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Using remote reading instrumentation to improve safety, productivity, and support design in underground coal mines

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USING REMOTE READING INSTRUMENTATION TO IMPROVE SAFETY, PRODUCTIVITY, AND SUPPORT DESIGN IN UNDERGROUND COAL MINES

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ABSTRACT: Accurate and timely monitoring of strata stability in underground excavations is a critical activity that forms part of the fundamental daily mine safety processes and is mandated by law to be carried out in all operations. Coal mine strata monitoring includes the use of instrumentation and observations carried out by personnel. Mechanical tell-tales are an instrument widely used throughout the coal mining industry and are used to measure displacement of roof rock horizons. They comprise of either 2 or 4 reading indicators that are connected by stainless steel wires to anchors secured up a purposely drilled hole and require personnel to read them individually and record displacements manually.

Prompted by the desire to improve safety and provide a system that could offer continuous monitoring of areas within the mine, without the requirement for manual recording of tell-tale data, Moranbah North Mine (MNM) initiated installation of a remote reading monitoring scheme in 2012. The monitoring system is entirely automated, and the data is automatically collected and transferred to the surface via an optical fibre cable. Alarms are pre-set to defined triggers and alerts are sent out automatically if triggers are reached. The real time data can be accessed anywhere with available internet connections and log on details. Significant amounts of data, previously not accessible, has been recorded and collected since the initial remote reading system was installed. This has provided critical information for support design work, remedial works, and development of accurate Trigger Action Response Plans (TARP). The data is increasingly being used for optimising mine support. Upgrades to the remote reading technology in recent time mean that the available system uses cutting edge technology and can be manipulated to meet different applications.

All Anglo American underground metallurgical coal mines within Australia now employ Remote Reading Tell-Tales (RRTTs) in longwall gate roads. The system is also being adopted by numerous other coal mines in other mining groups both in Australia and Globally

INTRODUCTION

Australia's coal mining industry accounts for 27 percent of total revenue for the Australian mining industry with longwall mining providing around 90 percent of Australia's underground coal production CSIRO, 2018). Longwall mines are characterised by development of roadways that constrain longwall panels, rapid retreat of longwall faces which extract all the coal in each longwall panel which then allows overburden strata to collapse into the resulting void. This means that the stress regime is constantly changing, and that the geotechnical environment can change within hours or even minutes (Guo et al. 2012).

The coal mining industry primarily uses manually read tell-tales as the main method of monitoring roof behaviour (Jayanthu et al). These instruments are often only read once per shift by underground officials, with readings recorded on paper sheets and sent to the surface to be entered into an online database. This process often limits the extent to which the system can act as a safety tool and as a means of assessing strata behaviour to determine the effectiveness of the roof support. With respect to safety, movement may go undetected due to the instruments not being continuously read. With respect to strata behaviour, the extent of the dynamic geotechnical environment ahead of the longwall and as the longwall approaches may not be captured as manual readings represent only a snapshot in time. MNM initially installed RRTTs and Remote Reading Strain Gauges (RRSG) in its surface to

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coal seam inclined drifts to continuously monitor strata movement in these critical excavations. These initial installations were simplified as the drifts are fixed and non-gaseous. Realising that RRTTs had great potential to improve safety and data acquisition around longwall panels, MNM worked with the provider to develop a system that could be applied in roadways which were retreating and had the potential to contain flammable gas. The initial system designed was based around two-anchor tell-tales and was limited to approximately 40 instruments in a 4km long roadway.

The results from the initial system were extremely encouraging, providing a full picture of strata behaviour as the longwall approached. A significant safety benefit was a reduced requirement for physical examination of the tailgate roadway. This not only reduced the exposure of underground officials to an environment typically elevated in gas and dust, but in doing so increased daily production time by up to an hour - a significant production time gain at a longwall mine operation.

Following initial success, the system has been developed to improve reliability, accessibility and to integrate with other existing technology at MNM. The new system is based on two and four-anchor tell-tales that, in addition to the electronic interface, can be visually read by all underground personnel. Each instrument can be readily reset if displacement exceeds the tell-tale range and the system can support up to 150 instruments along 10km of roadway.

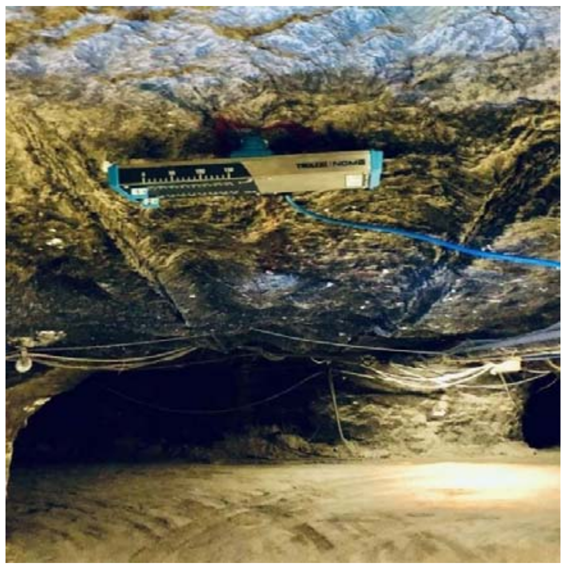

Figure 1: Installed RRTT in an underground Gypsum mine (courtesy NOME Services)

THE REAL TIME MONITORING SYSTEM

Real Time Monitoring Instrumentation

Individual RRTT instruments are simple to install and connect. They can be installed at the development face off the continuous miner in place of standard mechanical instruments. Once connected in the advancing development panel, a complete record of strata movement can be collected which enables primary development support and secondary longwall support to be assessed for effectiveness, which then in turn enables ground support systems to be optimised.

Data from the RRTTs is transmitted to software installed on a remote server on the surface. Alarms are set in the monitoring software to alert when any trigger levels for total movement or rate of movement are reached. The software then sends data to site Supervisory Control and Data Acquisition (SCADA) interfaces in real time. The SCADA interfaces are now also included in the sites digital transformation using underground tablets. This enables underground officials to receive alarm triggers relating to their panel in real time, allowing remedial measures to be put in place as necessary to manage safety risks and prevent operational delays e.g. longer cable support, standing support and pre-consolidation.

A variety of monitoring instruments are in use at MNM for remote and continuous monitoring of critical excavations in outbye areas and at the active coal faces.

Strain Gauges

HMA 3050 strain gauges with Campbell Scientific datalogger are fixed directly to installed steel sets and shotcrete lining in the Drifts. The strain gauges are a proven technology and have been used in the mining, civil and materials testing industry for many years. The device design is simple and robust, with no moving parts and can be monitored remotely or by the manual readout box. The devices are proven to be corrosion resistant, waterproof, dust proof and the strain induced by temperature change is corrected for automatically. The electric coil is detachable without damaging the gauge, providing a degree of flexibility in the event of cable damage.

The devices themselves are a vibrating wire strain gauge, mounted to the surface of the structural member (steel set or shotcrete lining), where any deformation of that substrate produces a change in the wire tension and corresponding change in its frequency of vibration. The frequency is measured through an electronic coil, connected through a signal cable to a data logging system and all measurements are made in terms of micro strain.

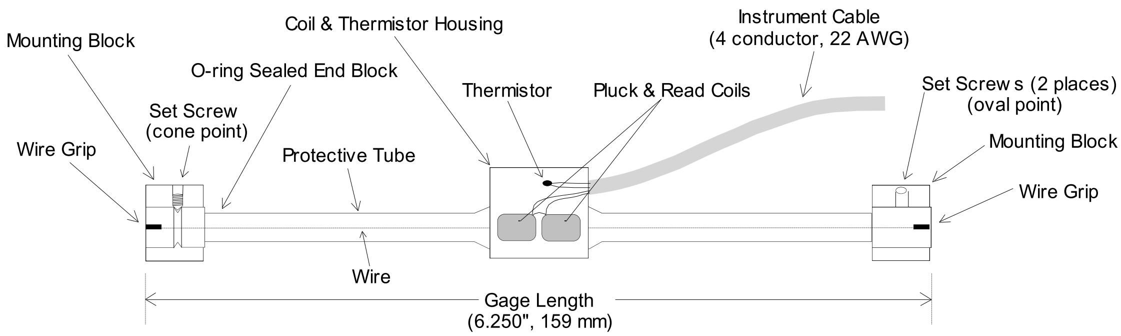

Figure *2*: Workings of strain gauge

Figure *3*: Strain Gauge installed

2 and 4 anchor Extensometry/ Tell-tales

The RockMonitor XR tell-tales are the latest version of the RRTT and are configured with both 2 and 4 measurement heights at MNM and currently the 4 x height RockMonitor design forms part of the active monitoring program in the mine. These tell-tales are being installed at the cutting coal face on continuous miner operations as part of the primary support process. The cable installation and connectivity is able to be achieved as part of the standard panel advancing. Because the newer version of the tell-tales have a manual user face they can be used as mechanical tell-tales until they are connected to the remote system.

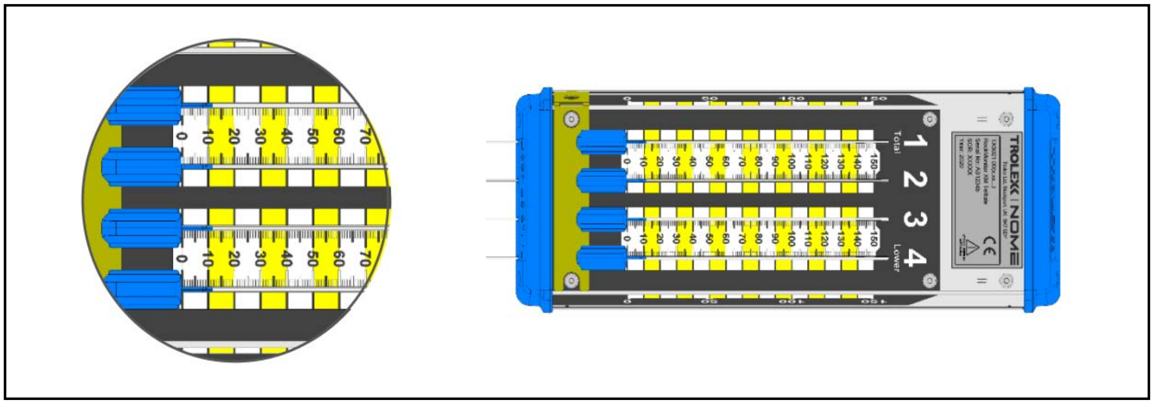

Figure *4*: User face of RRTT are able to be read manually

Data Collection and Storage

Typically, the equipment set up for the powering and connecting the RRTT system is installed in a life of mine areas such as the outbye mains. A power and data enclosure containing an intrinsically safe power supply and associated equipment is installed alongside an intrinsically safe certified controller. The equipment requires a 110-240V power feed and an ethernet cable that runs to a network switch inside any belt starter of transformer that already has a communication backbone. This allows the communication link to run to a virtual machine or server on the surface of the operation where the user software, called CORE, is installed. The software then communicates directly to the controller underground and receives continuous data packets. Up to 10km of underground roadways can be monitored from a single controller.

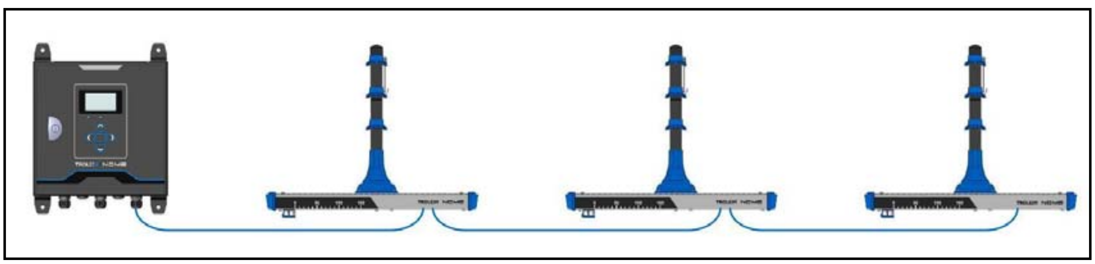

Figure *5*: Rockmonitor Controller and Telltales

Accessing and Storage of the Monitoring Data

Access to all instruments is quick and easy via plug and play connectivity. Users are created with the CORE software package and level of access can be assessed and provided based on the role of the individual. When SCADA exporting is being used any personnel on the surface or underground with access to a SCADA interface can visualize the system and access data trends/alerts in real time. Exporting data into Excel XLS or CSV is also available.

The data can be stored several ways and if required it can be easily secured on an offsite server for added security. On small systems not requiring connection in real time to the surface, a portable reader can be put into auto wake up mode and left underground connected to the main trunk line. It will wake up at predetermined intervals from 30 minutes up to 12 hours and take a log of every instrument reading along the line.

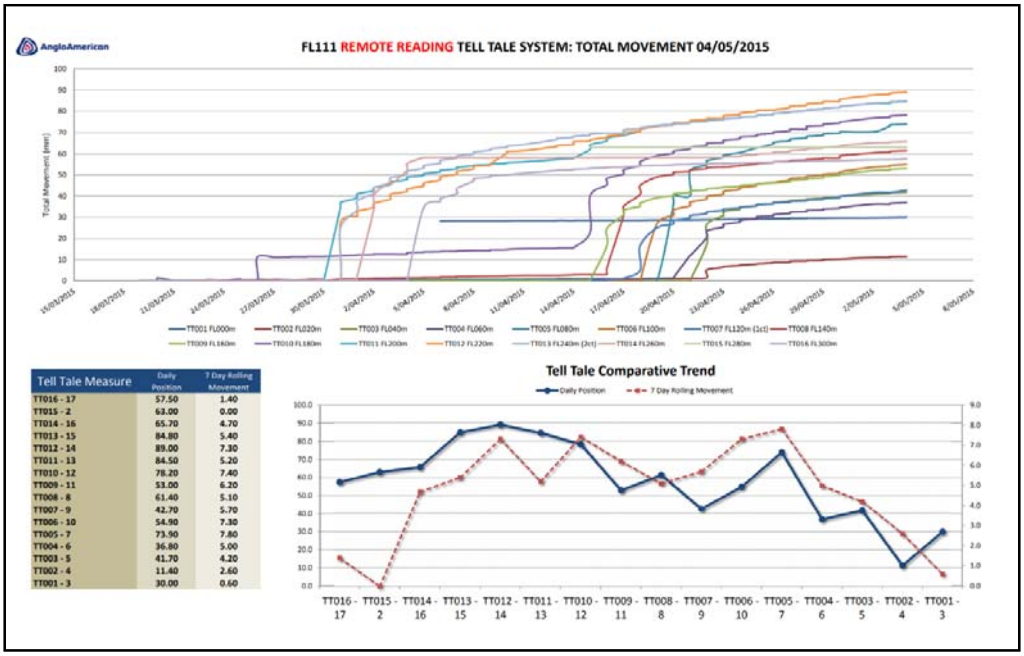

Figure 6: Monitoring Dashboard

BENEFITS AND APPLICATION OF CONTINUOUS REMOTE READING

Benefits of RRTT

Using remote monitoring systems at MNM has provided significant advantages and advances in monitoring of the strata across the mine. Visibility on the behaviour of critical excavations such as widened or high roadways has given feedback on support performance as well as provided opportunity for fast response times when needed. Some of the advantages of using the RRTT from a strata monitoring perspective at MNM are listed in Table 1.

Table 1: Strata Control Benefits of RRTT at MNM

STRATA MONITORING BENEFITS
Continuous monitoring of strata displacement
Strata displacement measurement up to 150mm (without reset)
Resettable height measurement for movement in excess of 150mm
Two or four monitoring points (anchor heights) between 0.6m and 15m
Fully customizable alarm settings including rate of movement and absolute displacement
Automated notifications via software or e-mail for improved response time
Detailed monitoring and display of data using powerful application software

Logistically, the system is relatively simple to have installed with some features including; the ability to monitor up to 10km with a single system, flexibility configuration – with spur or daisy chain available, plug and play installation, integration with existing systems such as SCADA, and connection of up to 150 devices per controller.

Applications of RRTT

The RRTT system was initially introduced to MNM following a roof fall in the mine's entry drift. The following recovery programme included the installation of support in both the P&E and Conveyor Drifts to a minimum Factor of Safety (FOS) value of >2. In addition to this support review, it was recommended that ongoing observations and measurements be undertaken in the drifts by way of a real-time monitoring program which monitors displacement trigger levels. Both tell-tales and strain gauges were installed throughout the drift to provide continuous monitoring along the length of both roadways. Figure 6 shows the location of the tell-tales installed along the drift, in cross section.

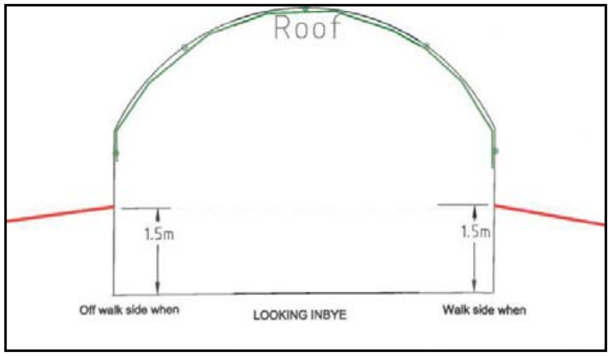

Figure 7: Schematic of tell-tale holes drilled in drift for installation of the RRTT system

Due to the success and benefits of this installation, the system has since been applied throughout the mine in outbye critical excavations and active production areas. Some notable optimisation strategies and safety improvements have been executed due to the use of the system, including capturing movement exceeding the capability of manual telltales or other systems, real time convergence monitoring and constant awareness of conditions in restricted or no go zones.

- In Longwall 112 an integrated monitoring system using convergence pogos was installed in the tailgate roadway to record the continuous ground movement outbye of the retreating longwall face and better understand both the roof and floor movement. This was able to be done without requiring any personnel to access the tailgate, which typically represents a limited access area due to respirable dust exposure, elevated gas during cutting and poor roof and rib conditions.
- Faceline 111, an exceptionally wide roadway designed specifically for installation of large longwall equipment, experienced extended standing time which resulted in ground movement exceeding the design expectations. The installed RRTT monitoring system was used to closely monitor and allow the geotechnical engineers to respond accordingly and in a timely manner to conditions that were occurring but were not necessarily detectable by visual observations. Having the continuous visual on ground movement in this critical excavation provided the mine confidence and reassurance that operations could continue despite being delayed.
- Faceline 112 excavation support was designed using the experience of Faceline 111, which had recorded magnitudes of movement that could not have been obtained without the RRTT system as they exceeded the limitations on other available systems. The strata characterisation and experience from Faceline 111 indicated that the support in Faceline 112 should be denser and extend above the height of softening. This provided precedent during the support design process that benefited the overall success of Faceline 112.

FUTURE AND NEW TECHNOLOGY

SMART Connectivity

SMART junction boxes are currently being designed and certified to allow for automated disconnection of instruments during longwall retreat. This will further reduce the need to put personnel at risk when disconnecting devices and will allow for personnel to remain and analyse data from remote operating centres.

Technology Transfer

Currently there is collaboration between Bond University and NOME to incorporate machine learning in order to develop artificial intelligence techniques for the prediction of strata movement in underground mines. The current intention is for this system to be capable of forecasting future strata movement in real-time based on current and past movement data, as well as key geological and mine features. Primarily, the purpose of this module would be to improve safety and reduce downtime by predicting and pre-empting catastrophic strata movement before it occurs.

Increased Design & Response Accuracy

The work being done on machine learning and strata movement prediction will eventually allow the incorporation of predictive TARPS for proactive strata planning in critical roadways.

Personnel Safety Systems

Collision avoidance and Proximity detection is planned to be incorporated into as part of the suite of real time monitoring systems offered with the system. This will also include the means to alert work groups of trigger points and eliminate the exposure of personnel once these situations occur, improving safety by reducing risk to personnel

CONCLUSION

Using remote monitoring systems at MNM has provided significant advantages and advances in monitoring of the strata across the mine. With continually improving technologies and advances in machine learning, the system has the potential to offer more safety benefits in addition to strata monitoring. As with the implementation of any new system to a mining operation, the successful onboarding requires a financial investment in addition to the resources to be allocated to ensure its success; personnel involvement at the implementation, maintenance and ongoing data analysis takes time and dedication to this success. MNM has invested the resources to integrate the system into its routine processes and routinely benefits from the ability to monitor remotely. With underground coal mining operations getting increasingly deeper and with more and more roadways that require continued serviceability, the option of remote monitoring can help improve support design, responses, and overall safety.

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