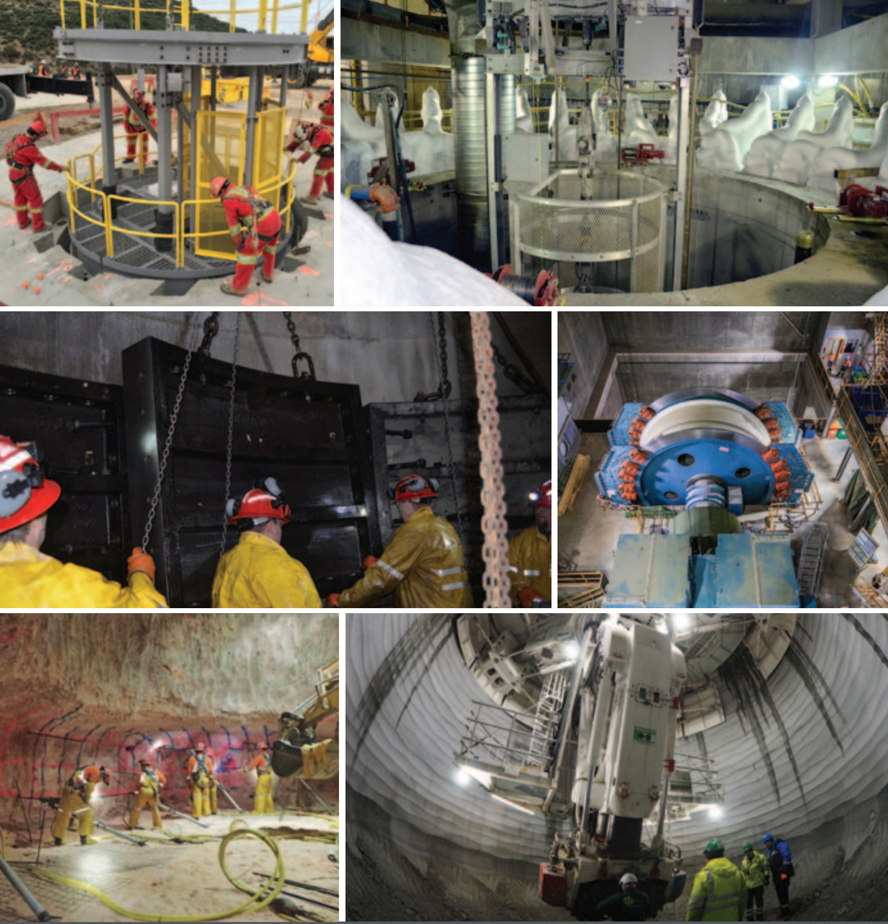
SESSION 2
10:45–12:15 | GRAND BALLROOM

10:45 Paper 7

Conventional Shaft Sinking Unconstrained by Equipment Availability

Sean Henley, Shaft Project Manager, GCR Mongolia

Shaft sinking design is typically driven by what has been successful in the past and the availability of sinking plant and equipment. In this case study, the sinking design and methodology is unconstrained by conventional thinking. Schedule was a key project driver; it led to an alternative sinking design that aimed to optimize sinking advance rates by specifying new winders that complement known sinking plant while providing improved safety, redundancy, and flexibility in each part of the sinking cycle. The project is remotely located in the South Gobi region, Mongolia. The scope of work included the blind sink and concrete lining of two ventilation shafts to a depth of ~1,150 m to a finished diameter of 10 and 11 m. All sinking and lining operations were to be completed as in-line activities. The design centred on the mucking cycle given that this is the most significant part of the sinking cycle. Vertical Shaft Muckers (VSMs) are typically operated in pairs; however, existing models did not have the extension to cover the required diameter shaft if only two units operated. Thus, the sinking stage design was optimized to allow for four stage mounted or "nested" VSMs in favour of an excavator/s. To accommodate the VSMs, the sinking design required reducing the size of the kibble well and ultimately the kibble payload. To counter the smaller kibble payload, two kibble winders were introduced to allow four kibbles to be used. This also doubled as the secondary egress, negating the requirement for an otherwise redundant "Mary-Ann" winder and provided the opportunity to sustain 50% hoisting capacity during planned and unplanned maintenance. It also provides greater flexibility to segment the cycle further and reduce waiting times for equipment being lowered to the shaft floor. The use of four VSMs also provides for a mucking efficiency of greater than 85% if a single mucker was out of service for an extended period of time, while maintaining approximately 93% coverage of the shaft bottom—far superior to what may be achieved with one or even two excavators. The use of VSMs provides other ben-



efits by removing the operator from the floor compared to an excavator, most significantly:

- No personnel required on the shaft floor during the mucking cycle: mitigates one of the highest risk activities from the sinking cycle and allows on-the-job training without additional exposure to sinking personnel (this requires the kibbles to remain attached during loading, i.e., no changing bale)
- Can excavate the full shaft round (4.5 m) without installation of temporary support (from the stage)

The same four kibble wells provide the same flexibility and redundancy during the delivery of concrete via concrete kibbles during the pouring of the concrete shaft lining. The design also catered for the delivery of concrete via two slicklines in the event that concurrent shaft lining (pouring of the barrel plates) is approved during mucking due to no personnel at the shaft bottom when mucking. The objective of the design was to provide a more safe and flexible sinking system that has redundancy within every part of the sinking cycle, which could thereafter achieve instantaneous sinking advance rates superior to current large-diameter blind shaft sinking advance rates.

11:15 Paper 48

Sinking Methods and Present Situation of Vertical Wells in China

Zhibin Cheng, Deputy Chief Engineer, China Coal No.5 Construction Co. Ltd.

The vertical shaft is a major development in mine exploitation. The shaft sinking technology is very complex: numerous pieces of equipment are arranged on the surface and underground. This paper briefly describes the characteristics of the single-line, parallel, and mixed working method, and once sinking shaft method of driving, supporting, and setting. The effects of shaft sinking amount and specialized methods are also summarized (including freeze sinking, grouting sinking, shaft drilling sinking, shaft sinking by caisson, and concrete diaphragm wall methods), as are construction cases of vertical shafts in various industries, such as coal, metallurgy, non-ferrous metal, hydropower, highway, railway, and nonmetallic. Finally, the sinking demand and development trends are forecast for the future.

11:45 Paper 42

Case Study on Drilling and Blasting Full-Face Frozen Shaft

Michael Mayhew, President, Nordmin Constructors Inc.

The objectives of this presentation are to provide information and actual data on drilling and blasting of a full-face frozen shaft. The history and start of the sinking of the frozen shaft in Saskatchewan will be briefly discussed, as will the hands-on development of sinking full-face shaft and associated challenges and hurdles that were overcome. The presentation includes actual data and pictures showing project progression. The case study will look at the following:

1. Previous history of sinking shafts in Saskatchewan
2. Progression of evolving to full-face blasting
3. Drilling pattern, hole size, and depth
4. Explosive product
5. Monitoring systems
6. Challenges

The audience will see the hands-on approach of the day-to-day operations. The challenges encountered will be discussed along with the innovative solutions that the team developed. Further, the fears and regulatory requirements for each of the stakeholders will be presented and the monitoring systems described that were put into place for their comfort and understanding.

SESSION 3

13:15–14:45 | GRAND BALLROOM

13:15 Paper 32

ISO TC 82 – Mining and the Importance of International Standards

William Kempson, Engineering Manager, Hatch

Mining Companies produce assets in increasingly diverse areas of the world. It is common for the owner, design team, mine contractors, and operators to be based in different countries. While mining company assets are always subject to the regulatory requirement of these countries, no international standards are available to review and evaluate assets. This becomes particularly important when considering safety critical items such as tailings dams, vertical shaft systems, and autonomous vehicles to highlight a few. The work currently being completed in ISO ensures these standards will be available and generated by and subscribed to on an international basis, thus removing any potential for patriotic partisanship and ensuring safe and predictable systems are installed. This paper will discuss the benefits of the international standards, the structure of the teams and working groups who are generating them, and the process by which the standards are generated. This will allow insight into the creation of a standard and will aim to demonstrate the "neutral" and technically strong manner in which this is achieved. In addition, the paper will discuss the standards that have been produced in the last five years as well as the current standards that are in place. The finale will discuss upcoming work and the timelines in which it is anticipated these will be completed.

13:45 Paper 43

Economics and Long-Term Planning for Shaft Projects in Mexico/South America

Michael Arriagada, V.P. of Mechanical Engineering, E.D.C. Mining Ltd.

As ever more mines turn to shafts to economically exploit deeper reserves, mine owners use two key means to attempt to minimize short-term costs: refurbishing existing shafts and sinking shafts in phases. For the former, whether attempting to utilize a decommissioned or current production shaft, the idea is the same—by taking advantage of what is there, both cost and time will be saved. However, when all of the problems of refurbishing become evident, the relative savings compared to the benefits of beginning a new shaft rapidly disappear, especially when looking at long-term benefits and, in the case of current production shafts, eliminating downtime. Similarly, sinking shafts in phases is seen as a means to get to production quicker with lower up-front costs. However, by failing to properly set up and plan for subsequent phases, short-term savings can lead to large additional costs down the road, increased downtime, and increased time to production of the succeeding phases, while also introducing unnecessary risks. By using the lessons learned from working on various shafts in Mexico and around the globe, this paper aims to provide mining companies with the opportunity to avoid the potential pitfalls of short-term gains that lead to long-term loses.

14:15 Paper 4

Deep Shaft Sinking Mechanisation Developments

Frederick Alan Auld, Consultant, Golder Associates

The drill and blast method is traditionally the method of excavation for shaft sinking. Since the 1970s, attempts have been made to develop blind shaft boring sinking machines to achieve faster sinking rates while providing a safer working environment for personnel. Five machines are described in this paper. The first and only attempt to produce a full-face sinking machine was by Robbins in the USA during the period 1975–1981. Its use in a trial sinking is discussed. As an alternative to the full-face machine, a new machine was developed by Robbins during 1983–1985, which used a cutter wheel attached to the bottom of a sinking stage. It was never used in a sinking. In 1971, the first Wirth shaft boring machine, the "V-mole", was put into service in the German coal mining industry. Herrenknecht in Germany took up the challenge again in 2010. Two shaft sinking machines were considered, the Shaft Boring Machine and the Shaft Boring Roadheader. The former uses the cutting wheel principle while the latter consists of

a roadheader arm attached to the bottom of a sinking stage. The paper concludes with a discussion on the future use of shaft sinking machines.

SESSION 4

15:00–16:30 | GRAND BALLROOM

15:00 Paper 16

Sinking of Two Freeze Shafts by Using the Mechanized Shaft Boring Roadheader (SBR) Technology for the Slavkaliy Nezhinsky Potash Mine in Belarus

Jochen Greinacher, CEO, Redpath Deilmann GmbH

In 2017, Deilmann-Haniel signed a contract with IOO Slavkaliy to sink two 750 m deep freeze shafts for the Potash mine Nezhinsky in Belarus. This is the second shaft project where this technology was employed after two >1000 m deep shafts were sunk for a potash project in Saskatchewan, Canada, by application of the Herrenknecht Shaft Boring Roadheader (SBR) technology. Developed to sink shafts for greenfield projects in soft to medium hard rock in frozen or unfrozen geology, the technology uses a roadheader type cutterhead on a telescopic boom to mechanically excavate the rock and a pneumatic mucking system to convey the muck from the face into the buckets. This leads to a manless face during the sinking cycle and thus a significant improvement in terms of workplace safety. For the Nezhinsky project, the SBR design was significantly modified in close cooperation between Deilmann-Haniel and Herrenknecht, based on the available experience and special requirements of the project. The modifications included adapting the Pneumatic Mucking System to cope with wet material (as well as dry material as originally planned) or moving the shaft lining from shotcrete application to jump for and tubbing installation for which a step-change hands-off tubbing erector for the placement of segments was designed. Further modifications to optimize the machine technology for the requirements during shaft sinking were applied on the two machines for the Slavkaliy project as well as several revisions to match the special project requirements. The SBR is suitable for soft and medium hard rock up to 100 MPa UCS. The main design limits are the maximum weight of the machine (400 tons) and length or height (50 m) due to

the depth of the pre-sink. The Pneumatic Mucking System was changed in all components, sheaves and rope arrangements were redesigned, and the concept of the hoist system was also re-engineered. The SBR in Belarus is configured for a daily sinking rate of 3 m and all systems behind the cutting boom are not the bottle neck of the whole system. The work on site began in November 2017, including freeze hole drilling, construction, site setup, and installation of hoist winches, permanent headgears and other components required for sinking. The SBRs arrived onsite in June/July 2018 and were preassembled on surface and then lowered in the 50 m pre-sink. SBR #1 started full face sinking in mid-December 2018, and SBR #2 in late January 2019. By the end of February 2019, SBR #1 and SBR #2 were at 150 and 100 m depth, respectively, and achieved up to 3.6 m/day concrete lined shaft.

15:30 Paper 53

Design and Application of New Series of Large Shaft Sinking Headframe

Bo Wang, Associate Professor, China University of Mining and Technology

On the basis of analyzing current design and applications, the structure form, working loads, and design principles of the shaft sinking headframe are summarized in this paper. In China, to overcome the insufficient bearing capacity and geometry size of the finalized shaft sinking headframe, a series of new large shaft sinking headframes was developed under the following vertical shaft construction conditions: maximum net diameter 12 m and maximum depth 1200 m. The new series of shaft sinking headframes includes two sets (single and double sheave platform), three optimum shaft diameters (<8.0 m, 8.0–10 m, and 10–12 m) for each set, and has innovation and optimization on the structure of the sheave wheel platform (MU type) and bracing frame (REN and ZHONG type). The largest new shaft sinking headframe can arrange up to four pieces of hoisting equipment simultaneously and has a bearing capacity of >10000 kN. Two of the new shaft sinking headframes were successfully applied in practical engineering at the three auxiliary shafts: Hulusu, Dahaize 1#, and Sishanling. These applications show that the new shaft sinking headframe has sufficient bearing capacity and reliable applicability. The new shaft sinking headframe could provide an effective means for safe and efficient sinking of deep-large shaft in the future.

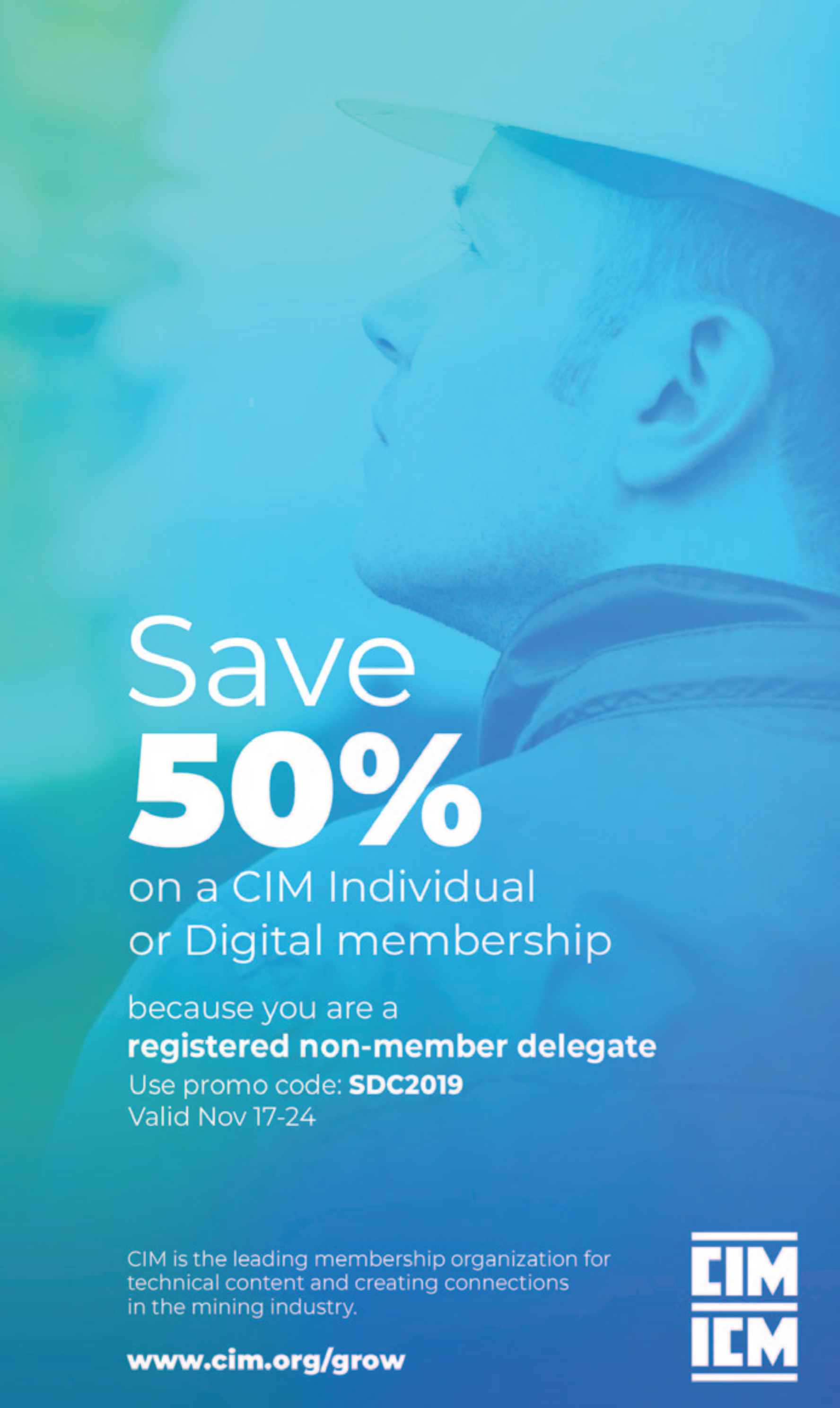
16:00 Paper 62

An Innovative Approach to Shaft Sinking Stage (Galloway) Design

James Holder, President, JB Holder Engineering Ltd.

A key barrier to vertical mineshaft construction is construction access required for workers. A suspended work stage is used to provide this access for mechanical, electrical, and structural applications and other tasks. Work stage design is complicated given the numerous types of construction activities that are executed simultaneously, the confined environment in which the work stage operates, the significant corrosion attack that is present, the weight limitations imposed by the mechanical hoist systems, and the risks associated with worker safety. Also complicating the design, these structures and their construction environment can vary with time. Hence, they can be described as four-dimensional structures. The author has discovered significant synergies and advantages with integrating engineering design with detailed three-dimensional fabrication design. The significant reduction of minor design errors needing field correction will be underscored. The tender process is also accelerated since the design output is fabrication shop drawings, including a detailed quantity take-off output that provides each component required and its specific quantity. The paper will document the numerous advantages to the project conferred by using this approach.

16:30 Closing Remarks | Grand Ballroom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TUESDAY NOVEMBER 19

08:30 WELCOME | GRAND BALLROOM

KEYNOTE SESSION | GRAND BALLROOM

08:40 Paper 61
Mine Hoist Plant Design Fundamentals

SESSION 5 | 09:20–10:20 | GRAND BALLROOM

09:20 Paper 35
Maximising Hoist Capacity Whilst Minimising Capital Investment

09:50 Paper 38
Principles of Ontario Hoisting Plant Operation and Maintenance in an MSHA Mine

SESSION 1 | 09:20–10:20 | SHAFT LINING DESIGN - TRINITY

09:20 Paper 3
Design and Construction of Deep Shaft Concrete Linings in the UK

09:50 Paper 14
The Assessment of Aging Shaft Linings for Potash and Salt Mines

SESSION 6 | 10:35 - 12:05 | GRAND BALLROOM

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Dynamic Analysis and Seismic Design of Mine Headframes

11:05 Paper 39
Developing a Standardized Approach to Shaft Inspections

11:35 Paper 12
Rapid Three-Dimensional Shaft Scanning from Spherical Video with Photogrammetry

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Comparative Study on Mechanical Properties of Concrete and Surrounding Rock in Xincheng Gold Mine Shaft Based on Unified Standard

11:05 Paper 9
Application of Structural-Thermal Modelling to Negate the Need for Movement Joints Within a Frozen Mine Shaft

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A Lining Design Method Consistent with NATM for Deep Shafts

SESSION 7 | 13:00–14:30 | GRAND BALLROOM

13:00 Paper 27
Monitoring the Stability of Closed Shafts

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The Design of High Pressure Piping in Vertical Shafts

14:00 Paper 52
Wireless for Mine Shafts – From Construction to Production

SESSION 3 | 13:00–14:30 | SHAFT LINING DESIGN - TRINITY

13:00 Paper 10
Buckling of Circular Rings Under External Pressure in a Confined Environment. "Amstutz Buckling" – An Enhanced Approach

13:30 Paper 46
A Simplified Approach for Evaluating Concrete Deterioration in Vertical Shaft Lining

SESSION 8 | 14:45–16:15 | GRAND BALLROOM

14:45 Paper 18
Accurate Live Measurements for Shaft Alignment During Sinking or Shaft Remediation

15:15 Paper 34
Phakisa Number 3 Ventilation Shaft Rehabilitation Project

15:15 Paper 11
The Amenability Theory: Applied in Rock and Soil to Maximize Productivity

SESSION 4 | 14:45 –16:15 | SHAFT LINING DESIGN - TRINITY

14:45 Open Table Discussion

16:30 CLOSING REMARKS

KEYNOTE SPEAKER

TUESDAY | NOVEMBER 19 | 08:40-09:10

Mine hoist plant design fundamentals for permanent operation for shaft sinking

By Richard (Dick) McIvor

It is important to ensure that the basic mine hoist plant design fundamentals are incorporated into any new mine hoist plant project before detailed design engineering is commenced. Where shaft sinking is involved, the design must take into account, in addition to the permanent service of the overall plan, the temporary service to allow for safe and efficient shaft sinking.

For nearly 20 years, McIvor Engineering and Maintenance Services Inc. has been providing hoisting plant design and support services to mining clients throughout North America. Prior to starting his consulting business, Dick McIvor was specialist, mechanical engineer at Sudbury's INCO Limited, where he was responsible for the stationary plant and all of INCO's hoisting plants. He is a CIM life member and currently serves on the executive committee of the CIM Maintenance, Engineering & Reliability Society (MER). Dick is also the chair of Hoist & Haul 2020, the International Conference on Hoisting and Haulage, taking place in Montreal, Canada, in August 2020.

TECHNICAL PROGRAM

TUESDAY | NOVEMBER 19

08:30 Welcome | Grand Ballroom

08:40 **Paper 61**

Keynote Session: Mine hoist plant design fundamentals for permanent operation for shaft sinking

Richard McIvor, President, McIvor Engineering and Maintenance Services Inc.

SESSION 5

09:20–10:20 | GRAND BALLROOM

09:20 **Paper 35**

Maximising Hoist Capacity Whilst Minimising Capital Investment

David Allison, Group Mining Engineer, Lundin Mining

Many hoists are built to handle a name plate capacity, however, as production increases in other parts of the operation, the hoist capacity often become the critical constraint. Such a situation occurred at Lundin Mining's Neves Corvo operation; this paper examines how each component of the hoist was examined and optimized. The hoist capacity was increased though a combination of cycle time reduction, increase in payload capacity, and increase in available hoisting time, without changing the hoist motor, drum, or headframe. Increased payload capacity was achieved by reducing the weight of the ropes and skips and improved load monitoring systems. The cycle time was reduced by shortening the creep distances , increased availability through the installation of a safety platform, and cooling of the electrical systems to reduce downtime during hot summer months. These changes will increase the capacity from the current 3.8 Mtpa to a planned 5.6 Mtpa, whilst maintaining the mine production during the upgrade work.

09:50 Paper 38

Principles of Ontario Hoisting Plant Operation and Maintenance in an MSHA Mine

Dan Miners, General Manager Salt Lake City Operations, Nordmin Group of Companies

As a result of a number of fatalities in the 1970s, a committee comprising labour, management, and suppliers was organized to develop comprehensive, black and white regulations for the safe operations of hoisting plants in Ontario, Canada. These regulations were based on 'best practices' and the track record of Ontario hoisting plants since the 1980s, which is second to none. There is a fair amount of overlap with MSHA regulations, however the Ontario regulations identify very specific details that eliminate the 'interpretation' of regulations that can cause tension between operators and MSHA inspectors. In addition to the regulations, the Ontario Ministry of Labour published comprehensive guidelines to aid in interpreting the Ontario regulations based on actual cases and rulings. The practical nature of these regulations and guidelines has led to them being adopted as an internal standard for many mining companies in their world wide operations. This presentation will serve as an introduction to the sections of the Ontario regulations as they pertain to hoist plants and how following their application will improve hoist plant safety and performance. Actual hoist logbooks used by operators, mechanics, electricians, and shaftmen will be reviewed, as will the regulations that cover them. A checklist of regulatory requirements for the year will also be provided to the participants that will allow an easy planning and auditing of daily, weekly, monthly, and annual maintenance. An additional portion of the presentation will aid maintenance personnel in identifying trouble spots in their inspections of headframes, shaft fittings, and the hoist equipment. This is aimed at helping on shift inspectors determine when it is a good time to call for the engineer.

SESSION 1

09:20–10:20 | SHAFT LINING DESIGN - TRINITY BALLROOM

09:20 Paper 3

Design and Construction of Deep Shaft Concrete Linings in the UK

Frederick Alan Auld, Consultant, Golder Associates

During 1958–1980, seven deep shafts were sunk from the surface in the UK. From 1977 until 1989, sixteen deep shafts were sunk in the UK, all of which were concrete lined. From 1989 up to the present day, a period of 30 years, no deep shafts have been sunk in the UK. Therefore, developments in the design and construction of deep shafts in the UK were predominantly carried out throughout 1977–1989. This knowledge is recorded in several published papers by the author over that period, which will be referred to in the paper. The paper includes a review of the past precedent for the design of deep shaft concrete linings in the UK and sets out the principles for future designs, including the design load to be adopted and Factors of Safety to be used in the design. Hydrostatic pressure increases with depth from the surface and therefore the concrete lining must increase in thickness and strength throughout its depth to resist the pressure. High strength concrete mixes were developed to enable economic linings to reach greater depths and these will be detailed. The ground conditions to sink through in the UK consist of predominantly competent (self-standing when excavated) rock, which can be water bearing, and hence a hydrostatic pressure resisting lining is required. The paper describes the measures needed to install such a lining to produce a dry shaft by way of pour length, joint detail, back-wall grouting, and joint sealing details.

09:50 Paper 14

The Assessment of Aging Shaft Linings for Potash and Salt Mines

Joe Anderson, Engineer, Golder Associates

Cast in place concrete shaft linings have been used in many salt and potash shafts sunk in North America over the last 100 years. Many of these shafts have exceeded their initial design lives, and as producers look to extend the life of their operational assets, maintenance costs and shaft downtime will continue to rise in many cases unless repair work is undertaken. Successfully implementing concrete liner

repair schemes in operating salt and potash shafts is complicated by their age, environment, and time constraints during inspection, detailed design, and construction. This paper outlines a general approach to repair concrete-lined portions of these shafts based on lessons learned from the author's involvement in a recent repair project.

SESSION 6

10:35 - 12:05 | GRAND BALLROOM

10:35 Paper 23

Dynamic Analysis and Seismic Design of Mine Headframes

Mickael Hardy, Project Manager, WSP in Canada

The structural design of mine headframes is often challenging due to the significant differences in the geometry, rigidity, and behaviour of these structures compared to conventional buildings. The differences are related to the main purpose of these structures, which is the support of hoisting equipment, not human occupancy. Currently, the structural design of mine headframes is carried out according to the same standards used for conventional buildings, with input from various guidelines, handbooks, and other references. The designers must adapt these standards to the headframe design, which can result in the structures being either over- or under-designed. In the latest update of CSA S16 "Design of Steel Structures", Annex M (informative) was added to provide designers guidelines for the seismic design of industrial structures. The main objective of this paper is to study the dynamic behaviour of headframe structures compared with conventional buildings—which are the base case for the definition of seismic loads—and evaluate the impact of various design philosophies. First, the dynamic behaviour of headframes is studied using modal and spectral analysis, and the results are compared to the equivalent static analysis proposed in the National Building Code of Canada. Then the design methods proposed in Clause 27.10 of CSA S16-01 and supplements Clause 27.11 and Annex M, both from CSA S16-14, are compared to identify differences and inconsistencies. This paper highlights the torsional sensitivity of headframes, which generates significant shear in the direction perpendicular to the spectral acceleration application. Therefore, the design of mine headframes using the described methodologies shows significant differences since some are much more restrictive than others. The

results are used to issue recommendations for further revision of Annex M such as the difficulty to use capacity design for headframe structures.

11:05 Paper 39

Developing a Standardized Approach to Shaft Inspections

Shaun Gillis, Mining EIT, Golder

Whether they are performed daily or weekly by members of the shaft crew at the mine or periodically by consultants, shaft inspections traditionally involve a visual inspection undertaken with personnel traveling on an inspection deck on the conveyance and taking notes and photos. Depending on the site, there can be many challenges associated with these inspections, especially compared to a typical inspection at surface. Some of these challenges are associated with the shaft environment itself, including limited access due to production and shift schedules, poor visibility due to lack of lighting or cleanliness, or no access at all. Other challenges are related to the subjectivity of inspections and a lack of standardization, particularly between multiple sites within the same operating company. Some of these challenges include unspecific regulations, inconsistent documentation and training, and personnel turnover. Recognizing these challenges, Golder (previously Alan Auld Canada) has developed a method of shaft inspection that is more consistent and repeatable. It involves a review of any historical data, comparisons between similar sites with similar conditions, reports, and updated as-built or condition drawings. Additionally, beginning in 2014, we have used an innovative 360-degree camera system with a high-power lighting rig that can be used either remotely or alongside personnel completing a traditional visual inspection. The system uses six cameras to take photos at a rate of 15 frames per second, with the images subsequently stitched together in stills, then joined into a high-resolution video where the viewer can move the viewpoint around as if they were in the shaft, similar to Google Street View. This tool increases time efficiency, objectivity, and repeatability of inspections. This paper presents the development of a more standardized approach to periodic shaft inspections that supplements the more frequent inspections performed by shaft crews at the mine.

11:35 Paper 12

Rapid Three-Dimensional Shaft Scanning from Spherical Video with Photogrammetry

Ryan Preston, Geological Engineer, Golder Associates Ltd.

Detailed three-dimensional (3D) surveying of shafts using modern scanning methods can be difficult, time consuming, and potentially prone to errors accumulated over the shaft length. Similarly, manned shaft inspections can be prone to human-induced errors and have limited repeatability. Remote video inspections offer a potential solution to both these issues. A spherical camera and lighting system can be mounted directly to the skip or lowered remotely on a winch. Video data are then captured over the length of the shaft for a detailed, permanent record of conditions that can be interrogated in detail later without tying up the hoist. These video data can be processed using structure from motion-based photogrammetric methods to generate 3D models of the inspected shaft length. The quality and accuracy of the models highly depends on data collection conditions as they impact the quality of the photographs and the availability of survey control. Photogrammetry models have been shown to accurately capture the shape of objects when compared to overlapping LiDAR surveys with mean fits of 2 mm but depend on control points within the model area for accurate scaling. Three shafts were modelled over their entire length using photogrammetric models built from video inspection data using a FLIR Ladybug® camera. Difficulty with accumulated errors were encountered in most models, making them suitable for general planning and change detection but not detailed surveying. Model generation is relatively low effort for personnel, but it is computationally intensive and benefits from a dedicated computer and an approximately 1-week minimum lag time between data collection and delivery.

10:35 Paper 50

Comparative Study on Mechanical Properties of Concrete and Surrounding Rock in Xincheng Gold Mine Shaft Based on Unified Standard

Xiaomin Zhou, Professor and Director, University of Science and Technology Beijing

To study the supporting effect of concrete on the surrounding rock of a metal mine, the concrete and surrounding rock were compared. First, the general situation of the ultra-kilometre shaft in Xincheng, surrounding rock, and geology are introduced. Second, the experimental scheme of material mechanical properties of surrounding rock and shaft lining concrete based on the same standard dimension and shape are explained, and the mechanical tests of rock and concrete based on different shapes and sizes are carried out. The study shows that the compressive strength and elastic modulus are 1.28 and 1.78 times higher for cubic than cylindrical rock samples, whereas the Poisson's ratio is lower (0.77 times). The dimensional effect law of the concrete cube and cylinder test data is consistent with the rock law. However, the test results of the concrete are less discrete than the rock; the test also shows that the strength and elastic modulus of the concrete lining of the main shaft of the Xincheng mine are much smaller than the surrounding rock that is also used as the concrete aggregate, which indicates that the support of the concrete lining in the surrounding rock shaft behaved weakly. Based on the development of the modern New Austrian Tunneling Method (NATM) rock support theory, it is suggested that the mechanical test standard of artificial support materials should be unified into the mechanics test standard of natural rock, which will help to improve the accuracy and practicality of scientific calculation of geotechnical engineering.

11:05 Paper 9

Application of Structural-Thermal Modelling to Negate the Need for Movement Joints Within a Frozen Mine Shaft

Sebastian Oliver Colbeck, Director of Engineering, Underground Structures, Golder Associates

To minimize mine shaft maintenance over the long term, some recent Potash mine shaft sinking projects have required the provision of a continuous, fully welded, waterproof, steel liner over a substantial depth to achieve zero water ingress. This brings many challenges, including how to successfully implement a bottom-up construction sequence that incorporates extensive waterproof welding. A further challenge is to ensure the integrity of the welded liner, especially when subject to the substantial construction and post-construction temperature fluctuations that are likely to occur with a composite concrete liner placed within an artificially frozen shaft excavation. This paper seeks to highlight the key challenges associated with substantial thermal load acting on thin steel shaft liners and outlines and discusses multiple mitigation measures including vertical shaft movement joints. Finally, this paper discusses a linked structural-thermal modelling approach to shaft lining design to challenge the need for vertical shaft movement joints and simplify shaft design and construction by explicitly demonstrating accrued stress in the shaft liner.

11:35 Paper 55

A Lining Design Method Consistent with NATM for Deep Shafts

Xiaonan He, PhD Candidate, Key Laboratory of Ministry of Education for Efficient Mining and Safety of Metal Mine, University of Science & Technology Beijing

With the increase of shaft excavation depth, the thickness of the shaft lining increases sharply. It is difficult to reduce the thickness of the lining effectively by improving high-strength concrete performance. The concept of the New Austrian Tunneling Method (NATM) is that surrounding rock plays a key role in tunnel support. The solution should be to find the correct relationship between shaft lining thickness and rock strength, which is related with the interaction between the surrounding rock and concrete lining. The plane strain mechanics model is introduced to calculate lining thickness. The shaft lining design of Cixi Colliery in China was completed with the mechanics-based method proposed in this study. The lining design was verified through numerical simulation and field monitoring. The simulation results show that the maximum mises stress is located at the inner edge of the shaft lining. Increasing the lining thickness cannot effectively reduce concrete grade. The monitoring results indicate that a lining design thickness of 900 mm with C60 concrete is safe and reliable in the shaft over 1000 m. This analytical design method can be referenced in similar deep shaft project.

SESSION 7

13:00–14:30 | GRAND BALLROOM

13:00 Paper 27

Monitoring the Stability of Closed Shafts

Sven Bock, Project Manager, DMT GmbH & Co. KG

Closure of unnecessary shafts is the natural stage of deep mine operations commonly occurring after depletion of the reserves of mined materials. All over the world, the number of liquidated shafts grows continuously, and the problem of shaft disposal is especially critical for deep shafts. The typical depth of 600 m of currently liquidated shafts in Poland may already be seen as a challenging task. Even greater is the challenge of shaft closure in Germany, where active coal mines with shaft depths of up to 1300 m have recently been closed. It is therefore extremely important to ensure proper shaft closure to avoid stability loss and associated damage to surface facilities. For active shafts, it can be done by a dedicated shaft closure design, but even then and depending on the shaft closure method, it may be necessary to perform regular shaft inspections. In many cases, inspection of old abandoned shafts is more important because the wall stability or liner type are not fully known. This paper presents a short overview of shaft closure methods and available tools and recently developed devices for such shaft inspections.

13:30 Paper 31

The Design of High Pressure Piping in Vertical Shafts

William Kempson, Engineering Manager, Hatch

As has been noted on numerous occasions, vertical shafts being sunk around the world are all tending to get deeper as we seek to take advantage of higher grades of minerals that can sometimes be found at greater depths. The challenges with deeper shafts are the requirements to supply services to the mines' operations at depth as well as to dewater the mine. Both the supply of water and the dewatering of mines is generally done using piping, which at greater shaft depths is now required to contain higher pressures as well as accommodate changes in temperature resulting from normal mine operations. This paper will discuss the requirements for the design of high pressure piping in deep vertical shafts. The discussion will start with the general definition of the systems and the detailed design requirement. Once this is clearly outlined, we will discuss the options available for fulfilling these requirement as well as the advantages and disadvantages of each of the systems. We will finish with installation recommendations and provide a basis for the maintenance of these systems.

14:00 **Paper 52**

Wireless for Mine Shafts – From Construction to Production

Jeremy Berg, Manager, Engineering & Technical Services, Redpath Canada Limited

There is a very small fraction of wireless experts in the world with experience in underground installations and an even smaller fraction that have experience specific to building mine shafts. This is why in 2009, Redpath created its own system to meet the demands specific to shaft construction. Today, after a dozen shaft installations and several design iterations, Redpath has the expertise and experience required to implement a proper wireless system in any shaft configuration. This document will explain multiple proven wireless communication designs optimized for shaft construction and suitable for permanent use. This includes line of sight installations up to 1200 m, short-range mesh networks, and the latest patent pending Integrated Leaky Feeder Mesh Network. Additionally, this document will explore the lessons that Redpath has learned in its effort to interconnect the people and tools needed to build a mine shaft.

SESSION 3

13:00–14:30 | SHAFT LINING DESIGN - TRINITY BALLROOM

13:00 Paper 10

Buckling of Circular Rings Under External Pressure in a Confined Environment. "Amstutz Buckling" – An Enhanced Approach

Alan Pearson, Principal Engineer, Golder Associates UK Ltd.

"The theory of buckling of shafts and steel tunnel-linings" was published by E. Amstutz in 1970 and commented on in 1974 by S. Jacobsen in his paper "Buckling of circular rings and cylindrical tubes under external pressure". The author has revised and enhanced Amstutz's original work to address Jacobsen's comments on its limitations and to extend its validity over a much wider range of pipe/shaft geometries, including those commonly found in deep mine access shafts. The author has also looked at Amstutz's assessment of strengthening with flexible shear anchorages and adapted the theory of non-linear shear deformation response of bolts as outlined in "Behaviour of eccentrically loaded bolted connections" by S.F. Crawford & G.L. Kulak to develop a method to assess increased buckling capacity using the full plastic shear capacity of studs based on widely available typical shear load deformation curves, which are easily collaborated by simple tests for detailed design. This paper seeks to both document these enhancements to the original Amstutz buckling design approach and provide context within a modern shaft design setting, linking back to established first principles of water-resistant shaft lining design.

13:30 Paper 46

A Simplified Approach for Evaluating Concrete Deterioration in Vertical Shaft Lining

Xiaodong Zhao, Associate Professor, China University of Mining and Technology

This study describes the strain behavior in vertical shaft lining (VSL) embedded in thick soil deposits and its application to assessment of concrete deterioration. The observed strain in VSL continuously decreased and was accompanied by a sinusoidal fluctuation due to the influences from negative skin friction and temperature. The increase in strain increment between peak and trough at each monitoring year, compressive strain level as the serv-

icing time continued, and VSL depth implies that the concrete strength was attenuated, and this attenuation significantly depended on the existing compressive strain level in the VSL. The reliability of the proposed approach was validated by Schmidt Hammer Technique–based concrete strength and is applicable in concrete assessment and fracturing prediction of VLSs in thick soil deposits.

14:00 Paper 21

Nutrien Allan Potash Shaft Concrete Liner Remediation

David Murray, Chief Mine Engineer, Nutrien Allan Potash

In 2017, Nutrien Allan Potash remediated a portion of the concrete liner in the production shaft. A set of underslung work platforms and collection boxes was used in conjunction with hydraulic splitters, jack legs, and hand chippers to excavate and remove the broken concrete. New concrete was placed in kind per the original pressure relief design using a shaft slip form. Shortly after excavating, the estimated breaking rate and amount of original concrete in-situ was determined to be under-estimated. Completion of 15 ft of excavated concrete and 10 ft of replaced new concrete occurred on April 28, 2017, and the production shaft was turned over to mine operations. Starting in February 2019, Allan Potash has remediated a portion of the concrete liner in the service shaft. The project differs from the 2017 project in that the remediation will occur during normal running operations and only during the night shift. Rather than hydraulic splitters and hand chippers, the contractor's methodology includes a concrete saw and mechanical excavator off a working platform. The selected methodology is based upon the lesson learned from the 2017 project in the production shaft. The service shaft project is scheduled to complete in July 2019. This presentation will highlight the design and methodology of remediation, comparing the two projects in separate shafts.

SESSION 8

14:45–16:15 | GRAND BALLROOM

14:45 Paper 18

Accurate Live Measurements for Shaft Alignment During Sinking or Shaft Remediation

Gabino Preciado Paz, Project Engineer, Golder Associates

Accurate, easy to obtain, and reliable methods of measurement are the cornerstone of shaft and tunnel development during sinking and at other points of operation, maintenance, or in some cases remediation. This paper presents a new methodology to capture present shaft conditions in such a manner that they can be taken from the physical to the digital world, where they can be stored and used for engineering design purposes in a space not directly affected by the costs associated with shaft time and sinking performance. The methodology uses the basic principles of shaft alignment (plumb lines and survey instruments) while adding modern LiDAR, geolocation, and survey control tools that can more completely capture the surrounding environs. The complete cycle of collection through to processing and delivery of pertinent information underground can take less than an hour. During sinking, capturing data as a live stream measurement and being able to assess the alignment of the shaft liner can be critical to the design (or redesign) of infrastructure with very tight tolerances, maximizing space and conveyance travel. Minute changes in alignment can be captured as the sinking progresses such that actions can be taken immediately to correct out of tolerance alignment or liner deviation issues that ultimately could affect the final furnish after the shaft is finished. Likewise, post-construction, optimal operating conditions, and maintenance for the life of this critical access to the mine can be recorded and digitized. Observed changes can be identified and planned as future shaft repair works or changes in the design to make full use of the installed shaft infrastructure. The methodology has been developed and successfully deployed during the ongoing sinking works of the shaft at the Jansen Potash Project in south-central Saskatchewan.

15:15 Paper 34

Phakisa Number 3 Ventilation Shaft Rehabilitation Project

Lawrence Schultz, Managing Director, Redpath Mining

The amenability theory was developed by Alex Naudts and considers grouting operations as continuous permeability tests where Newtonian test fluid water is replaced by a cementitious or solution grout. It uses hydraulic conductivity and grouting data to establish the amenability coefficient of a particular grout zone. The amenability coefficient reflects the quantity of apertures or voids accessible to the selected grout divided by the quantity of apertures accessible to water in the zone intersected by the grout hole. By calculating in real time the effectiveness of a particular grout at the start of a grouting operation, the most appropriate grout to match design criteria can be targeted. By incorporating the amenability theory in every grouting operation schedule, savings and an increase in productivity are typically achieved. Three short case studies illustrate different enhancements in productivity:

- At an underground mine during the construction of declines, a cement based suspension grouting program was highly ineffective and did not appear to affect the inflow into the mine workings. The amenability theory was used to evaluate the grouting program and based on this evaluation, changes to the grouting program were made that allowed the grouting to meet the project's objectives.
- A pre-excavation grouting program implemented during shaft sinking operations used the amenability theory to select the most suitable grout for the program. Schedule constraints also influenced grout selection.
- In a highly heterogeneous 'soil' formation in a tunnel/shaft project in Miami, the amenability theory was used to select the grouting sequence of every individual grout hole.

15:15 Paper 11

The Amenability Theory: Applied in Rock and Soil to Maximize Productivity

Ward Naudts, President, ECO Grouting Specialists Inc.

The amenability theory considers grouting operations as continuous permeability tests where Newtonian test fluid water is replaced by a cementitious or solution grout. It utilizes hydraulic conductivity and grouting data to establish the amenability coefficient of a particular grout zone. It reflects the quantity of apertures or voids accessible to the selected grout, divided by the number of apertures accessible to water, in the zone intersected by the grout hole.

By calculating in real time, the effectiveness of a particular grout at the start of a grouting operation, the most appropriate grout to match design criteria can be targeted.

By incorporating the amenability theory in every grouting operation schedule savings and an increase in productivity are typically achieved. Three short case studies will illustrate different enhancements in productivity.

At an underground mine during the construction of declines, a cement-based suspension grouting program was highly ineffective and did not appear to affect the inflow into the mine workings. The amenability theory was utilized to evaluate the grouting program and based on this evaluation, changes to the grouting program were made which allowed the grouting to meet the project's objectives.

A pre-excavation grouting program implemented during shaft sinking operations utilized the amenability theory to select the most suitable grout for the program. Schedule constraints also influenced the selection of the grout.

In a highly heterogeneous 'soil' formation in a tunnel/shaft project in Miami, the amenability theory was used to select the grouting sequence of every individual grout hole.

SESSION 4

14:45–16:15 | SHAFT LINING DESIGN - TRINITY BALLROOM

14:45 Open Table Discussion on Shaft Lining

As part of the shaft conference, there will be a special session dedicated to shaft lining design. Golder and the University of Beijing, both conference sponsors, are recognized experts in this field and will have presenters providing reviews of global best practices in this specialized area. After the papers are presented, there will be an open table session, providing participants a chance to engage directly with presenters to discuss shaft lining design in more detail. If this is an area of expertise that you engage in, you won't want to miss this unique

16:15 Closing Remarks | Grand Ballroom

WEDNESDAY NOVEMBER 20

08:30 WELCOME | GRAND BALLROOM

SESSION 9 | 08:40–10:10 | GRAND BALLROOM

08:40 Paper 5
Engineering Excellence into Large Diameter Drill and Blast Shaft Galloways for Safety and Productivity

09:10 Paper 6
Case Study – Blind Shaft Sinking for BHP Jansen Project

09:40 Paper 20
Lucky Friday's No. 4 Shaft – Ten Years from Concept to Completion

SESSION 10 | 10:25–11:55 | GRAND BALLROOM

10:25 Paper 37
The NioCorp Developments Elk Creek Project: A Shaft Design Case Study

10:55 Paper 54
Development of Pan American Silver's La Colorada Shaft

11:25 Paper 8
Shaft Sinking to the Potash Level in a Sedimentary Basin – Scissors Creek Case Study

SESSION 11 | 13:00–14:30 | GRAND BALLROOM

13:00 Paper 24
The Largest Fully Lined Blind Bored Ventilation Shaft Constructed to Date in Australia

13:30 Paper 29
An Investigation of In-Situ Ground Conditions Through the Application of Advanced Shaft Wall Monitoring Tools

14:00 Paper 13
Design and Construction of a Unique Shaft Bottom Structural System for a Potash Mine

SESSION 12 | 14:45–16:15 | GRAND BALLROOM

14:45 Paper 19
Installation of Shaft Bottom Steel Prior to Shaft Sinking

15:15 Paper 33
Raise Drilling a 1,892 m Deep Service Shaft in Zambia

15:45 Paper 63
The York Project: Shaft Sinking Mission 2021: Reaching Polyhalite

16:15 CONFERENCE SUMMARY AND CONCLUSION

TECHNICAL PROGRAM

WEDNESDAY | NOVEMBER 20

08:30 Welcome | Grand Ballroom

SESSION 9

08:40–10:10 | GRAND BALLROOM

08:40 Paper 5

Engineering Excellence into Large Diameter Drill and Blast Shaft Galloways for Safety and Productivity

Timothy Wakefield, Engineering Services Executive, Murray & Roberts Cementation

Final Galloway designs for vertical shaft sinking projects evolve from complex thought processes that integrate operational processes and systems and methods of communication, power supply, drilling, blasting, ventilating, mucking, supporting, surveying, dewatering, sealing, concrete lining, and shaft furnishing. Attention to ergonomic design detail at the shaftsman / structure interface is at the heart of safe and successful multi-deck working platforms. For economy, the end-product must: have a low mass to reduce suspension rope end loads to be able to use smaller suspension hoists and have lighter headframe structures; be robust to withstand concussion damage; be easily constructible on site; be maintainable in the shaft barrel; and comply with safety and legislated standards. This paper describes a systematic design framework and sequenced thought process that delivers a product that is engineered with excellence, illustrated by making use of the design that evolved during a recent Galloway project destined for a 10 m diameter shaft. The Galloway engineering iterative process starts with laying out horizontal deck plans, mostly dictated by the permanent shaft purpose and configuration, whilst maximizing openings to enable muck to be removed rapidly for the best sinking cycles. Concurrently, the designer needs to understand the chosen sinking methodologies in conjunction with crewing to determine the number of decks and fix their spacing. Insufficient access to move and line up formwork, set reinforcing rods,

and pour concrete in the confined spaces of the Galloway is inherently a major risk to be mitigated. An iterative and integrative process follows for the primary configuration, which delves into increasing design detail, accommodating all other methodology influences and resulting in 3D layouts for further risk assessment, review, and fine tuning by seasoned shaftsmen.

09:10 Paper 6

Case Study – Blind Shaft Sinking for BHP Jansen Project

Patrick Rennkamp, Product Manager, Herrenknecht

In 2011, Herrenknecht developed the Shaft Sinking Roadheader (SBR), a shaft-sinking machine suitable for applications in frozen ground and medium soft rock of up to 120 MPa for BHP Billiton's Jansen Mine Project in Saskatchewan. The SBRs were manufactured and assembled at the Herrenknecht headquarter in Schwanau, Germany during 2012 after a pre-design phase. August 2018 marked the successful completion of both ~1000 m deep shafts by DMC Mining Services using the SBR technology. This paper gives insight to the machine set-up and technology, an overview of its assembly, and a review of project success and challenges related to the SBR at the Jansen Mine. In addition, the enhanced safety for personnel working on such a machine will be outlined, which is a significant benefit of the SBR. The machine is divided in three main areas: the infrastructural platforms, the area of rock support, and the core machine. Due to the machine set-up, workers will not be exposed to the unsupported shaft wall during regular operation. Sinking is achieved by performing the three main tasks simultaneously: partial face excavation, mucking of cuttings, and application of primary rock support. The development of a pneumatic mucking system solved the problem of removing cut material from the bottom of the shaft and its vertical transportation through the machine to a discharge point on one of the machine's work decks.

09:40 Paper 20

Lucky Friday's No. 4 Shaft – Ten Years from Concept to Completion

David Robert Berberick, Senior Project Manager, Hecla Limited

Hecla Limited's No. 4 Shaft at the Lucky Friday Mine is the largest capital expenditure in the corporation's 128-year history and is considered the deepest shaft in the United States. This paper will discuss the project's history and lessons learned from the initial conceptual design work in 2007 through project commissioning in 2017. Change management was key for the owner, contractors, and vendors in delivering the operational and organizational success on the project. The No. 4 Shaft has extended the life of the Lucky Friday mine by 21 years to 2039.

SESSION 10

10:25–11:55 | GRAND BALLROOM

10:25 Paper 37

The NioCorp Developments Elk Creek Project: A Shaft Design Case Study

Chris Dougherty, Chairman, Nordmin Group of Companies

The Elk Creek Project will become Nebraska's first underground metals mine, built to access the Elk Creek niobium/scandium deposit. Development of the design for this facility required the review of challenging hydrogeological conditions, mine production requirements, demanding CAPEX limitations, and tight schedules. Through an extensive review of various alternatives to satisfy these many constraints, the Nordmin Group was able to define a concept and design that addressed risks to the project, met production, cost, and schedule constraints, and improved constructability. This paper will review the many challenges faced and solutions arrived at in a demonstration of a methodology used in designing a modern shaft and hoisting plant.

10:55 Paper 54

Development of Pan American Silver's La Colorada Shaft

George Greer, Senior Vice President Project Development, Pan American Silver Corp.

In early 2014, Pan American Silver Corp. commenced a project to construct a second shaft at its La Colorada underground mine located in the northern part of Zacatecas state in Mexico. The mine dates back to the 1920s, and with favourable exploration results resulting in additional reserves below the current mining levels, an increase in mine production was justified. The existing shaft could not be expanded as it was already at maximum capacity, and mining had progressed well below the shaft depth. In addition, it could not be used to transport personnel nor materials. This was the first new shaft development project undertaken by Pan American Silver in the history of the company. The new shaft was designed to extend to 618 m below surface, with the option for a future extension to 1,000 m. The existing mine workings allowed the use of a raise bore for excavation of the shaft opening, using directional drilling to control the pilot hole. The shaft was located between two separate vein systems and had to avoid extensive historic workings in the upper levels. A further challenge included poor ground conditions, particularly near the transition area between the dacite in the upper section of the shaft and the limestone structure below. This was an interesting project with many successes and numerous lessons learned. These include numerous raise bore pilot hole drilling challenges, the need to shotcrete the shaft pilot raise, the evolution of the sinking strategy, and a somewhat unique loading level design. The project was successfully completed in 2016, with the shaft operating at full mine production capacity within weeks.

11:25 Paper 8

Shaft Sinking to the Potash Level in a Sedimentary Basin – Scissors Creek Case Study

Arnfinn Prugger, Retired Geophysicist, Independent

The Rocanville potash mine (owned and operated by Nutrien Inc.) in southeast Saskatchewan, Canada, has been in continuous production since 1971. Devonian potash, formed approximately 380 Mybp, is mined in a sedimentary basin environment at approximately 1000 m depth below surface in this area of Saskatchewan. In 2007, it was announced that the Rocanville mine would be expanded to increase production from 3 Mtpa to approximately 6 Mtpa of finished potash products, requiring an increase in hoisting capability from approximately 9 Mtpa to over 18 Mtpa. The Rocanville potash mine has historically been accessed through two shafts: a production and ventilation exhaust shaft and a service and ventilation fresh-air shaft. A very important part of the Rocanville expansion involved construction of the new service shaft (6 m diameter, 1143 m deep) for fresh-air ventilation and access, 15 km from the existing surface plant. Once this third shaft was completed in 2015, the historical service shaft was converted to a second exhaust and production shaft. Three shafts are now available for mine access, ventilation, and ore hoisting at Rocanville. Construction of the new Scissors Creek shaft at the Rocanville mine, the first potash shaft successfully completed in Saskatchewan since 1979, is summarized here. Shaft construction in the Saskatchewan sedimentary basin involves sinking through five rock types: glacial tills, shales, sandstones, carbonates, and salts. The first four rock-types are all water-bearing, and the salts will dissolve in water. This results in five sinking challenges and requires five shaft lining designs. The upper 580 m of rock (till – shale – sands) was frozen before sinking, and grouting methods were used for water control through deeper carbonate levels. Challenges that were faced and overcome during shaft sinking are reviewed, and ideas are discussed that future operators working in sedimentary basin environments might consider in order to avoid these difficulties.

SESSION 11

13:00–14:30 | GRAND BALLROOM

13:00 Paper 24

The Largest Fully Lined Blind Bored Ventilation Shaft Constructed to Date in Australia

Michael Boyle, Managing Director, Abergeldie Complex Infrastructure

The blind shaft boring method is a mechanized process of excavating large-diameter vertical shafts downward from the surface. Blind boring is a rotary drilling technique that eliminates any requirement for personnel to work within the shaft or access the underground workings during the drilling and lining phases. All excavated material is delivered to the surface, carried by a flow of circulating fluid through the centre of the drill rods. A heavily weighted drilling assembly, suspended from above, provides the vertical thrust to a hard rock cutter head. The drill assembly is suspended from a large A-frame rig and powerful winch at ground level. As depth increases, more drill rod and pipe is added to the load supported by the A-frame. The two largest rigs operated by Abergeldie are the largest of their type in the world, capable of drilling shafts to 500 m deep with 6.5 m diameter or even deeper at smaller diameters. The shaft most recently completed by Abergeldie was to a record-breaking depth of 523 m with a raw diameter of 6.2 m and a finished, lined diameter of 5.5 m. The shaft is kept full of water throughout the drilling and later lining process. Rock fragments are transported from the working face to the surface by a strong flow of water around the cutter head, piped up through the drill rods and discharged into a sedimentation pond at ground level. The water filling the shaft also provides counter-pressure to contain naturally occurring aquifers, oil, and gas that might be encountered in the strata, helps to stabilize the shaft walls, and means that shaft linings (prefabricated in sections from steel, concrete, or a composite of the two) can be installed and grouted under pressure. Slight overbalance with the natural pressures in the ground eliminates water flow from the strata into the shaft, which could otherwise dislodge the grout.

13:30 Paper 29

An Investigation of In-Situ Ground Conditions Through the Application of Advanced Shaft Wall Monitoring Tools

Sven Bock, Project Manager, DMT GmbH & Co. KG

At the start of a new shaft project, a specific number of ground investigations is performed. In most cases, the investigations are based on the analysis of rock and soil probes obtained from boreholes. However in practice, such analysis performed on a single core often leads to different results when conducted by various experts or companies. Such discrepancies in core analysis influence further rock mass assessment and design assumptions. Furthermore, it is not uncommon for ground conditions during shaft sinking to differ from the designed ones, which has a great impact on the estimated stress and strain state of the shaft lining. Therefore, it is extremely important to use tools to minimize such discrepancies and to include in the shaft design a sufficient monitoring system, allowing control of all important phenomena, not only during shaft sinking, but also during lifetime of the shaft. The paper presents an overview of existing monitoring techniques and discusses future work required to further improve not only the underground works during shaft sinking, but also the shaft lining design methodology.

14:00 Paper 13

Design and Construction of a Unique Shaft Bottom Structural System for a Potash Mine

Eric Nolasco, Chief Engineer, Stantec

Shaft bottom structural systems are used in underground mining to support transfer of personnel, equipment, and ore to and from underground to the surface. This paper first summarizes the evolution of design philosophy from a concrete tower supported on a concrete plug to the current structural steel design arrangement with unlined shaft walls and a clear shaft bottom area with only a concrete housekeeping pad. The paper then reviews the design parameters, analysis and design, and construction methodology for this rather unique shaft bottom structural system consisting of three sets of hitch beams, each having specific functional requirements.

14:45 Paper 19

Installation of Shaft Bottom Steel Prior to Shaft Sinking

Dwayne Ziebarth, Director – Industrial, Central and Western Canada, WSP Canada Inc.

The normal sequence of operations to develop a new underground mine is: construct and outfit headframe for shaft sinking; sink shaft; construct and outfit shaft sump; and develop shaft station and shaft bottom steel. In an effort to reduce the overall project schedule, an innovative plan was developed to install service shaft steel below station level prior to completion of the shaft sinking effort. To better evaluate the construction of this substantial steel tower, a preliminary constructability evaluation was conducted, including the best method of supporting the main tower from the bottom, middle, or top of the tower. The design criteria and plan involved:

- Develop access from existing service shaft 25 km underground
- Use materials to maximize strength while minimizing corrosion exposure
- Estimate the location of the shaft centerline
- Over-excavate the station and shaft below station to allow future shaft steel repositioning
- Design the tower steel for modular installation
- Incorporate commissioning considerations, such as suspension of the cheese weights during steel installation
- Provide for covered stair access to shaft bottom
- Enclose the shaft envelope with open panels to allow visibility and ventilation
- The design approach was innovative and this paper will describe the design principles and challenges encountered while providing insight into the solutions developed and implemented, especially the modular construction and installation methodology.

15:15 Paper 33

Raise Drilling a 1,892 m Deep Service Shaft in Zambia

Lawrence Schultz, Managing Director, Redpath Mining

This paper describes raise drilling a 6.1 m diameter vertical service shaft in Kitwe, Copperbelt Province, Zambia. The scope comprised establishing a shaft collar, pre-sink to -90 m, and raise drilling the shaft from surface to a final depth of 1,892 m underground in four separate lifts of approximately 500 m each, as well as equipping the shaft steelwork, erecting the headframe, and commissioning the shaft for hoisting. The paper describes the initial challenges faced, the safe methodology developed, and the execution thereof. In addition, it details the hurdles encountered during execution and the corrective actions taken to overcome them.

15:45 Paper 63

The York Project: Shaft Sinking Mission 2021: Reaching Polyhalite

Wolf-Dieter Trödel, Manager OEM Projects, DMC Mining Services

Sirius Minerals is a UK-based fertilizer development company focused on advancing into operation its polyhalite project in North Yorkshire, England. The operation is known as the Woodsmith Mine, which has an estimated 2.7 billion tonnes of reserves and is currently in the construction phase. DMC Mining Services was selected to carry out construction of four shafts for the project: a 6.75 m diameter production shaft to a depth of 1594 m, a 6.75 m diameter ventilation shaft to a depth of 1565 m, and two additional shafts to support the construction of the material transport system (the MTS and Lockwood Beck intermediate) to 360 m depth for servicing the underground conveyor network for transport of product from the mine site to the costal port facilities located at Teesside. This paper will review the status of the project to date and the innovative approaches that DMC is using to ensure a safe and successful shaft sinking project.

16:15 Conference Summary and Conclusion | Grand Ballroom

CORPORATE EXHIBITS

The corporate exhibit is showcasing 21 shaft sector suppliers of equipment, services and technologies and are strategically located in meeting and networking areas throughout the event.
Lower Convention Centre

01	Nordmin
02	University of Science and Technology, Beijing
03	Hepburn Engineering Inc.
04	Stantec
05	ABB
06	Cementation
07	Herrenknecht
08	Mine Hoist International Limited
09	Technica Mining
10	Golder
11	Huron Mining
12	DMT Gmbh & Co. KG
13	FLSmidth
14	Timberland Equipment Limited
15	DMC Mining Services
16	Komatsu Mining Corp. Group
17	FKC-Lake Shore
18	Multicrete Systems Inc.
19	Nordic Minesteel Technologies
20	Keller Foundations, LLC
21	Mine Vision Systems

USEFUL INFORMATION

Conference Language

The official language of the convention is English.

Time Zone

Toronto is 5 hours behind Greenwich Mean Time (GMT -5h or UTC -5h). But in the summer, it does have daylight savings time, changing it to UTC -4h from mid-March to early November.

Climate - November

The average daytime temperature in November is high: 10°C / 50°F; low: 2°C / 36°F. It is a great time to combine business with pleasure and head outside to discover the city.

Currency and Credit Cards

The Canadian currency is the dollar. The dollar can be divided in 100 cents. Coin denominations are 5¢, 10¢, 25¢, $1 and $2. Bank notes are $5, $10, $20, $50 and $100. Foreign currency and traveller's cheques can be converted into Canadian dollars at foreign exchange banks and other authorized money exchangers. Credit cards such as Visa, MasterCard and American Express are accepted in hotels, department stores and restaurants.

Automated Teller Machines (ATM)

Travellers who carry internationally recognized credit cards can get a cash advance in Canadian dollars at ATMs installed at airports, hotels, department stores, subway stations and tourist attractions. Credit cards like Visa, MasterCard and American Express are the most widely accepted in Canada. They will also take Interac cards, from known banks.

Transportation

The Toronto Pearson International Airport is only 26 km from downtown. Public Transportation, shuttle buses, car rentals and taxis are available.

Business Hours

Most government offices, private companies and banks are open between the hours of 09:00 and 17:00 and closed on weekends. Shopping malls are open from 09:00 to 21:00 on weekdays, and 19:00 on weekends.

Tipping

In bars and restaurants, it is very rare that gratuities are included in the bill. In general, people are expected to leave 15% of the bill to the waiter, and 10-15% to a taxi driver or tour guide. For porters or other hotel employees, the average tip is $2 per bag or $5 for heavy items.

Tax

In Ontario, there is a Harmonized Sales Tax (HST) of 13%. Usually, HST is added at the cash register so the amount on the price tag may not be the final price. 8% of the HST goes to the provincial government and 5% goes to the federal government.

Electricity

The standard electrical supply is 110 volts (60Hz).

Telephone / Mobile Phone

To make international phone calls, outside of the United States, dial 011 + country code + area code + phone number. North America area codes and frequently called international country codes can be found in phone books or online.

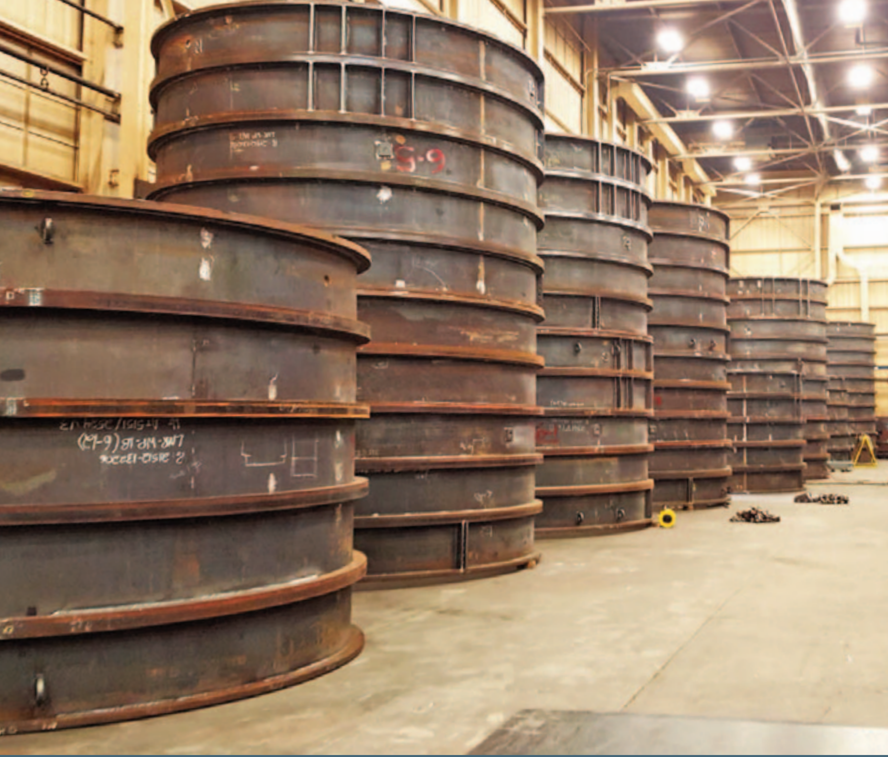
Please note that emergency (911), directory assistance (411) and international directory assistance (1+area code+555-1212) phone calls are free from pay phones. In Toronto, 416 is the area code.

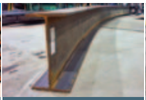
Insurance

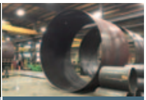
Participants are advised to get adequate travel and health insurance before leaving their respective countries.

Useful Phone Numbers

Police, Fire and Ambulance	911
Emergency health services	1-800-461-6431
Health Assistance Line - Telehealth	1-866-797-0000
Ontario Poison Control Centre	416-813-5900 / Toll-free: 1-800-268-9017
Directory Assistance	411/ Toll-free: 1-800-555-1212
Highway and Bridge Conditions	511
Overseas/International Calls Assistance	0 (zero)
Long Distance Directory Assistance	1+Area code+555-1212
Tourist Information	416-392-9300







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