Published as: A.D.S. Gillies, H.W. Wu, N. Tuffs and T Sartor Real Time Integrated Mine Ventilation Monitoring, *Proceedings, Queensland Mining Industry Health and Safety Conference*, Townsville, pp133-140 August 2003.

Real Time Integrated Mine Ventilation Monitoring

A.D.S. Gillies, Hsin Wei Wu,
University of Queensland, Brisbane, Australia

N Tuffs and
Ventilation & Gas Engineer, Capcoal

T Sartor
Ventilation Engineer, BHP Billiton Cannington

ABSTRACT:

Software has been developed to link real time information generated by underground mine ventilation airflow monitoring sensors into a network simulation program to undertake network simulations and allow interpretation of key system data and operational changes. Results are used in the development of a computerized monitoring and simulation system to provide immediate or real time data on air behaviour within each branch within an underground mine ventilation network through linking of sensors to the ventilation network simulation software. The outcome of the project is an online system which can report changes in the mine ventilation system, allow causes of changes to be isolated and rectified, improve balancing of available air throughout the mine, allow improved approaches to regulator setting and dispense with much of the labour used for underground ventilation measurement. The main work activities involved in the research program have involved examination and modelling of regulators used in two Queensland mining (coal and metalliferous) environments, software modification and considerable mine site testing and optimising activities. The mathematical modelling of airflow through operating mine regulators was an important part of the project and this aspect is discussed.

1. INTRODUCTION

There is a move world wide to remote or telemetric monitoring of mine atmosphere conditions. Robust, suitable and intrinsically safe instruments are available for measurement of, for instance, gas concentrations, air velocity and air pressure. These are often tied to extensive mine monitoring and communication systems.

One approach to establishing air quantity through a ventilation branch is through measurement of differential pressure across an opening or regulator. Mathematical relationships are available to relate (with some qualification) pressure drop and quantity through a regulator orifice placed symmetrically in a round flow conduit. However these can, at best, only be used to approximate mine regulator behaviour due to:

- The irregularity of mine regulators in shape and symmetry and their positioning in normally roughly square or rectangular mine airways,
- The construction of the mine regulator opening which may result from, for instance, the operation of louvres, a sliding door, window or curtain or placement of drop boards, and
- Uncontrolled air leakage through the regulator or adjacent bulkhead.

The study briefly describes efforts to characterize or mathematically model regulators. It then describes how this information is used in the development of a computerized monitoring and simulation system to provide immediate or real time information on each branch within an underground mine ventilation network through linking of sensors to the ventilation network simulation software. Software has been developed to link real time information generated by mine ventilation monitoring sensors into the network program to undertake network simulations and allow interpretation of key system data and operational changes.

The outcome of the project is an online system which can report changes in the mine ventilation system, allow causes of changes to be isolated and rectified and improve balancing of available air throughout the mine, It is envisaged that in time the real time model will be an integral part of an online mine wide planning, monitoring and control software platform that will be updated continuously along with the mine plan. The main steps involved in examination and modelling of regulators, software modification and considerable mine site testing and optimising activities are described.

2. THEORY OF REGULATORS

A regulator is an artificial resistance (in the form of shock loss) introduced into an airway to control airflow. A regulator can be described as a large thin plate installed in a fluid conduit with an orifice. When a difference in pressure exists between the two sides fluid flows in the pattern shown in Figure 1. On the low pressure side the fluid issues as a converging jet in line with the centre of the orifice. The jet converges to its smallest area at a distance of about half the orifice diameter (Le Roux, 1990). This area is called the "vena contracta" (A_c at Fig. 1). The ratio between vena contracta and orifice area is the "coefficient of contraction", C_c (A_c/A_r at Fig. 1).

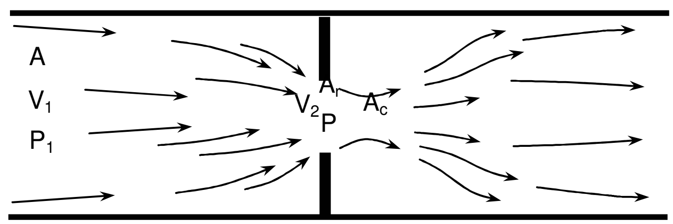

Figure 1. Airflow pattern through an orifice (after Burrows et al, 1989).

McElroy (1935) found that the C_c value is a relation between the ratio of the orifice and airway cross sectional area, N (A_r/A at Fig. 1), and Z, which is an empirical factor designated as the contraction factor, which is expressed as:

$$C_c = \sqrt{\frac{1}{Z - ZN^2 + N^2}} \qquad (1)$$

Values of Z vary according to the edge shape of the orifice. Since most regulators are square edged, a Z value of 2.5 is most commonly used in calculating C_c. Bernoulli's equation can be applied to both sides of the orifice as shown in Figure 1 in order to calculate the velocity and hence the airflow quantity.

A correction must be made for the contraction of the jet at the vena contracta. Since the orifice is larger than the vena contracta, orifice velocity is lower than in the vena contracta. The velocity equated based on Bernoulli's equations is the velocity at the vena contracta. Therefore, the velocity at the orifice can be obtained with the following equation:

$$V_2 = C_c \sqrt{\frac{2\Delta P_s}{\rho}} \frac{1}{\sqrt{1 - N^2}} \qquad (2)$$

where C_c is the coefficient of contraction, as described before. Since airflow quantity through regulator $Q = V_2 A_r$, it follows that:

$$Q = C_c \sqrt{\frac{2\Delta P_s}{\rho}} \frac{1}{\sqrt{1 - N^2}} A_r \qquad (3)$$

where A_r is orifice opening area in m^2.

3. FIELD TESTS OF REGULATORS

Field tests on several types of regulators were conducted at various underground metalliferous and coal mines. Initially verification of air behaviour in flow through regulators was investigated. Parameters measured were airflow quantity and pressure drop across regulator. From pressure drop measurements, airflow quantity through regulators can be calculated with Equation 3. Results of this calculation can be compared with measured values and the reasons for significant differences investigated.

3.1 Drop board regulator tests

The regulator test at the University of Queensland Experimental Mine (UQEM) is the drop board type as shown in Figure 2. Details of the tests and equations derived to account for leakage during measurements were described and discussed by Wu et al (2003) and Gillies et al (2002).

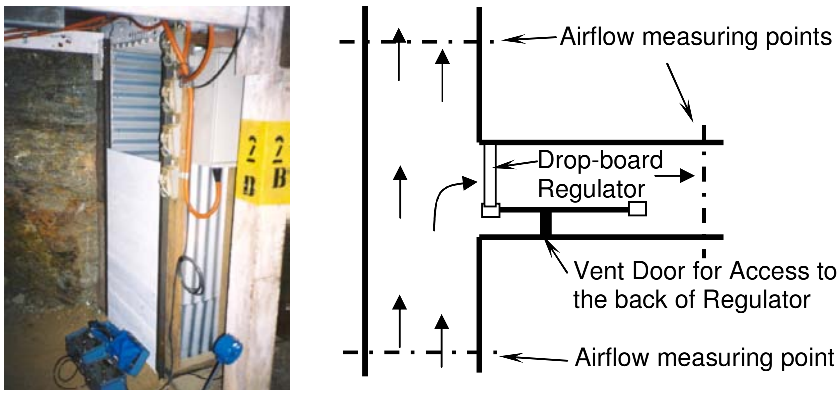

Figure 2. Drop board regulator tested at UQEM.

The relationship between the regulator opening area and total resistance can be derived as shown in Figure 3. Based on this, pressure and airflow quantity relationships can be calculated from mine regulator impedance characteristic curves. These can be drawn for different mine configurations as shown in Figure 4. The three curves shown illustrate relationships for one, three and five boards removed from the regulator.

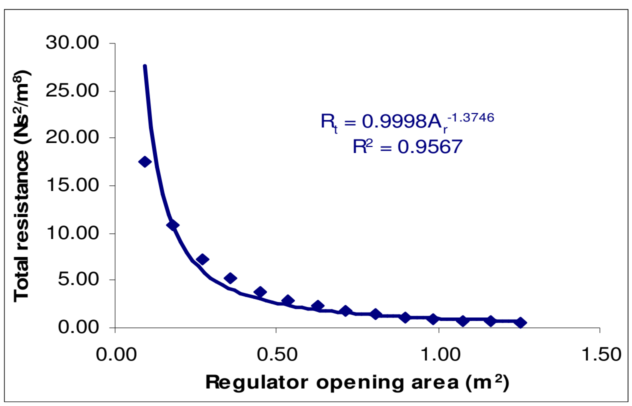

Figure 3. Relationship between new total resistance and regulator opening area.

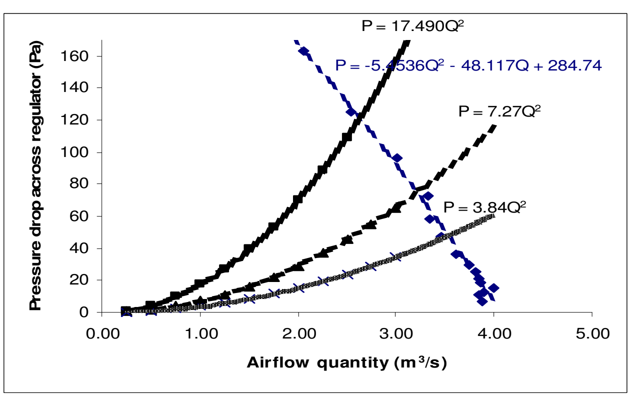

Figure 4. Drop board regulator characteristic curves.

3.2 C-section regulator tests

Similar tests were conducted on Drop Board style C-section regulators. Figure 5 shows a photographic view and the engineering drawing of a C-section regulator used by an Australian mine. The regulators were installed in either half or full sizes depending on the magnitude of the airflow regulation requirements and the locations.

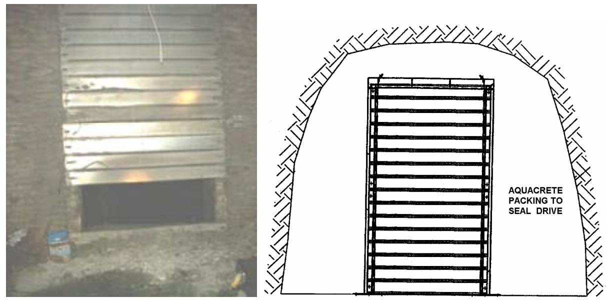

Figure 5 Photographic views and engineering drawing of a half size C-section regulator.

A half size ventilation regulator may consist of up to a total of 16 C-section galvanised steel boards, which are secured with humpback split pins to the frame structure. The full sized version is two of these regulator frames placed side by side. The frame structure is secured in place using rock bolts to the concrete floor base. Packing is used to seal the bulkhead around the regulator frame structure. Dimensions of each C-section board are 1.65 m in width and 0.2 m in height. The maximum opening area of a half size C-section regulator is 5.28 m^2.

Several test series were also undertaken to verify the relationship between the equivalent total regulator resistance, R_t, and equivalent opening areas, A_r at various locations at the same mine. Figure 6 shows the calculated relationships between R_t and A_r for the C-section regulators. It can be seen that the relationships are similar to the relationship established from the drop board regulator tests.

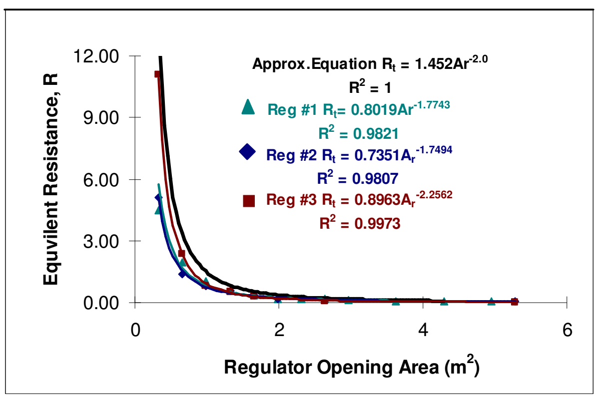

Figure 6 Relationship between R_t and A_r for C-section regulators.

In Figure 6, a theoretical relationship between the equivalent resistance and the opening area of a regulator similar to the approximation equation proposed by Le Roux (1990) was also included with assumptions made to account for the general mining conditions, for example, $C_C \cong 0.64$ and $\sqrt{(1-N^2)} \cong 1$. Therefore a value of 1.1 was suggested to replace these terms and R_t can be calculated from the following equation at standard air density of 1.2 kg/m^3.

$$R_t = 1.452 A_r^{-2.0} \qquad (4)$$

In Figure 6, it can be seen that the equivalent total resistance calculated from the tests was lower than the theoretical regulator resistance. As mentioned before, the equivalent total regulator resistance also takes into account resistances of the leakage paths which parallel air paths through the regulator opening. It is expected that the values of R_t will be lower than the regulator resistance itself.

3.3 Louvre regulator tests

Tests were carried out on louvre type regulators. This type of regulator is popular in Australian coal mines and an example is shown in Figure 7. Generally a double vehicle door design has louvres placed within panels of both doors. The louvre blades can be adjusted to various angles to control airflow. In this test both left and right doors could be set at nine positions. Tests were undertaken both by holding one side fixed and varying the other and by varying both sides. Relationships between resistance and the equivalent opening areas are shown in Figure 8.

Figure 7 An example of a louvre regulator.

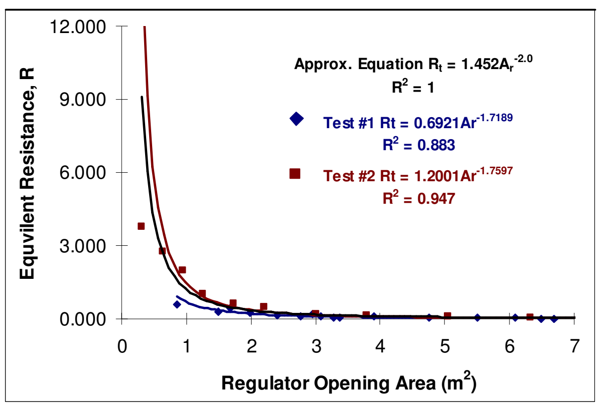

Figure 8 Relationship between resistance and equivalent opening area for louvre regulator.

It would appear that both aspects follow a similar relationship to that observed for the drop board or C-section regulators tested. There is no doubt that the resistance values increased as the equivalent opening areas decreased. However, it is suspected that due to the nature of fluid flow through louvre blade settings, the relationship between the resistance and equivalent opening areas is a more complex than drop board flow behaviour. A literature review on louvre regulators indicated that only limited research had been conducted on louvre flow behaviour.

3.4 Roller door regulator tests

Use of a roller door as a ventilation regulator was examined. Adjustment of the height of this door is undertaken via an automated control system. There is very little information on the use of roller doors as ventilation regulators and on the automation of such a system.

For this study, a roller door was installed for trial purpose as shown in Figure 9. Basically the roller door works like a Venetian blind, that is the lifting belt (made from sling material) is attached at the bottom corners of the door leaf and runs up inside the side guides to the drive assembly at the top. As the drive winds the belt, it lifts the bottom beam and each successive horizontal aluminium beam stacks on the top causing the vinyl coated fabric to billow out on the both sides as the air is expelled.

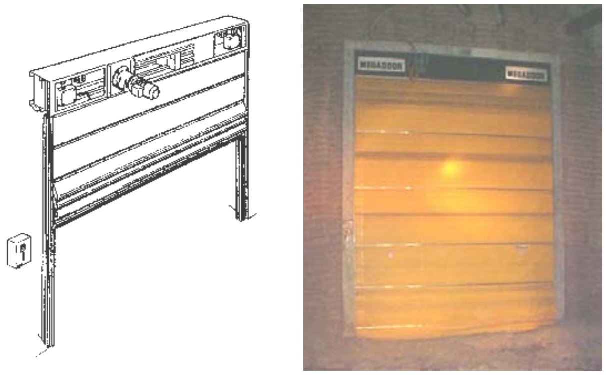

Figure 9 Schematic and photographic views of a roller door regulator

Several regulator characteristic tests were carried out to establish the relationship between Rt and A. The following figure shows the relationship between R_t and A_r for roller door tested. It should be noted that the air quantity and pressure was very low during the tests. Therefore, the calculation of equivalent resistance from measurements was difficult.

Also as one of the tests was conducted when the roller door was installed without a proper bulkhead built around it, a temporary brattice was erected to stop the airflows around the door. For this reason the leakage was substantial which means the equivalent resistance of the roller door regulator structure tested was much lower. As measurement was taken with the door fully closed it was possible to work out the equivalent resistance of the leakage paths around the door structure and then back calculate the resistance of the roller door only, R_{door}, without the leakage paths as shown in the Figure 10. It can be seen that it gives a much better comparison with the theoretical relationship between R_t and A_r.

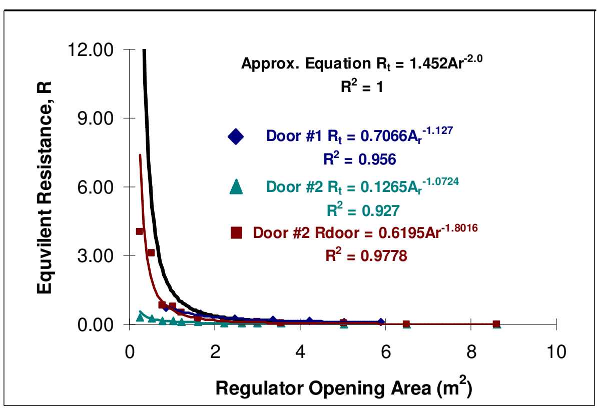

Figure 10 R_t vs. A_r for Roller Door regulator tested

It is proposed that further tests should be undertaken under higher air pressure and quantity conditions with a proper bulkhead built around the roller door regulator. In summary, the behaviours of various types of regulators examined can be described by the equations shown in the following table.

Table 1 Summary of equations for various regulators tested

Type of Regulator	Regulator Equations*
Drop Boards	$R_t = 0.9998A_r^{-1.3746}$
C-sections	$R_t = 0.7685A_r^{-1.7619}$
Louvre	$R_t = 1.2009A_r^{-1.7597}$
Roller Door	$R_t = 0.6195A_r^{-1.8016}$

** Some equations derived from averaged results of multiple regulator tests.*

4. REAL TIME MINE VENTILATION SYSTEM

The aim of this mine ventilation research was to develop a computerised monitoring system to provide immediate or real time simulated information on each branch within an underground ventilation network. The system measures airflow or air pressure changes in selected ventilation branches and simulate flows through all other branches. This new approach to ventilation provides improved understanding of airflows through all mine sections. The popular ventilation simulation modelling program Ventsim has been used as a simulation engine within the system. This software has been altered by the program author, Mr Craig Stewart to accept real time information generated by underground mine ventilation monitoring sensors, undertake network simulations and interpret key system data and operational changes. Once the simulation program has updated readings it can remodel the whole mine system, report the flows in all branches and compare individual branch readings with expected values.

Initially, the UQEM was used to test the integration of a telemetry system into the Ventsim network analysis environment. The mine airflow monitoring system consisted of one El-Equip "Flosonic" and two vortex shedding Sieger BA5 air velocity sensors. The Flosonic air velocity sensor is an ultrasonic anemometer measuring the average air velocity value across a drift (Casten et al, 1995 & McDaniel et al, 1999). The aim of this testing was to use the system to monitor changing ventilation conditions, to establish airflow characteristics within the UQEM and to observe the resimulated network results. Details of the integration of the UQEM real time ventilation monitoring system including Ventsim modification have been described by Gillies et al (2000).

4.1 Real Time Ventsim Modifications

Real time monitoring and simulation functions have been built into a recent version of the original Ventsim network simulation program. To run network simulation with real time data input, real time sensors installed in the ventilation network need to be numbered initially. Details of the real time sensors was input and edited in the Remote Station database as shown in Figure 11.

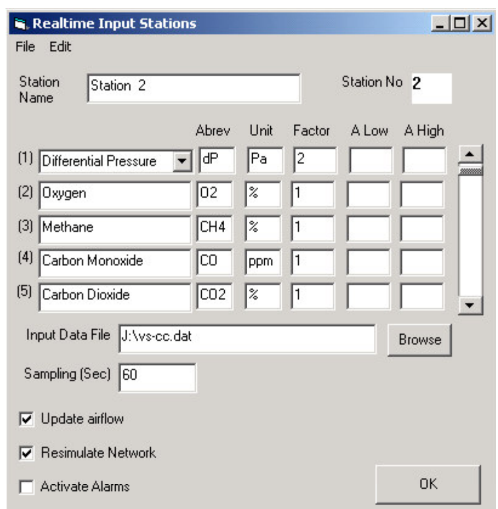

Figure 11 Example of information required for real-time input stations

The Remote Station database consists of a list of remote locations and their detailed information such as type of sensors (up to five sensors for each station); unit of real time data, scale factor, alarm levels (low and high) for each sensors; location of real time input data file; sampling interval. Users have the options to select whether they want the real time Ventsim to update airflow values, re-simulate network and activate alarm or not. Up to 50 different remote stations may be stored within the current version of real time Ventsim.

The real time data from underground remote stations must be made available to Ventsim through a text file with a special format that can be recognised by Ventsim and stored in the directory as specified in the Input Data File path. A specific tab delineated text file format is required by real time Ventsim as follows.

Table 2 Specific data format required by real time Ventsim

Station	Date	Time	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5
1	13/06/2003	14:58:28	287	000	000	000	000
2	13/06/2003	14:58:28	438	000	000	000	000

Once the details of each remote station are stored in the real time Ventsim, a remote station number needs to be selected in the Airway Edit window as shown in the following figure for each airway containing real time sensors. If in a particular airway the remote station is selected all remote sensors' data eg. air velocity, quantity, differential pressure and various gas levels will be available to Ventsim for display or for network simulation purposes. Once all airways with remote stations have been edited, the network can be simulated with real time data.

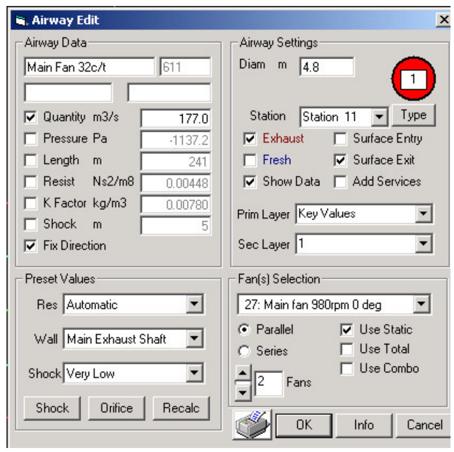

Figure 12 Airway Edit Windows with Remote Station Selection

4.2 Trial at Capcoal Central Colliery

Capcoal's Central Colliery located in the Bowen Basin was the first modern underground longwall operation in Queensland. Central colliery has an annual production of 2.5 million tonnes per year (mtpy). Major ventilation changes were undertaken at Central Colliery in 2000.

Longwall operations at the colliery had spanned over 16 years before these ventilation changes were made. Before the changes, there were two main fans on the top of the upcast shaft near the transportation drift. In addition, the mine has fans on top of two bleeder raises at the back of longwall panels on both sides of the pit primarily for gas (methane) management. Changes to the main ventilating system was made including downcast air via the drifts and the original upcast shaft near portal and then upcast return air through a raise bored shaft at 32 cut through (ct) with two refurbished main fans from nearby Southern Colliery.

As delivering the required air quantities to the operating faces was becoming very difficult due to the high mine resistance, it was determined that the ventilation system at Central need to be closely monitored with the installations of louvre type regulators and real time sensors at strategic locations throughout the mine. Various airflow sensors were investigated initially for the project. Certain problems have been identified with air velocity sensors using vane anemometers, thermal mass cooling, and vortex shedding techniques. As all these sensors measure spot air velocity instead of average air velocity. They are found to be difficult to re-calibrate to variable airflow requirements in operating mines and the output signal has a tendency to "wander away" immediately following re-calibration (McDaniel, et al, 1999). The unreliability and lack of repeatability of these instruments will hamper the continued development and use of these types of sensors in mining industry. It was determined to install differential pressure sensors across regulators to measure the pressure drop induced by the shock loss.

A total of eight underground remote monitoring stations using intrinsic safe differential pressure sensors have been installed for the trial at Central Colliery. An additional four remote stations with monitoring data for surface fans were also included in the system. Details of these monitoring stations and their status are shown in the following table. In Capcoal Central Colliery, real time underground monitoring data are displayed on their mine control and monitoring system – Microview. This information is displayed in a purpose made page as shown in the Figure 13.

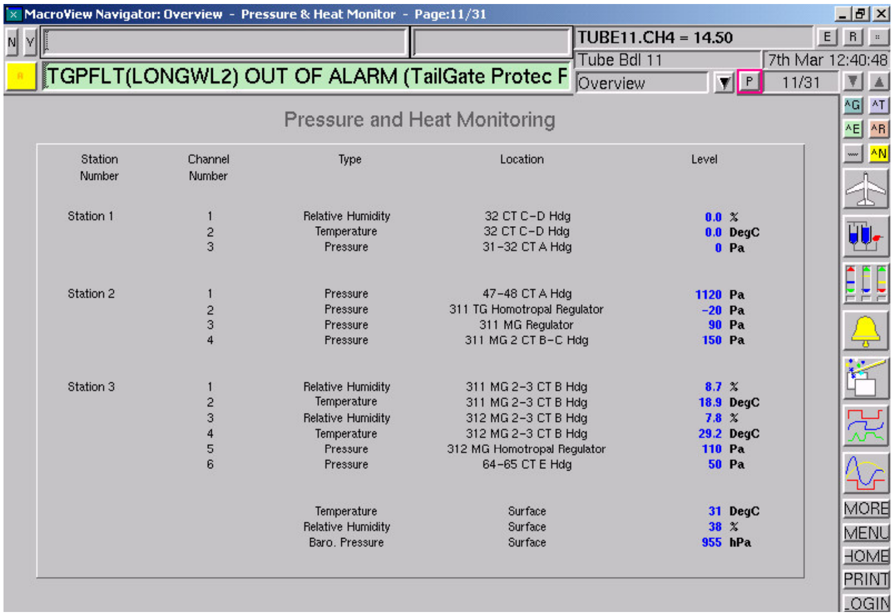

Figure 13 Pressure Monitoring Display at Central Colliery Microview System

Table 2 Details of Remote Monitoring Stations Information at Central Colliery

Stations	Locations	Type of Data	Remarks
1	31-32ct A Heading	Differential Pressure	*Not reading*
2	47-48ct A Heading	Differential Pressure	*Will be moved soon*
3	311 TG Homotropal regulator	Differential Pressure	*Fully opened*
4	311 MG regulator	Differential Pressure	
5	311 MG 2ct B-C Heading	Differential Pressure	
6	312 MG 2ct B-C Heading	Differential Pressure	
7	64-65ct E Heading	Differential Pressure	
8	Surface Station	Barometric Pressure	*Not for simulation*
9	Borehole Fan 311	Air Quantity	*Sensor faulty*
10	Borehole Fan 311	Differential Pressure	*Sensor faulty*
11	Main Fans	Air Quantity	
12	Main Fans	Differential Pressure	

An example display of the Capcoal Central Colliery real time Ventsim model with "live" data is as shown in Figure 14. Due to the site operational constraints, currently, only five real time sensors have been included in the Capcoal Central Colliery's real time Ventsim model. However, during the trial it was found that the system has the ability to update the mine ventilation network model and keep this mine planning tool current. Mine ventilation models are normally static simulation models that are accurate when calibrated after a mine ventilation survey. Even with care in frequent updating, models will tend to lose accuracy. The real time approach allows the model to be seen as a dynamic entity that can be tested for its accuracy at any time without the effort of undertaking a full ventilation survey.

In a typical coal mine operation, any ventilation change must be authorized before the change is made. Alternative options are evaluated through computer network simulation or manual calculations in the planning phases. Once the " best achievable" alternative is determined, authorization is gained and necessary adjustments to some of the system regulators made. Underground ventilation measurements may at some time be conducted to verify the effects of the change.

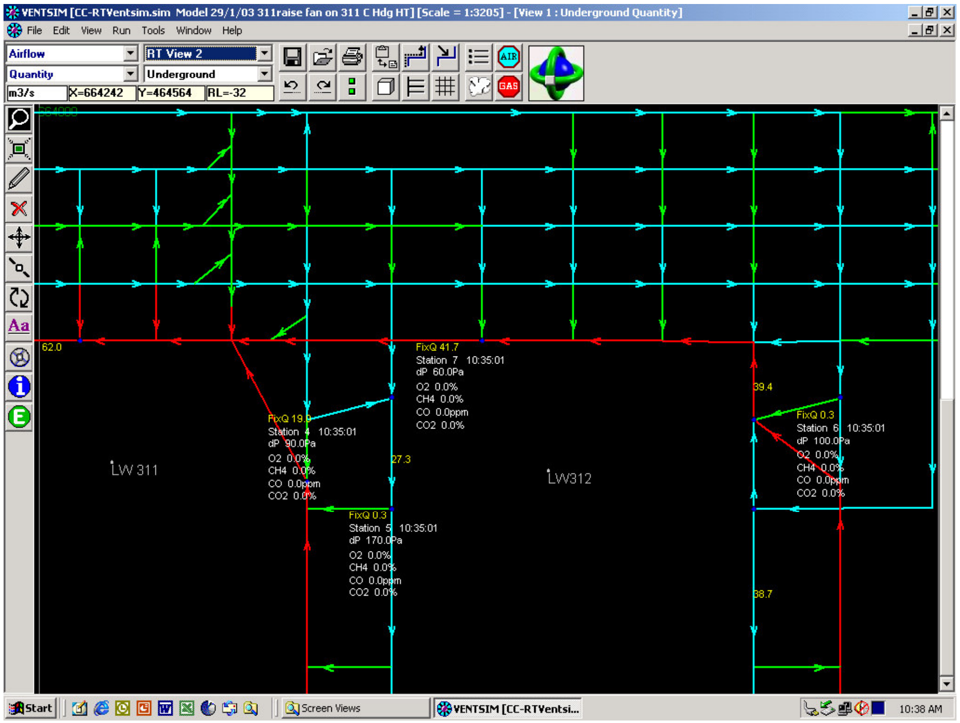

Figure 14 An example of the real time Ventsim simulation display

A real time ventilation monitoring system can reduce or eliminate the need for numerous underground measurements necessary to verify the effects of ventilation system changes. The real time sensors installed in strategic locations will pick up airflow changes and subsequently make prediction of quantities in all other airways. However, the real time Ventsim models after detection of the changes should be modified to form an updated system model representative of the changes that has taken place and ready for future planning exercises. The project was initiated in an attempt to achieve the following benefits from improved understanding of the mine ventilation system:

- Trouble shooting that would detect any abnormal situation in the underground ventilation system directly indicating where the trouble is located (i.e. indication of airway numbers) and what type of problem is involved (eg. insufficient air quantity, air short circuiting and major leakage paths).
- Monitoring the air quantity and air quality in the return airway for determining the effectiveness of the ventilation design.
- Detecting regulator failure or incorrect setting from a sudden increase of air velocity, air quantity values, and a decrease of differential pressure.
- Detect stopping or seal failure from changes in airflow and the resultant potential for gas migration or spontaneous combustion.
- Detecting any blockage in the airway, which will indicate the potential of roof, back or rib failure, or appropriate utilisation of equipment in the airway.
- Monitoring goaf leakage due to sudden change of air velocity or air quantity and increase of gas contamination levels through incorporated real time gas monitoring system.
- Providing an overall assessment of the fan performance in order to provide recommendations to alter the fan's ventilation capacity to its optimal level, and consequently saving of costs.

4.3 BHP Billiton Cannington Trial

The Cannington silver mine is located in north-west Queensland, 200km south east of Mount Isa. The deposit was discovered in 1990 and the mine was commissioned in 1997. Full production was achieved in early 1999 and since then capacity has been expanded from 1.5 mtpy to over 2.2 mtpy. Cannington is the world's largest single silver producer, representing about six percent of the world's primary silver production.

Cannington is an underground mine accessed via a 5.2m-high by 5.5m-wide decline. The main hanging-wall orebodies of the deposit are mined by transverse, longhole open sloping. During the first year of production, a vertical hoisting shaft with a finished internal diameter of 5.6m was constructed from the surface to 650m depth for ore haulage.

The ventilation system is designed around a main exhaust shaft from surface to a main return air level at the 325m level (mLv). Return air from lower operating levels is exhausted through various return air raises (RARs) or sometime ore passes connected to a collection drive on 325 mLv. The main intake airways are the decline and the hoist shaft. The system has a total combined airflow capacity of approximately 450 m^3/s.

To maintain an efficient ventilation system, it was decided to have one unimpeded open split on a level towards the bottom of the mine and install a series of regulators in the levels above to control airflow in each levels. Levels below the open split level can have booster fans incorporated within bulkheads to the RARs to assist airflow and improve conditions during hot and humid summer months (Gillies, 1999).

Initially, C-section regulators were installed and tested at each levels. However, due to the difficulty in changing the regulator setting (opening), it was decided to replace the C-section regulator with roller-door type regulators. Adjustment of the height of this type of regulator is undertaken via an automated control system. At the start of every shift regulator positions are adjusted as required via the integrated mine monitoring and control system. Airflow and/or differential pressure sensors could be incorporated as part of such an automated control system to monitor changes made. At the end of the shift prior to blasting, the regulators are set open fully to avoid the damage of the regulator caused by shock waves from blasts.

In the BHP Billiton Cannington mine, real time underground monitoring data have been transferred and displayed in their Citec mine control and monitoring system. Currently, there are nine underground remote monitoring stations planned to be included in the real time Ventilation monitoring system. These stations are mainly located at various levels accessing the Sa50 RAR and use both differential pressure sensors and ultrasonic airflow sensors to monitor airflow conditions at each station. Both Sa50 and Qb80 surface fans are also monitored and included in the system. Details of these monitoring stations and their status are as shown in the following table.

Table 3 Details of Remote Monitoring Stations Information at Cannington

Stations	Locations	Type of Data
1	Sa 50 RAR 575 mLv Roller door Regulator	Air Quantity
2	Sa 50 RAR 550 mLv Roller door Regulator	Air Quantity
3	Sa 50 RAR 520 mLv Roller door Regulator	Air Quantity
4	Sa 50 RAR 500 mLv Roller door Regulator	Air Quantity
5	Sa 50 RAR 475 mLv Roller door Regulator	Air Quantity
6	Sa 50 RAR 450 mLv Roller door Regulator	Air Quantity
7	Sa 50 RAR 425 mLv Roller door Regulator	Air Quantity
8	Sa 50 RAR 375 mLv Roller door Regulator	Air Quantity
9	Sa 50 RAR 350 mLv Roller door Regulator	Air Quantity
10	Sa 50 Main Fans	Air Quantity
11	Qb 80 Surface Fans	Air Quantity
12	Sa 50 RAR 575 mLv Roller door Regulator	Differential Pressure
13	Sa 50 RAR 550 mLv Roller door Regulator	Differential Pressure
14	Sa 50 RAR 520 mLv Roller door Regulator	Differential Pressure
15	Sa 50 RAR 500 mLv Roller door Regulator	Differential Pressure
16	Sa 50 RAR 475 mLv Roller door Regulator	Differential Pressure
17	Sa 50 RAR 450 mLv Roller door Regulator	Differential Pressure
18	Sa 50 RAR 425 mLv Roller door Regulator	Differential Pressure
19	Sa 50 RAR 375 mLv Roller door Regulator	Differential Pressure
20	Sa 50 RAR 350 mLv Roller door Regulator	Differential Pressure

Figure 15 shows a snap shot display of the Cannington real time Ventsim model with “live” data input. Due to some specific site operational constraints, not all the regulators and sensors have been installed and calibrated to date. However, during the initial trial with only five stations online, it was found that the real time ventilation system at Cannington has the ability to detect the changes in ventilation circuit and re-simulate the network under the new conditions. Further trials will be required to evaluate the real time ventilation system behaviour more closely.

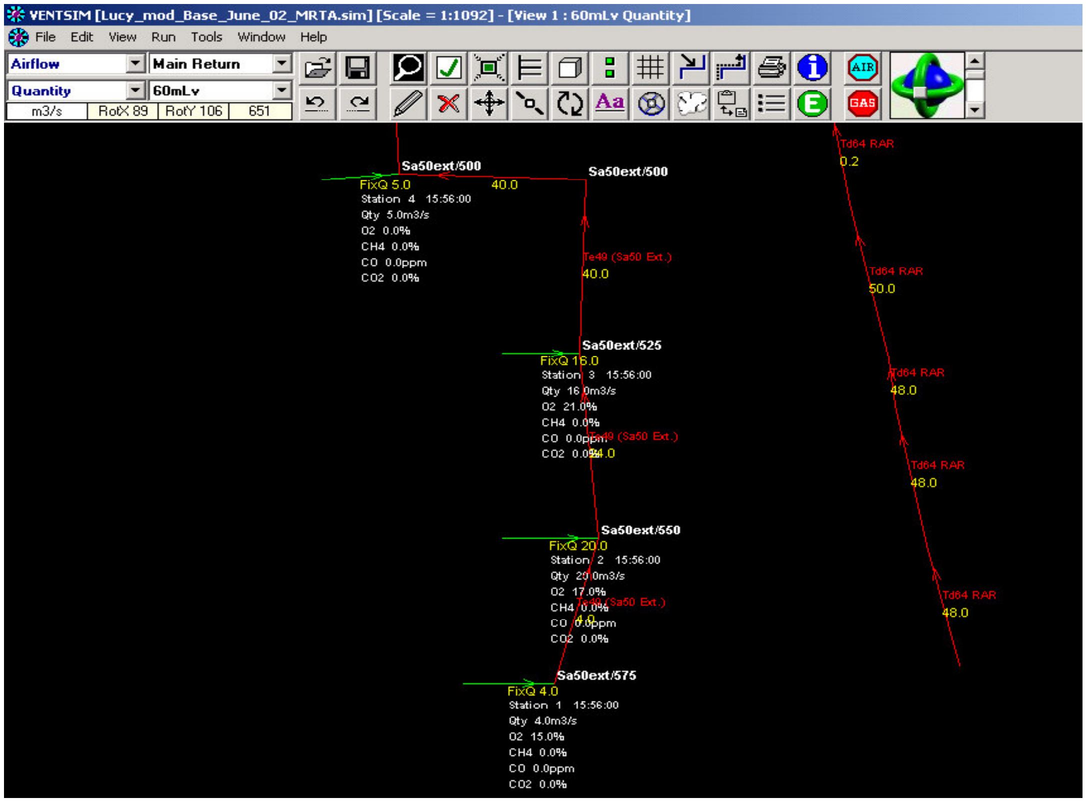

Figure 15 Snap shot of the real time Ventsim model at Cannington Sa50 RAR lower levels

One major point of interest is the delay time or transient period between the instant of a change and when the system detects the change during the trials. The transient period in the UQEM is short and therefore is not of great significance in interpreting the network system. However, in large-scale mines like Cannington, the period can be up to 10 minutes. What this means is that reliance cannot be placed completely on “real time” airflow readings being instantaneously correct as reported for all branches within a mine ventilation simulated network. There is nothing that can be done to eliminate this characteristic as it is representative of the nature of airflow within underground mines. A change which leads to a hazardous condition may go unreported for time interval of this transient period. Of course changes in mine ventilation systems measured manually are rarely immediately picked up but this limitation of an automatically reporting real time system should be recognised.

5. CONCLUSIONS

Efforts to characterize or mathematically model a number of operating mine regulators have been described. Underground measurements have indicated that theoretical calculations to predict airflow quantity through practical mine regulators based on measured pressure drop are inadequate. The theoretical approaches are limited as they are based on prediction of fluid flow through a circular orifice in the middle of a plate whereas most mine regulators have a rectangular non-symmetrically positioned orifice. Also, most importantly, there is air leakage through the regulator bulkhead frame and gaps that increase actual quantity compared to that predicted.

The way to overcome this difference is to quantify the resistance of the leakage path based on regulator opening area and then to recalculate the total resistance of the regulators. The relationship between leakage path resistance and regulator opening area varies, but the resistance should increase along with an increase in opening area. Based on measured pressure difference, the airflow quantity can be predicted accurately using the basic square law. It requires field measurements to quantify the leakage path resistance of each regulator, since each regulator has its own leakage characteristic (size and number of gaps, etc.). This is a tedious work, since the regulators can be set with many opening areas. However, it was found that with limited measurement data, prediction results are still accurate within acceptable tolerance appropriate to understanding mine airflows.

The aim of the study was to gain greater understanding of a computerized monitoring system to provide immediate or real time simulated information in each branch of an underground ventilation network. The system measures airflow in selected ventilation branches and simulates flows through all other branches. Investigations were undertaken in two Queensland mining (coal and metalliferous) environments as to whether the Real Time Airflow Monitoring system can detect changes within the mine ventilation system, examine accuracy of the system and identify constraints that will limit performance of the system. As a result of trials, it was demonstrated that the system was able to detect changes occurring within the mine ventilation system and was also able to predict the changes accurately. Limitations caused by transient period delays have been examined. Updating of simulation models from use of real time data has also been discussed. It is envisaged in the future that the ventilation model would be an integral part of a real time mine wide planning, monitoring and control software platform from which the model would be updated in real time.

ACKNOWLEDGEMENT

The support of the University of Queensland, Mr Craig Stewart and a number of operations within the Australian mining industry in funding this study are acknowledged.

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