

Development, Application and Potential of a Real-time Return Gas Monitoring System

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ABSTRACT

This paper presents an overview of the design and development, application to date and potential of a real-time return gas monitoring system.

Initially developed as an ACARP/Industry funded project, whose prime aim was to create a 'turn-key', prototype, stand alone, real-time, Return Gas Monitoring System (RGMS) capable of providing quantitative assessments of gassiness levels on a shift by shift basis, enabling unusual gas emission patterns to be readily flagged.

GeoGAS designed and commissioned the RGMS and 'live-trialled' it at Tahmoor Colliery and Dartbrook Mine. The system has a number of features new to Australian underground coal mines and is comprised of three distinct components:-

1. Hardware high accuracy CH₄ and CO₂ gas analysers, air velocity meter, belt weigher, PLC, modems and computer.
2. Real time software - SCADA based control, trending and data logging software.
3. Offline software - GeoGAS's RGMS data post-processing software implemented to perform the calculations and data reduction, facilitate analysis, and present results.

The system, currently monitoring longwall return conditions at Dartbrook Mine, has been in continuous use since February, 1995. Areas of potential application include :-

- Provision of an additional safety barrier in quantifying gassiness levels.
- Rationalisation of drilling & drainage operations.
- Post-analysis of real events.
- Support of operators and staff.

Introduction

In January 1994, GeoGAS Pty. Ltd. was awarded an ACARP grant (Project 3076) to research the development of a real time, Return Gas Monitoring System (RGMS) over a three year period.

The prime objective was to create a turn key, prototype, stand alone, real time, gas monitoring system capable of providing quantitative assessments of gassiness levels on at least a shift by shift basis and enabling unusual gas emission patterns to be readily flagged.

Sub objectives were to:

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- Define and document the process of using these data to back analyse gas drainage effectiveness.
- Assess the potential for using the technique to quantitatively define seam gassiness on a sub shift period basis.
- Define indices relating the gas emission response (rate of emission, peak emission rate, quantity, composition) to outburst proneness in terms significance to outbursting.

The project scope covered design and fabrication of the gas monitoring system, trial of the system at Tahmoor Colliery and Dartbrook Mine, and development of reporting procedures and associated software to facilitate its real world application.

System Development

The GeoGAS RGMS is comprised of underground and surface located hardware (Fig. 1), Scaleable Architecture Data Acquisition (SCADA) software, and data post-processing software.

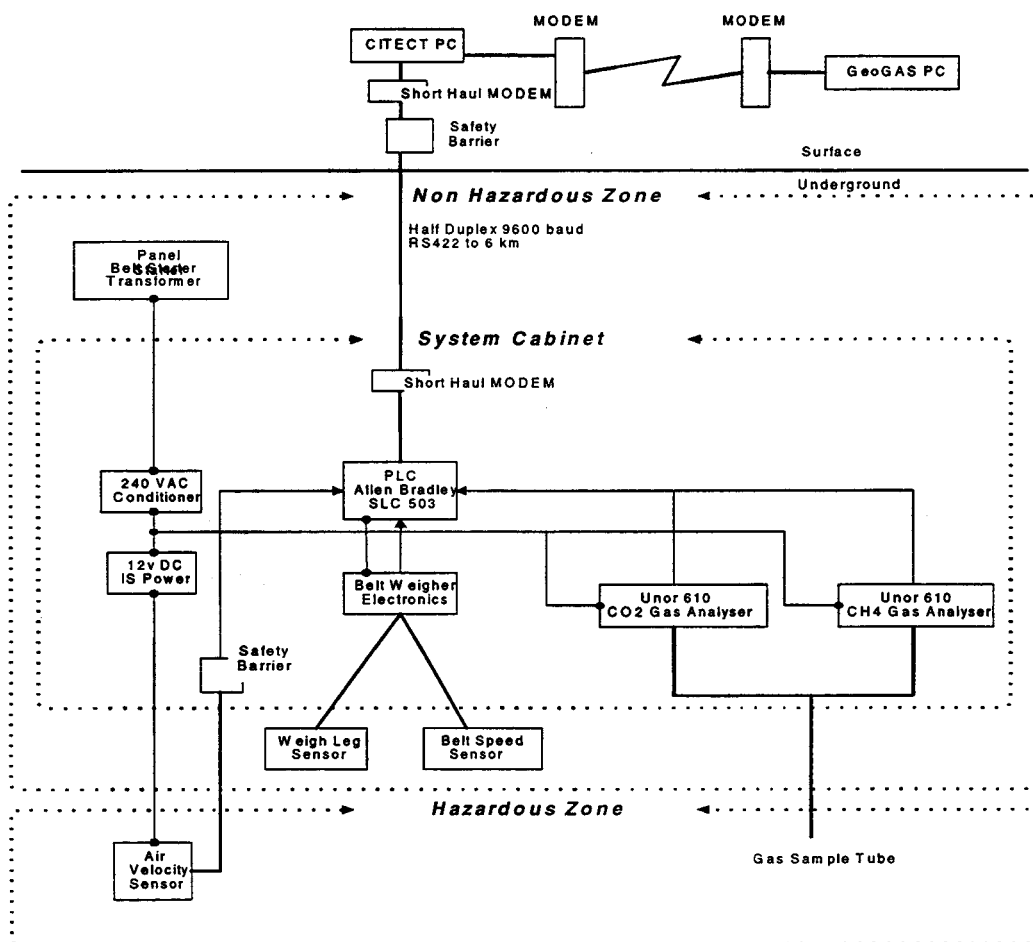


Fig.1 - GeoGAS return gas monitoring system - layout

Underground hardware

The system cabinet contains a mix of electrical and mechanical components, some intrinsically safe (IS), but most non-IS. It must be operated within non-hazardous conditions at all times. If the PLC detects CH₄ levels at or above 1.25% for 10 seconds it sends an alarm flag to the surface PC and then shuts the system down, isolating power to the interlocked door switch. Major underground hardware items include :-

- Two UNOR 610 gas analysers (CO₂ and CH₄).
- One Allen Bradley SLC 500 Programmable Logic Controller (PLC).
- One Control Systems Technology IPM-10 belt weigher monitor.
- One Mikan short-haul modem.
- One Trolex TX1322 vortex shedding air flow sensor.

A separate gas bottle cabinet houses two calibration gas bottles

- One "DS" size Alpha standard span gas.
- One "D" size zero gas (High Purity N₂).

The system PLC maintains autonomous control of the underground system accepting input data from the gas analysers, belt weigher controller and air velocity sensor every 2 seconds. It maintains continuous interactive communication with the surface CITECT monitoring PC, buffering then forwarding data.

The PLC program features :-

- Scaling of analog inputs under full auto-ranging analyser output.
- Calculation of moving averages of analog inputs to allow damping of signal levels, in particular, fluctuations in the air velocity signal.
- Totalised coal production, as recorded by the belt weigher, on per shift, per day and year-to-date basis.
- Control of the auto-calibration procedure for the gas analysers. The PLC is programmed to calibrate the gas analysers at an automated interval (weekly), or under command from the surface PC. Pressure sensors in the Zero and Span gas lines allow the PLC to indicate fault alarms when the calibration gases are spent.
- Alarm monitoring of CH₄ and CO₂ concentration levels.
- Decoding of gas analyser control signals to enable text display in the surface CITECT PC, of the current status of the gas analysers and calibration gas bottles.

A formal risk assessment of the system was conducted in December 1994 prior to the underground installation of the equipment at Tahmoor Colliery. It's aim was to ensure the system incorporated sufficient designed safeguards against hazardous operations in underground environments and recommend any further safeguards deemed appropriate.

Above ground hardware

- One IBM Compatible PC running SCADA and data post-processing software.
- One Mikan short-haul modem.

SCADA software

The operator's interface with the RGMS is provided by the CITECT for Windows (v3.4) SCADA package. This software hosts communications between the surface PC and PLC in real-time. It enables user interaction for logged data, graphically trended results and privileged user access control for PLC settings, alarm set-points and acknowledgements.

Logged data from the SCADA software (CITECT) provides values and trends for

- CO₂ flow rate (l/s).
- CH₄ flow rate (l/s).
- CO₂ concentration (%).
- CH₄ concentration (%).
- Air velocity (m/s) and air quantity (m³/s).
- Production rate.

Data post-processing software

GeoGAS's RGMS data post-processing software was implemented in 32 bit Windows Pascal (Borland Delphi 2.0). It accesses ASCII or dBase files generated by the SCADA package and provides a means for calculating, checking and reporting the gas emission data.

At the completion of a shift the software is used to differentiate background from production related emission levels (on a shift by shift basis) and calculates the following face area emission :-

- Peak CO₂ emission rate (l/s).
- Peak CH₄ emission rate (l/s).
- CO₂ quantity (m³)
- CH₄ quantity (m³)
- CO₂ gas make (m³/t).
- CH₄ gas make (m³/t).

The software defines a process for calculating the gas emission indices and assessing the validity of the data. In addition to quantifying the gas emission, the software compares the results to historical readings and provides a rating of the emission (abnormally high, normal higher than average, normal lower than average, abnormally low).

A number of methods were devised and tested, to automatically set background levels. The 'Rate of Change' algorithm was applied. It involves :-

- Mapping the distribution of each gas flow value (CO₂ l/s and CH₄ l/s), against the rate of change between values (the actual change over a moving average of 5 consecutive readings, divided by the elapsed time in seconds). The background emission level in l/s is that corresponding to the minimum rate of change value (Fig. 2).
- Integrating the shift's total emission and subtracting the background component.

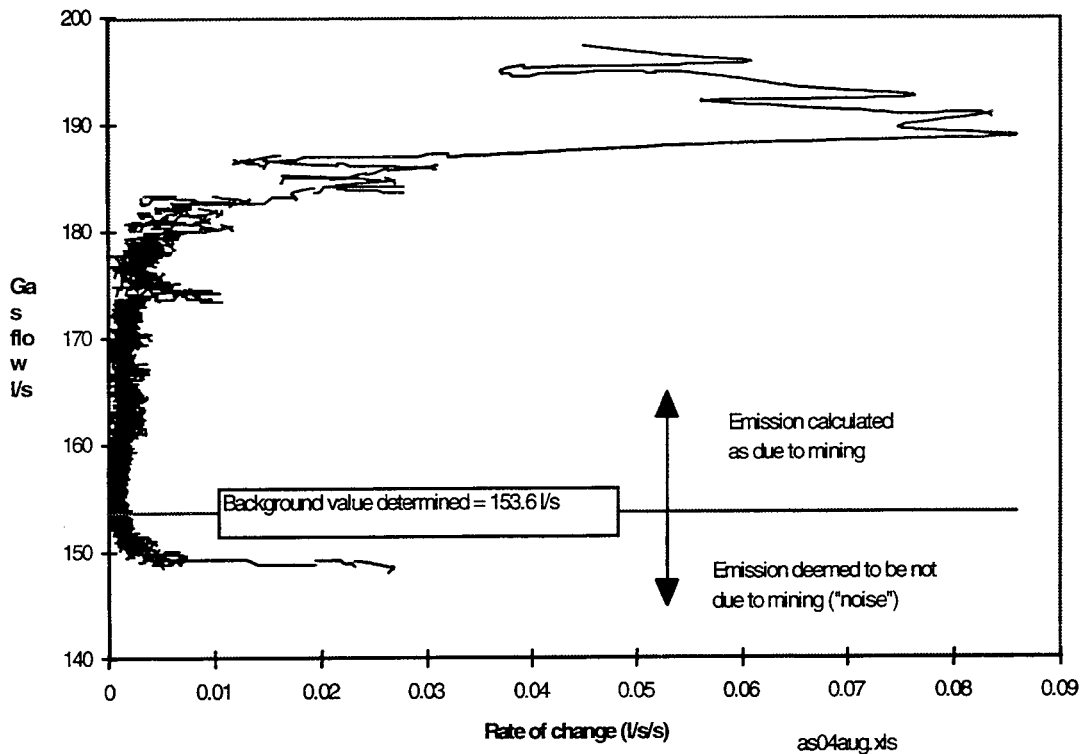


Fig. 2 - Analysis of rate of change

System application

Tahmoor Colliery

Tahmoor Colliery agreed to provide a site for trial and financial assistance. 510 Panel was the first project field site (Fig. 3).

The trial was conducted over an 8 month period from 13th February 1995 to the 13th October 1996. Actual monitoring took place for the months of June, July and August with the balance in commissioning, decommissioning and production delays.

The Bulli seam is mined to a height of 2.2 m. The virgin gas content is around 12 m³/t at 80% CO₂ and 20% CH₄, but within 510 Panel had been pre-drained to less than half this value with the gas composition at 73% CO₂ and 27% CH₄. Analysis of the data highlighted rhythmic fluctuations in air velocity as a significant source of noise. Rapid swings of about 5% were evident in air velocities (in this case equating to 45 m³/s to 43 m³/s). These transient changes were not reflected in corresponding CO₂ and CH₄ gas concentration readings, resulting in a higher level of 'noise' in the CO₂ and CH₄ gas flow results. The noise is partially controlled by the PLC's data averaging and moving average settings. There is further scope to adjust these settings.

The belt weightometer stand, originally configured for West Cliff Colliery, proved unsuitable for the belt structure at Tahmoor Colliery and was damaged. Production data in both trials was subsequently sourced from colliery records.

During the monitoring period, 510 Panel mining was periodically delayed when gas content tests did not achieve the required threshold value. The maximum shift gas content plots would therefore be indicative of the threshold values that could be applied using the RGMS (Fig. 4). While more data and further analysis is required in defining threshold values for the system, it does give an indication of how thresholds may be applied to the continuously monitored data.

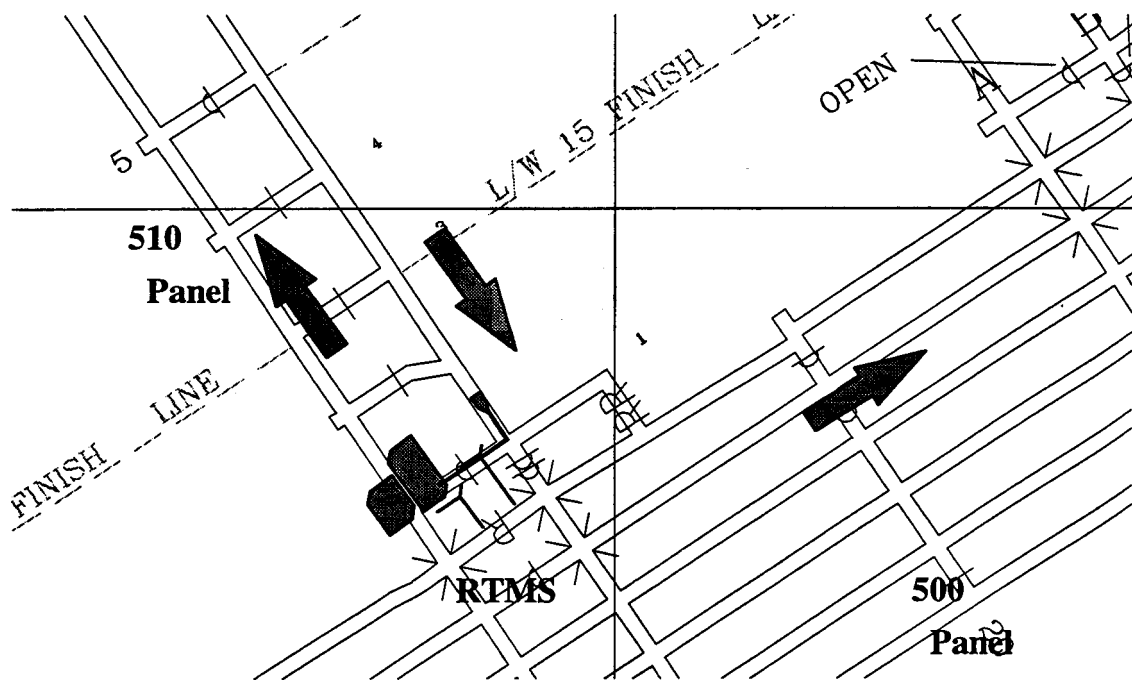


Fig. 3 - Tahmoor monitor site

The Tahmoor Colliery trial succeeded in quantifying and characterising the gassiness on a shift by shift basis for coal that had been pre-drained to below the threshold limit for outburst alleviation.

For constant levels of inherent gassiness, the gas make varies with production (Fig. 5).

While production in 510 Panel was subject to an outburst management plan, and proceeded only below prescribed gas content threshold, a potential application of this system would be development of additional threshold criteria based on shift gas make.

Dartbrook Mine

Dartbrook Mine provided a site and financial assistance. G101 Panel was selected as the second project field trial site (Fig. 6). The system was committed to the Dartbrook trial for a total of 11 months, from 13th October 1995 to the 14th September 1996. Installation was delayed initially by 3 months while Dartbrook drafted site-wide specification for belt weightometer equipment and its installation.

Continuous monitoring took place from mid April to mid September. The data set related to production within the panel, spans the period 25th April to 17th July 1996. In this time G101 panel developed from inbye 18 cut through to its termination at 25 cut through in essentially undrained gas conditions.

Dartbrook's gateroad developments mine to a height of 3.9 m from an essentially continuous 25 m sequence of coal. The gas content of the coal monitored averaged 7.8 m³/t (Q1+Q2+Q3 at 20°C) with a composition of 75% CO₂ and 25% CH₄.

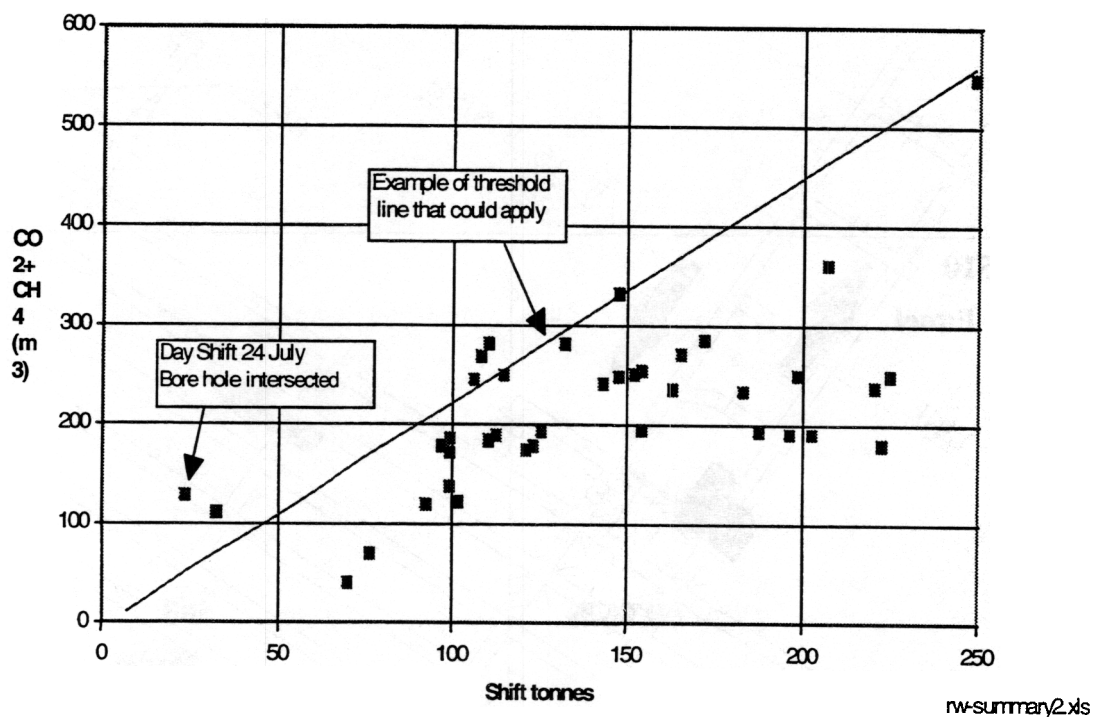


Fig. 4 - Shift gas quantity (CO₂+CH₄)

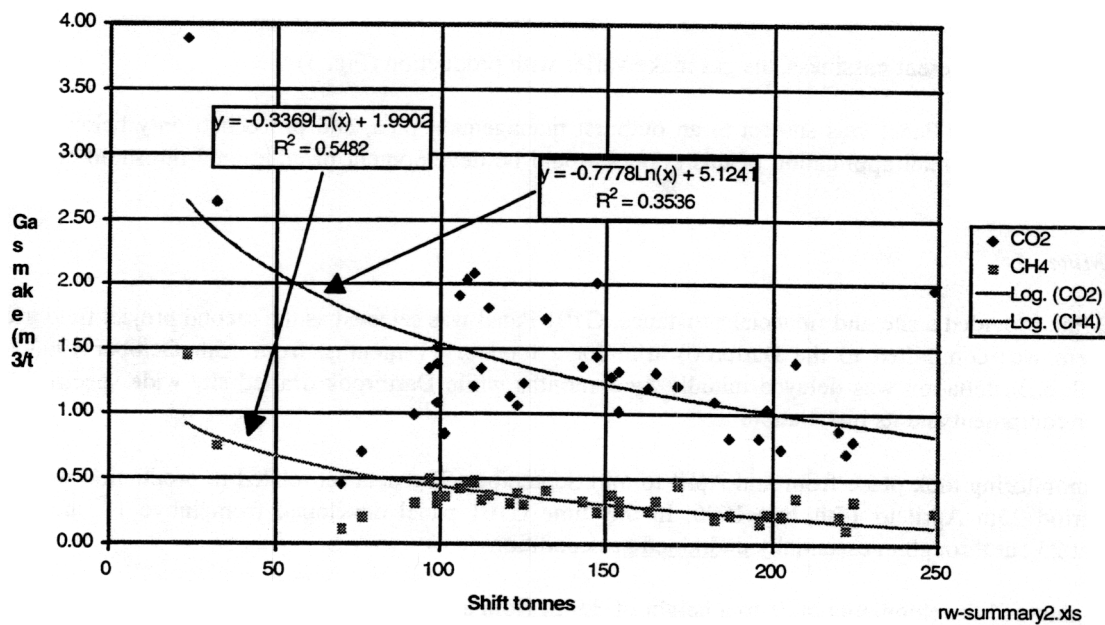


Fig. 5 - Shift gas make

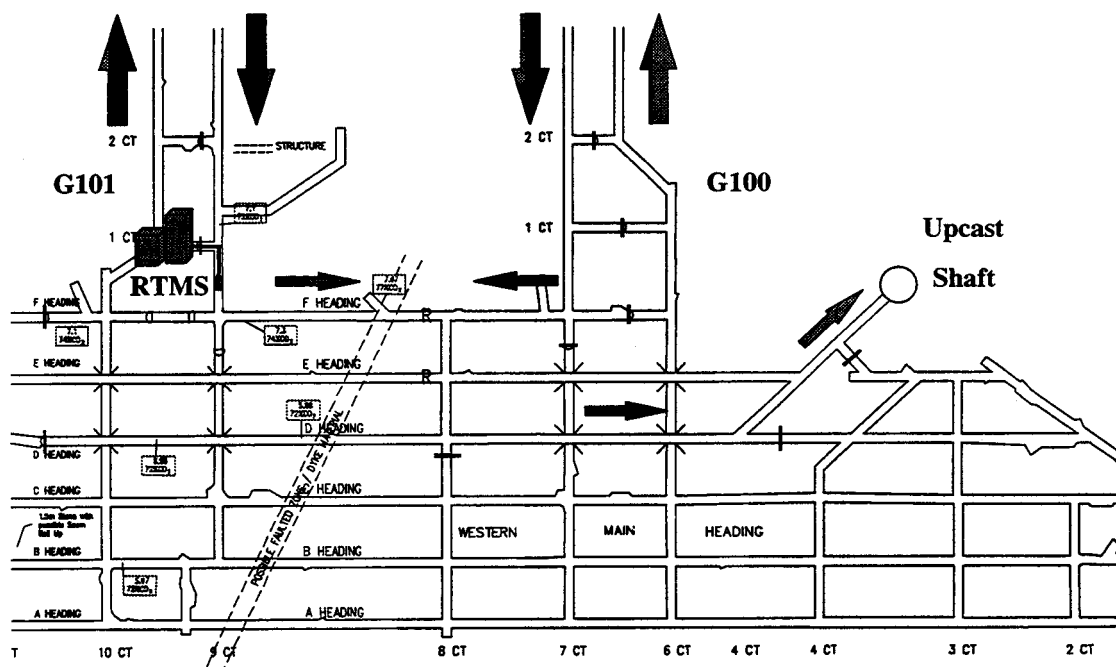


Fig. 6 - Dartbrook monitor site

Most mining conducted within the monitored period was 'conditional'. Production was halted and face drainage instituted twice as a result of gas levels in cores taken ahead of development. High face gas levels on development interrupted production in June and the panel was terminated in mid July shortly after connection of the Longwall 1 installation roadway.

As in the first trial, air velocity data introduced noise (up to 5%) in raw emission rate determinations. Of more concern was drift in the air velocity response. Stone dust from the airflow and adjacent stone dust barrier racks progressively fouled the sampling chamber of the velocity head, drifting the indicated value by approximately 0.005 m/s per day.

The trial succeeded in quantifying and characterising the gassiness on a shift by shift basis for coal that had not been gas drained. The background emission accounted for 80% of the panel emission (contrasting with just 46% at Tahmoor). This is due to the large gas reservoir being mined. Gas quantities generated in the face areas were around 5 times higher than those seen at Tahmoor.

Transient gas events related to the intensive drilling and drainage program at Dartbrook were seen most days. No production related 'abnormal' emissions were detected.

The system logged and processed shift-based data for over 93% of the shifts when power was available. In the absence of power interruptions, the first trial showed the equipment, once properly installed and commissioned, to be robust and reliable. In this trial only four data shifts were lost, resulting from dust loading of the air velocity sensing head.

System potential

Provision of an additional safety barrier

There is a renewed focus on control of hazards associated with gas emissions by implementation and application of mine specific management plans. Direct real-time return gas monitoring, with subsequent analysis, provides an important additional barrier.

New mines, especially those in Queensland where depth (and gas content) are progressively increasing, need to ensure mining is carried out in an environment of zero dynamic gas incidents. Conditions will change with depth. In addition to measures (such as the GeoGAS Desorption Rate Index) aimed at defining when to take action to alleviate outburst potential, return gas monitoring should prove to be an important additional barrier.

A real life application for return gas monitoring occurred at South Bulli Colliery as response to a small outburst in a cindered zone. At one stage, preparations were under way to transfer the RGMS equipment from Dartbrook Mine, but it was decided to adapt the mine's own gas monitoring system to this application.

GeoGAS accessed South Bulli's data files daily via modem. Daily reports and analysis were provided to the mine on the level of gassiness encountered. As a guide, a draft threshold established for Tahmoor Colliery was utilised. Emission levels remained low.

The incident provided a ideal example of the potential application of the system. The South Bulli Colliery cinder zone was so fragmented, that gas content cores could not be taken and in-seam drilling for gas drainage was very difficult. Return gas monitoring became the only real option in assessing gassiness during mining. As rudimentary as South Bulli's system was, it did provide data (in a timely manner) which the colliery then incorporated in management of the hazard.

Rationalisation of drilling and drainage operations

In existing mines with functional outburst management strategies, data provided by the system should allow fine tuning of gas drainage system planning and operation. There is potential for the increase of respective gas content threshold levels without compromise in safety.

GeoGAS has been involved in assessments aimed at raising management plan related gas content thresholds in some mines (on the basis of an inherently low gas desorption rate as measured by the GeoGAS Desorption Rate Index, Williams 1997). Return gas monitoring is an additional barrier, directly measuring the mechanisms involved, and raising confidence in the determinations made.

Post analysis of real events

The return gas monitoring system enables the best possible back analysis, quantification and diagnosis of a gas dynamic event. Two such events were captured by the RGMS at Tahmoor Colliery. It was initially scheduled for installation at South Bulli Colliery, but sent to Dartbrook Mine as part of the gas management effort required there. The system would have been ideally placed and utilised at South Bulli Colliery.

Support of operators and staff

Underground operators frequently discern increased (or decreased) gassiness. Timely access to return gas monitoring data can aid in understanding the environment, alleviate concerns, and facilitate effective responses.

CONCLUSIONS

The system's control, communications and gas analysis components have proved responsive and robust. Improvements can be made in the air flow sensors, and re-specification of the belt weigher equipment is required to provide reliable coal production rate data.

The system has demonstrated its utility in actual gas dynamic incidents and capabilities in gassiness determination within development panels. Additional areas of application have been identified.

The system has increased (and increasing) potential application; today more than when engendered in 1994.

REFERENCES

Williams R.J., 1997: Definition of outburst threshold limits from core testing in "Safety in Mining Role of Geology" symposium Newcastle November 1997.

ACKNOWLEDGEMENTS

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