Understanding mine ventilation and introduction of inertisation gases with fire simulation software

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ABSTRACT

A study has reviewed the variety of mine inertisation systems available in Australia and their technical specifications. Exercises which involved "evaluation or auditing" of selected mines as to the ability to deliver inert gases generated from inertisation units to high priority underground fire locations have been undertaken in a number of mines. These exercises have been built around the use of the fire simulation computer program VENTGRAPH and modelling of fire scenarios in selected different mine layouts. A coding system has been developed from these audit exercises.

Designs have been developed to allow delivery of high volumes of inert gases down mine bore holes. A section of the paper has examined considerations presented by the layouts of underground mines developed from surface extraction pits.

Inertisation and dilution issues in mine openings create complex situations. Mains headings present a complex ventilation network with often numerous parallel headings, hundreds of cut-throughs and a variety of ventilation control devices. In these complex systems the additional interference from a fire means maintaining control of the movement of inert gas is more difficult than elsewhere in the mine. Some illustrations of these issues are given.

Mine fires and heatings are recognised across the world as a major hazard issue. New approaches allowing improvement in understanding their use of inertisation techniques have been examined. The outcome of the project is that the mining industry is in an improved position in their understanding of mine fires, use of inertisation and the use of modern advances to preplan for the handling of possible emergency incidents.

Keywords: Mine fires, simulations of fires, inertisation systems, inertisation of mine fires, mine safety.

INTRODUCTION

The primary objective of the study is to use mine fire simulation software to gain better understanding of how inertisation approaches such as Jet Engine exhaust, Nitrogen, Carbon Dioxide, Pressure swing adsorption or Membrane nitrogen and diesel exhaust units can interact with complex ventilation system behaviour underground during a substantial fire. Inertisation systems for handling underground fires, spontaneous combustion heatings and elimination of the potential explosibility of newly sealed goafs have been accepted as important safety approaches within many parts of the international industry. Examples of the recent use of inertisation systems to assist in stabilising mine fire situations are given.

Case studies have been developed to examine usage of inertisation tools and particularly application of the Polish developed jet engine unit, the Gorniczy Agregat Gasniczy (GAG). Gorniczy Agregat Gasniczy loosely translates to Mine Fire Extinguisher. Considerations for selecting the best surface portal location placement for the inertisation unit for most efficient suppression of a fire have been examined. Introduction of inert gases can present difficult emergency management decision making. Should the main mine fans be turned off to reduce dilution of the inert gas, or will this action cause, in conjunction with fire induced buoyancy effects, airflow reversal and the drawing of combustion products or seam gases across a fire leading to an explosion?

The possibility of a wider and proactive application of the GAG in Australian mines responding to or recovering from mine fires or spontaneous combustion heatings or elimination of the potential explosibility of newly sealed goafs is examined. Attainable designs for panel boreholes and how GAG docking to boreholes can improve delivery of GAG exhaust are discussed. Some considerations presented by open cut highwall "punch" mines layouts are examined.

Simulation software has the great advantage that underground mine fire scenarios can be analysed and visualized. A number of fire simulation packages have been developed to allow numerical modelling of mine fires (such as Greuer, 1984; Stefanov et al, 1984; Deliac et al, 1985, Greuer, 1988; Dziurzyński, Tracz, and Trutwin, 1988). One of the most update fire simulation programs is the Polish Ventgraph software. Details of the Ventgraph program have been described by Trutwin, Dziurzynski and Tracz (1992). The software provides a dynamic representation of a fire's progress in real time and utilizes a colour-graphic visualization of the spread of combustion products, oxygen and temperature throughout the ventilation system. During the simulation session the user can interact with the ventilation system (eg, hang brattice or check curtains, breach stoppings, introduce inert gases and change fan characteristics). These changes can be simulated quickly allowing for the testing of various fire control and suppression strategies. Validation studies on Ventgraph have been performed using data gathered from a real mine fire as undertaken by Wala, et al (1995). Wu, Gillies and Wala (2004) examined application of fire simulation to modern Australian mines. Gillies, Wala and Wu (2005) examined some aspects of understanding use of inertisation through use of Ventgraph simulation. Gillies and Wu (2007) examines a comprehensive review of use of inertisation systems in underground coal mines and in particular focuses on the assistance that mine fire simulation systems can offer.

The paper examines the effects of fires and introduced inertisation on mine ventilation systems using the Polish numerical fire simulation software VENTGRAPH. Case studies from the modelling of fire scenarios with introduced inertisation in a number of Australian longwall mine layouts are discussed.

INERTISATION SYSTEMS

Simulation of inertisation usage

Inertisation has been accepted to have an important place in Australian mining emergency preparedness. The two jet engine exhaust GAG units purchased from Poland by the Queensland government in the late 1990s for the Queensland Mines Rescue Service have been tested and developed and mines made ready for their use in emergency and training exercises. Their use in real and trial mine fire incidents has underlined the need for more information on their application. The NSW Mine Shield (liquefied nitrogen) apparatus dates to the 1980s and has been actively used a number of times particular in goaf heating incidents.. The diesel exhaust unit has been purchased by a number of mines and is regularly used as a routine production tool to reduce the time in which a newly sealed goaf has an atmosphere "within the explosive range" and for goaf spontaneous combustion heatings (Stephan and Blanch, 2000). Nitrogen Pressure Swing Adsorption and Membrane units are available and in use both for reducing time in which goafs are "within the explosive range" and for goaf spontaneous combustion heatings. Each of these facilities puts out very different flow rates of inert gases. Each is designed for a different application although there is some overlap in potential applications.

Overview of Mine Inertisation Systems

Successful underground mine inertisation is fundamentally dependent on being able to dilute or displace oxygen in the presence of an inerting agent to less than combustible levels. A number of factors contribute to the success of underground inertisation such as the flow rate, pressure and density of the inert gas and the continuity of the inert gas supply.

Low flow inertisation systems have been successful in the proactive inertisation of goaf areas and have the ability for total mine inertisation. A substantial period of time is required due to their low flow rates. To put it simply, large volume units take less time to achieve the results of the smaller capacity systems, but consideration must be given to relative cost factors. Experience to date has shown that, where large volumes of inert gases are required, the GAG 3A system can deliver these volumes at a lower cost per m^3/s of inert gas than many of the low-flow methods for which total cost information is available.

Each inertisation system has an optimum application dependent on the site-specific variables existing at a mine at the time of a combustion event. Experience has indicated that a risk based logic approach will aid in the selection and determination of the appropriate system for a particular application. To assist with selection of an inertisation system of choice Table 1 indicates both positive and negative variables for consideration prior to application.

Table 1 Comparison of inertisation methods (after Mucho et al, 2005)

Inertisation Methods	**Advantages**	**Disadvantages**
GAG 3A Jet Engine Inertisation System	▪ Large Volume ▪ Low cost per m^3/s of inerts ▪ Mobility ▪ Access to the mine ventilation system ▪ Self Contained	▪ Manpower required ▪ Support Materials/Supplies ▪ Transport and Availability ▪ Training ▪ Higher O_2 (than CO_2 and N_2) ▪ Fire gas ratios unstable (due to CO & H_2 production)
Diesel Exhaust (Tomlinson)	▪ Versatility ▪ Manpower (2 people/24 hrs) ▪ Portability ▪ Minimal support materials/supplies	▪ Low Flow ▪ Time Duration ▪ High Maintenance ▪ Fire gas ratios unusable
CO_2 Liquid and/or Gaseous	▪ Cool ▪ Denser than air (can be advantage application dependent) ▪ Ease of movement ▪ Detection relatively easy	▪ Low Flow ▪ Method of application ▪ Transport and Availability ▪ Fire gas ratios unusable ▪ High cost
N_2 Liquid and/or Gaseous	▪ Cool ▪ Lighter than air (can be advantage; application dependent) ▪ Non-toxic ▪ Injection ability ▪ Operational logistics relatively simple	▪ Low Flow ▪ Method of application ▪ Transport and Availability ▪ Fire gas ratios unusable ▪ High cost

Tables 1 and 2 examine some typical characteristics of the outlet flow of inert gas units.

Table 2 Characteristics of the outlet flow of the Jet engine (GAG), Liquified Nitrogen (Mine Shield), Diesel Exhaust (Tomlinson) and Membrane Nitrogen (Floxal) inertisation units.

	Diesel Exhaust[1] (Tomlinson)	**Liquid Nitrogen [2] (Mineshield)**	**Jet Exhaust[3] (GAG)**	**Membrane[4] Nitrogen (Floxal)**
Inert Output Range, m^3/s	0.5	0.2 – 4.0	14 – 25	0.12 – 0.7
Default Quantity, m^3/s	0.5	2.0	20	0.5
Delivery Temperature, ^oC	54	Atmospheric	85	20
Oxygen, %	2	0	0.5	3
Nitrogen, %	81.5	100	80 – 85	97
Carbon Dioxide, %	15.3	-	13 – 16	-
Carbon Monoxide, ppm	0	-	3	-
Water Vapour, %	1.2	-	some	-

[1] Tomlinson Boilers, 2004
[2] Mine Shield, 2002/03
[3] GAG, 1997
[4] Sajimon, J. 2005 and AMSA Membrane Nitrogen Unit, 2006

Water Droplets			significant	

Underground mine fires lead to complex interrelationships with airflow in the mine ventilation system (Wala, 1996). Addition of the gas stream from an inertisation unit adds another level of complexity to the underground atmosphere behaviour. Important questions are raised such as should the main mine fans be turned off so as not to dilute the inert gas or will this action cause, in conjunction with buoyancy effects, airflow reversal and the drawing of combustion products or seam gases across a fire leading to an explosion?

EXAMPLES OF INERTISATION WITHIN MINE VENTILATION SYSTEMS

Simulation of the introduction of the GAG or other apparatus has indicated that there is a substantial lack of knowledge on use of these facilities. The Queensland GAG units were first used actively in 1999 at the Blair Athol mine to handle a spontaneous combustion issue in old underground workings that were about to be mined by surface techniques (Prebble and Self, 2000). The GAG unit was subsequently used successfully in an underground mine fire at the Loveridge mine, West Virginia in early 2003 (Urosek et al, 2004). On this occasion the GAG ran for approximately 240 hours over 13 days and was successful in stabilising the mine so that rescue teams could enter the mine and seal and fully extinguish the fire affected zone. Much was learnt about the ventilation network behaviour and the need to have an upcast shaft open. Observations were made on the effects of natural ventilation pressure, barometric changes and rock falls on the backpressure experienced by the operating GAG.

A fire suspected to have been caused by lightening strike at the Pinnacle mine, also in West Virginia, was out of control from October 2003 to May 2004. A Polish owned GAG unit was successfully used to stabilise the situation although there were a number of underground gas explosions during the course of the incident (Campbell, 2004). Following these experiences the US Micon company has purchased GAG units and has developed a commercial mine emergency and recovery business.

New and innovative approaches to mine recovery are occurring. In the US an equipment unit fire in the Dotiki mine, Kentucky, in early 2004 was stabilised using a Nitrogen and Carbon Dioxide (Wesley et al., 2006). Also in early 2004 carbon dioxide was used to stabilize a goaf spontaneous combustion heating in the West Ridge mine in Utah (Stoltz et al., 2006).

Simulations using the fire simulation software VENTGRAPH can be undertaken to gain better understanding of how inertisation units or systems interact with the complex ventilation behaviour underground during a substantial fire or hating. Aspects worthy of examination include:

- Location of the introduction point for inert gases for high priority fire positions; eg. portal docking position, special boreholes;
- Size (diameter) of borehole or pipe range required to deliver inert gases and back pressure issues;
- Time required for inertisation output to interact with and extinguish a fire;
- Effects of seam gas on fire behaviour with inertisation present;
- Changes which can be safely made to the ventilation system during inertisation including switching off some or all fans;
- Need for remote controlled underground doors to channel inert gases to the fire location;
- Complications caused by underground booster fans; and
- Spontaneous combustion issues.

IMPROVEMENTS TO VENTGAPH WITH NEW INERT UNIT AND GAS SOURCE FUNCTIONS

The authors of this paper have worked with the Polish program authors to undertake inertisation related modification to the VENTGRAPH program. The modifications were as follows.

1. Simulation of use of additional inertisation units. The original program only allowed use of a GAG form of inertisation unit within the ventilation network. The modified version includes additional units. An additional pull down menu (figure 1) “Inert Units” was added. Under the “Inert Units” submenu a selection of inertisation units namely GAG, Liquified Nitrogen, Diesel Exhaust and Membrane Nitrogen can be included. Once the unit is selected, a pop up window shows up with the

operating parameters and output parameters displayed. The users can then accept the default parameters or opt for changes in the operating or output parameters.

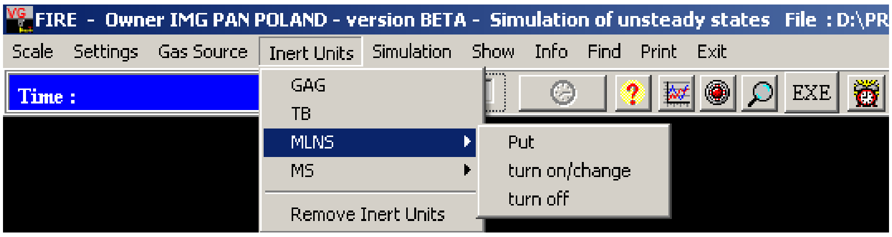

Figure 1 New Inert Units pull down menu in VENTGRAPH

2. Including extra mine gas sources. The original VENTGRAPH version only allowed the seam gas of CH_4 to be included. The new version allows in addition CO_2 and N_2 to be placed in the model. A new pull down menu facilitates this.

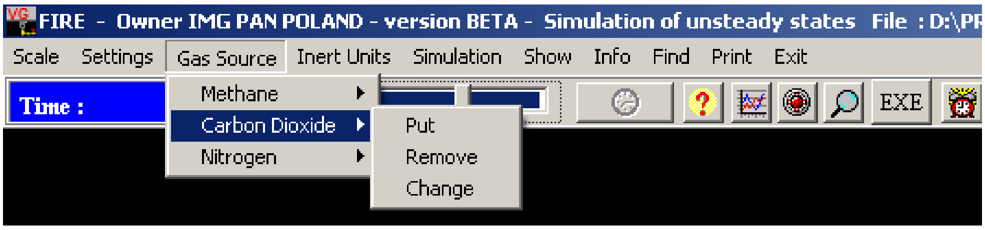

Figure 2 New Gas Source pull down menu in VENTGRAPH

Beta version of the new form of VENTGRAPH was created and tested. The new additions were trialled and tested on various mines' VENTGRAPM models and as a result and a list of suggested improvements to the Beta version was sent to the authors of VENTGRAPH for consideration. All recommendations were accepted and VENTGRAPH is now significantly more useful for mine inertisation studies.

FIRE SCENARIO SIMULATION EXERCISE 1 – MEMBRANE NITROGEN INERTISATION SYSTEM

Under this exercise a simulated fire was burning with the belt drive head hydraulic oil caught on fire at longwall panel A1 Maingate between 0 cut-through (ct) and 1 ct B Heading in an Australian coal mine as shown in Figure 3.

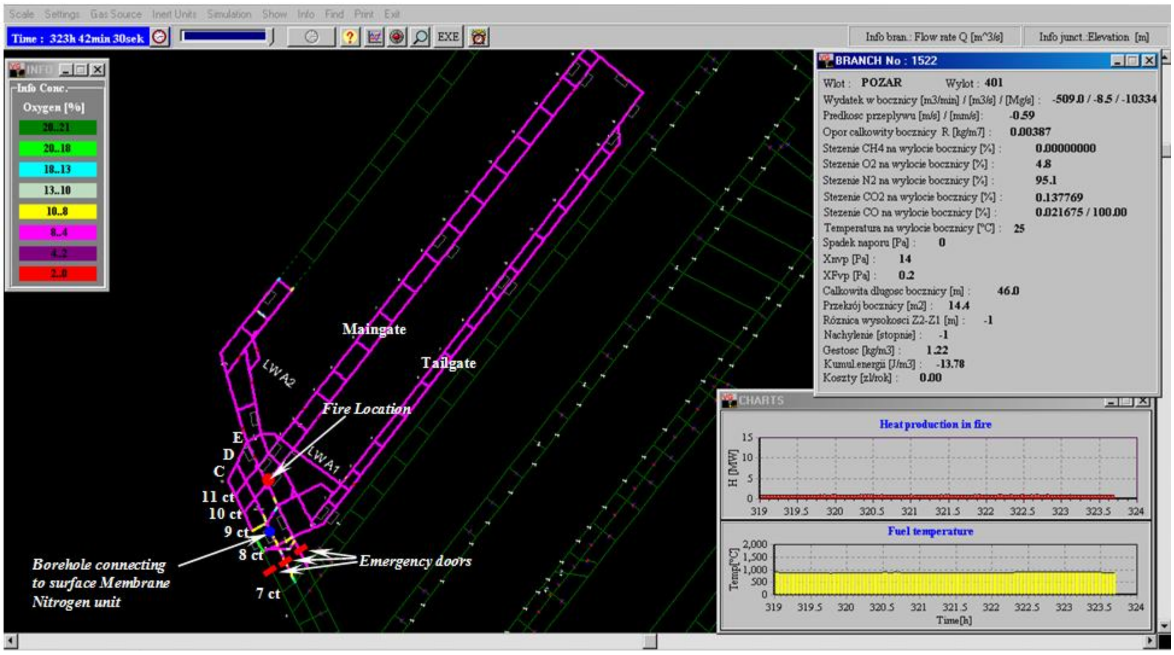

Figure 3 Oxygen distribution after 323 hours in the sealed area with combined control actions of closing emergency doors, short-circuiting and running the Membrane Nitrogen System.

The two Headings of the active longwall panel A1 Maingate are connected to the Main at 10 and 11 ct. The mine has several sets of emergency fire doors set up in Heading C, D and E Hdgs between 7ct and 8ct in the Mains which can isolate the current active longwall panels from the rest of the mine. A surface borehole is located in between 8ct and 9ct Mains D Hdg just outbye of the longwall panel A1 Maingate. The borehole with pipe works is connecting to a Membrane nitrogen inertisation system with a capacity of providing a nitrogen flow rate of 0.5 m^3/s or 1800 m^3 per hour in the case of emergency or for panel inertisation after production is completed and the panel sealed.

Simulation exercises assumed that the fire is out of control one hour after the initially hydraulic oil fire has started and adjacent standing coal has ignited. The table with Figure 3 sets down various information related to the state of the ventilation air about to move across the fire. This included the gas percentages for CH_4, O_2, N_2, CO_2 and CO. It was decided to take various control actions available to regain control of the fire at this point in time. Five separate simulation exercises were undertaken as follows.

1. Open 7ct D-E Hdgs double doors to short circuit the Mains air (113 m^3/s of air is short-circuited).
2. Close Emergency Doors at 7-8 C, D and E Hdgs to seal off the section with fire (13 m^3/s was still leaking into the section with two surface fans still running).
3. Close Emergency Doors at 7-8 ct C, D and E Hdgs and reduce door leakage through use of brattice cloth over the doors to seal off the section with fire (about 1 m^3/s was still leaking into the section with two surface fans running). Open 7ct D-E Hdgs access double doors to short circuit the Mains air (126 m^3/s of air is short-circuited).
4. Close Emergency Doors at 7-8 ct C, D and E Hdgs and reduce door leakage through use of brattice cloth to seal off the section with fire (about 1 m^3/s was still leaking into the section with fans running). Open 7ct D-E Hdgs double doors to short circuit the air (126 m^3/s of air is short-circuited). At 10 hours shut one of the surface fans (total air quantity through upcast shaft reduces to 117m^3/s @ 915 Pa).
5. Close Emergency at 7-8 ct C, D and E Hdgs to seal of the section with fire (about 1 m^3/s was still leaking into the section with two fans running). Turn on surface Membrane Nitrogen System (flow rate is 0.5 m^3/s or 1800 m^3 per hour) outlet at 9-10ct D Hdg.

The simulations were left running for at least 60 hours to find outwhether the control actions taken at each alternative exercise were effectively controlling the fire or not. It was found that

1. Short-circuiting the air reduced the fire but this alone will not put the fire out. Oxygen level in sealed area reduced to a minimum of 16-18%.
2. Closing emergency doors at 7-8 ct C, D and E Hdgs restricted further development of the fire but this alone will not put the fire out. Oxygen level in sealed area reduced to a minimum of 16-18%.
3. Closing emergency doors at 7-8 ct C, D and E Hdgs, use of brattice seals across doors and short-circuiting air through 7 ct D-E Hdg restricted further development of the fire but this alone will not put the fire out. Oxygen level in sealed area reduced to a minimum of 10-13%.
4. Closing emergency doors at 7-8 ct C, D and E Hdgs, use of brattice seals across doors, short-circuiting air through 7 ct D-E Hdg and shutting off one fan restricted further development of the fire but is never going to put the fire out with oxygen level in sealed area reduced to 8-10%.
5. Closing emergency doors at 7-8 ct C, D and E Hdgs, use of brattice seals across doors and short-circuiting air through 7 ct D-E Hdg prior to running the Membrane Nitrogen System restricted further development of the fire with oxygen level in sealed area reduced to below 5% as shown in Figure 3.

The Membrane Nitrogen unit helps to reduce the oxygen level in the sealed area but this result is dependent on the capacity of the Nitrogen unit and the fresh air leakage into the sealed area (that is the conditions of emergency doors or seals). If good sealing can be achieved it is possible to create a very low oxygen environment within the sealed area that will effectively control the development of fire.

FIRE SCENARIO SIMULATION EXERCISE 2 - EFFECTIVE DOCKING POSITIONING OF INERTISATION UNITS

Positioning of inertisation units

Studies were carried out to examine usage of inertisation tools and particularly application of the GAG jet engine. The best surface portal location placement for the GAG for most efficient suppression of a fire has been examined. Case studies of the typical Australian longwall examples in previous section were modified. A generalised longwall mine layout was used with the length of Mains set at 2 or 4km. A 1.0 m diameter borehole was connected to the back of longwall panel about 400m from the longwall panel.

Two GAG jet engine positions were investigated. The first position is at the portal B heading and the second position is at the top of the borehole located at the back of the longwall panel. A diesel fire with a 30m length of fire zone, a fire intensity of 10 and a time constant of 120 seconds is started 50m outbye of the current longwall face was simulated.

Procedures to implement the GAG for both positions are as follows.

1. Start the simulation and let the fire run for 1 hour.
2. Start the GAG after 1 hour and close the emergency door at portal B Heading just outbye the GAG.
3. Shut off the fan and close off the other two emergency doors located at C and D heading.
4. keep GAG run till the heat from fire is minimal and the fuel temperature is less than 250^{o}C.

It was found that it made no difference for the second case study GAG position whether the emergency doors at the portal was closed or not. When the length of the Mains is 2 km, the time it takes to have the GAG put the fire out was similar whether the GAG unit is at the Mains portal or at the top of longwall back borehole. However, when the length of the Mains is increased to 4 km, it was found that a GAG unit located at the back borehole has significant advantage in terms of time in reducing the fire to significantly reduced state (see Figures 4 and 5).

It should be noted that the advantages can be gained from use of various GAG positions depends on a number of considerations including the location of the fire, the relative distance from the GAG placement portal location and the attributes and complexity of the mine ventilation network. Operation of a GAG unit requires preplanning in terms of infrastructure requirements for a GAG surface portal docking station and access for operating personnel, jet fuel, water and other operating requirements.

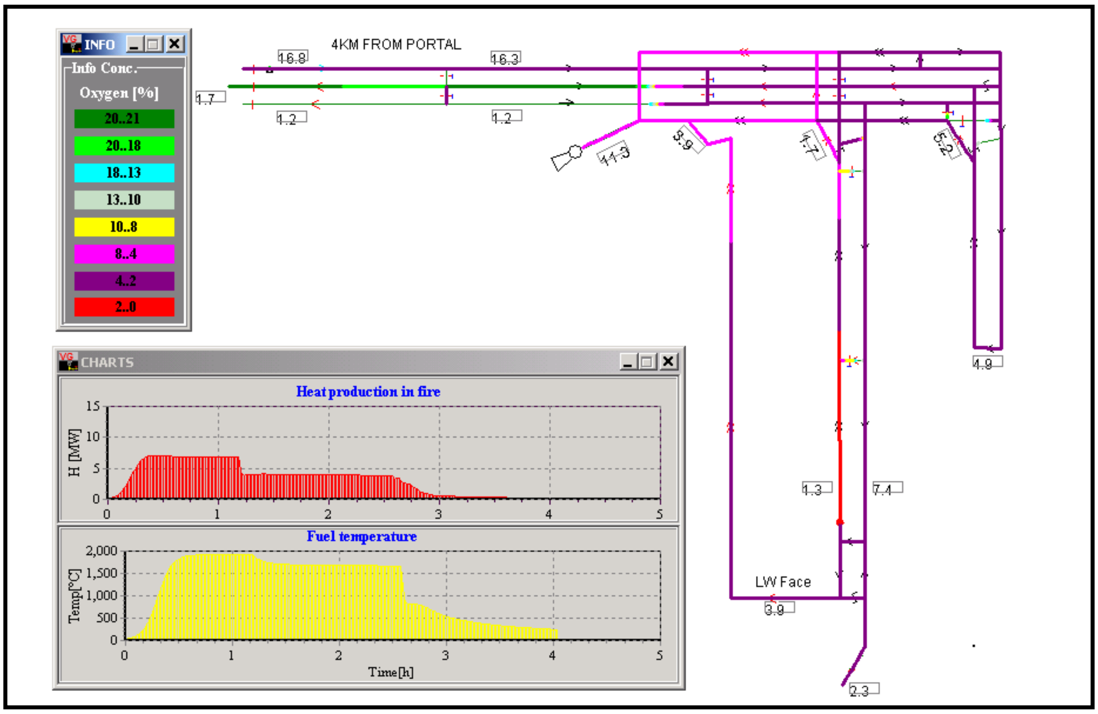

Figure 4 GAG position at the portal B heading for 4km Mains length

The same conclusion from GAG studies also applies to use of other inerting tools such as the large capacity Nitrogen generators. Any evaluation requires a detailed study of each mine’s ventilation and fire simulation model to identify optimum unit position placement for various fire locations.

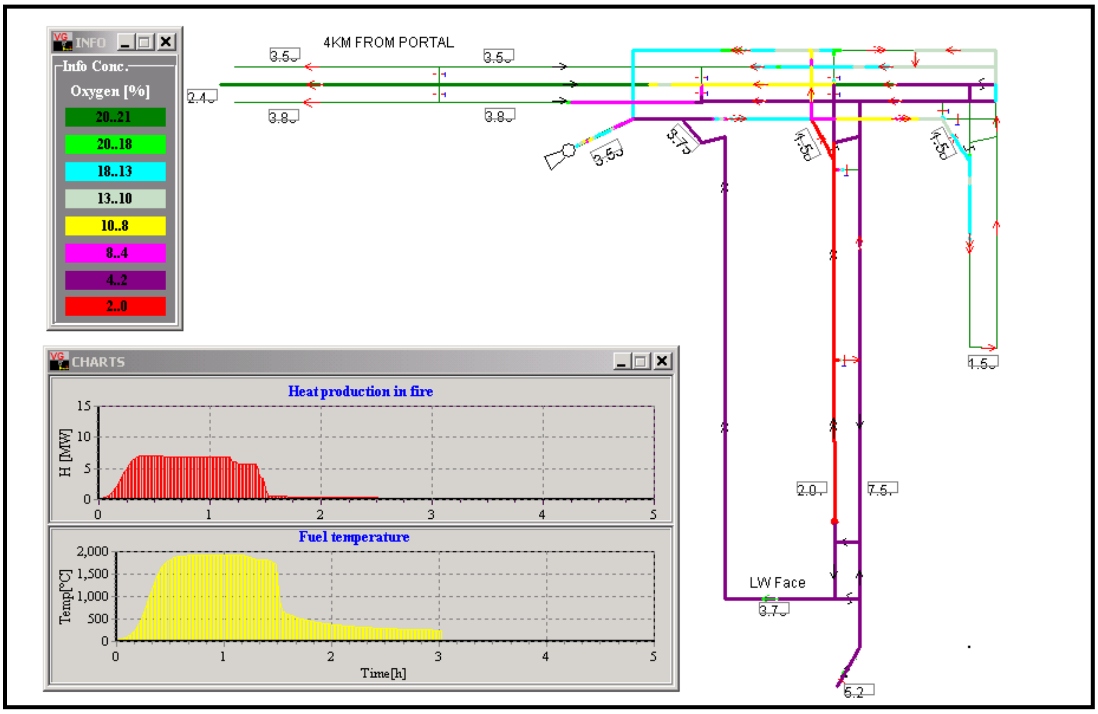

Figure 5 GAG position at the top of back longwall borehole for 4km Mains length.

Fire with high gas level at face

Investigations were also carried out to examine usage of inertisation tools and particularly application of the GAG jet engine in a mine with high gas emission level at the longwall face. Case studies of the typical Australian longwall examples used in previous section were modified. A seam gas face source of CH_4 of 400litres/s was introduced in the middle of the longwall face line in the model to simulate this case. This gives a CH_4 concentration level of about 1% on the return side of the longwall face. In the simulation a diesel fire of 10m length of fire zone, a fire intensity of 10 and a time constant of 120 seconds was started 50m inbye the maingate end of the current longwall face.

The longwall face was examined under two situations of dip angles of 2.5% and 5% (-6 and -12m respectively on a longwall face 240m long) down from maingate to tailgate. This gives descentional ventilation effects. The fire in this situation will work against the main ventilation direction along the longwall face. The GAG unit is positioned at the Mains travel road portal B heading.

Procedures to implement the GAG for both positions were as follows.

1. Start the simulation and let the fire run for 1 hour.
2. Start the GAG after 1 hour and close the emergency door at portal B Heading just outbye the GAG.
3. Close off the emergency door located at C, Shut off the fan and then close off the emergency door located at D heading.
4. Let the GAG run till the heat production from fire is minimal and the fuel temperature is less than 250°C.

It was found that when the longwall is dipping at 2.5%, the GAG unit is successful in reducing the fire to minimal heat production and fuel temperature of less than 500°C around 4 hours after the GAG was started as indicated in Figure 6. No airflow reversal was observed at the longwall face.

However, when the dipping angle increased to 5% for the same fire situation, as soon as the fan is turned off, the airflow on the longwall face reversed. This leads to the high concentration of face CH_4 flowing back across the fire with high likelihood of an explosion occurring as shown in Figure 7. A sharp drop of the heat produced from the fire is observed.

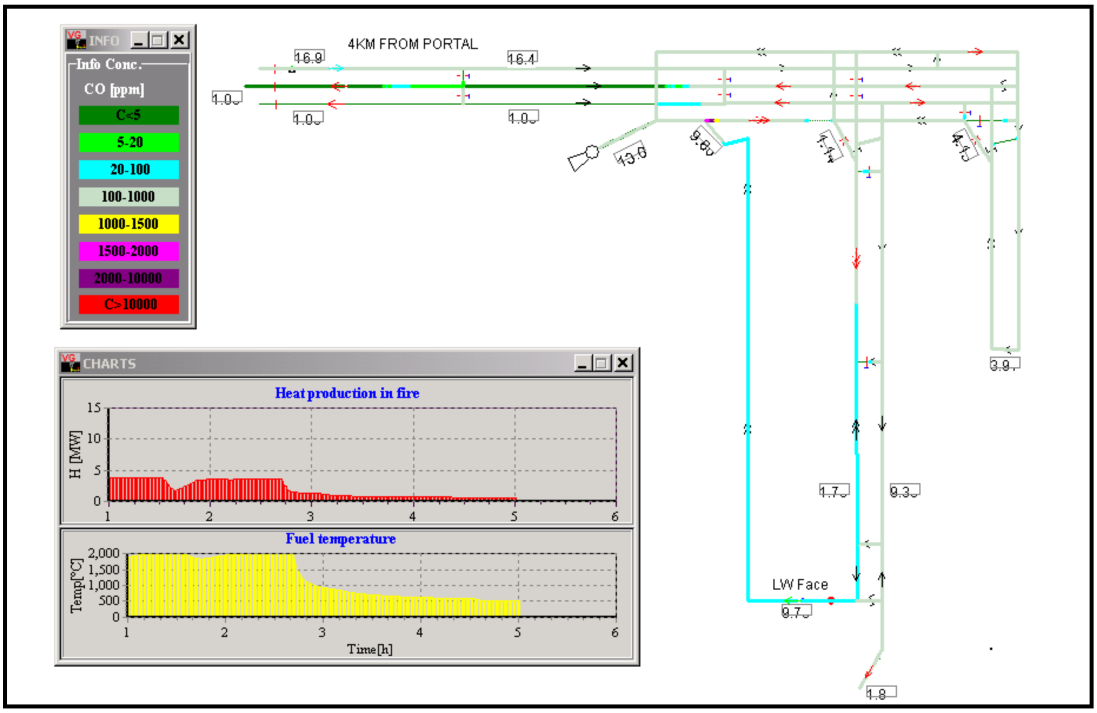

Figure 6 Gassy longwall dipping at 2.5% from Maingate to Tailgate.

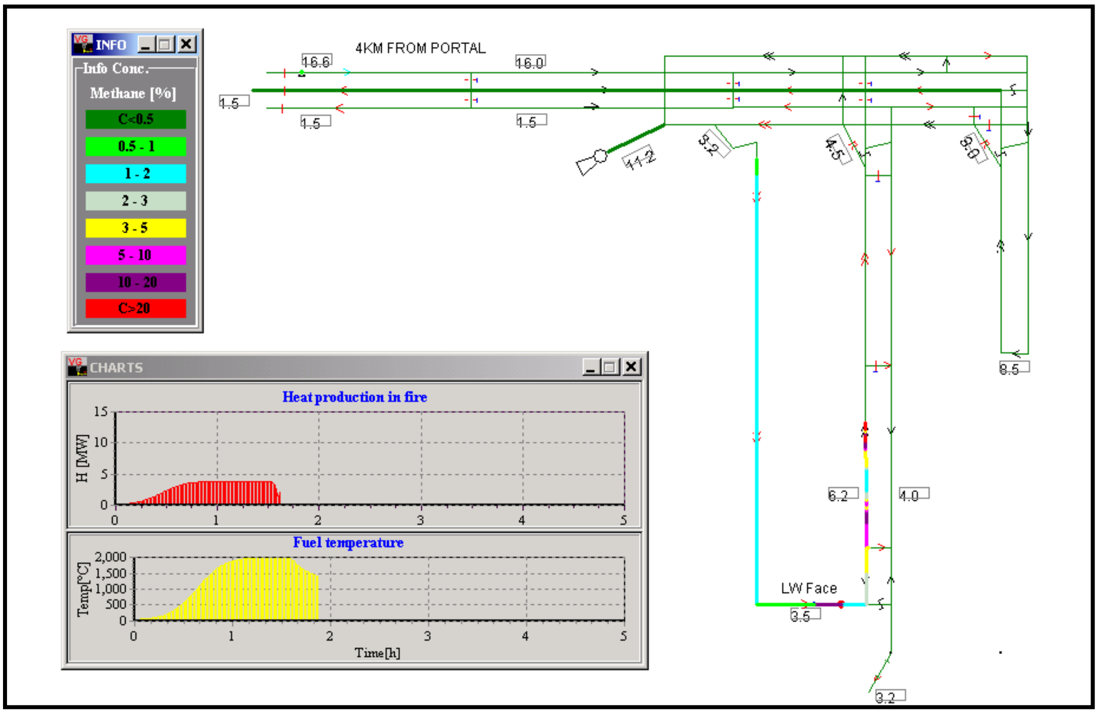

Figure 7 Gassy longwall dipping at 5% from Maingate to Tailgate.

As soon as an explosion "occurs" in the VENTGRAPH simulation program, the program will no longer simulate the heat production from fire.

Addition of the inert gas stream adds another level of complexity to the already complicated interrelationships between the mine ventilation system, the presence of seam gases and a mine fire. Should the main mine fans be turned off to reduce dilution of the inert gas, or will this action cause, in conjunction with fire induced buoyancy effects, airflow reversal and the drawing of combustion products or seam gases across a fire leading to an explosion?

FIRE SCENARIO SIMULATION EXERCISE 3 - EFFECTIVE DOCKING POSITIONING OF INERTISATION UNITS

Positioning of the inertisation units is a major determinant of potential success for most efficient suppression of a specific fire. Traditionally in Queensland docking points have been placed on intake ventilation headings (either travel or conveyor belt roads). Some mines have prepared docking points on boreholes of about 1.0 to 2.0m diameter placed at the back of longwall panels. The advantages that can be gained from use of various inertisation docking positions depends on a number of considerations including the location of the fire, the relative distance from the inertisation docking portal location and the attributes and complexity of the mine ventilation network. Operation of a GAG unit requires preplanning in terms of infrastructure requirements for a GAG surface portal docking station and access for operating personnel, fuel, water and other operating requirements.

A system was derived for categorising mines' principal inertisation docking points as to their ability to inert a priority fire location in the mine recovery stage as set down. In the study it was assumed that the GAG would be docked at a prepared position designated by the mine (most commonly the current fabricated docking installation; in most mines this is at the portal of a Mains travel or belt heading).

- Category A covers fire in which the inertisation product is directed fully over the fire. No mine priority fire examined achieved the situation in which the simulated fire is directly stabilised to aid recovery in a timely manner.
- Category B covers situations in which the inertisation product goes straight to the fire but there is significant dilution from other ventilation air or leakage through stoppings. Because of dilution stabilisation of a fire through inertisation can only be achieved with some main surface fan changes. 20 percent of mines are in this category and under these situations the fire should, over time, be abated or stabilised to a point where conventional recovery approaches can be initiated.
- Category C covers priority fires in which the GAG output will never reach the fire location without stopping of one or more main surface fans to rebalance ventilation within the pit. In many of these cases requiring fan changes to put GAG output across the fire location effective ventilation air velocity has been reduced to the extent that local reversal across the fire occurs and fire fumes are pulled across the fire. This is an unsatisfactory situation as fire smoke and fumes can carry combustible products. This situation broadly prevails for 46 percent of the cases examined
- Category D covers priority fires in which the GAG output will never reach the fire location even if surface main fans are altered. These are fire locations within panel sections in which either the fire behaviour stops normal intake ventilation flow into the section headings or the GAG docking point is in an airway that is isolated from the section. This situation is seen in 14 percent of the cases examined.

Table 0 Effectiveness of GAG delivery

Code	Description	Results from 35 scenarios simulated	Percentage %
A	GAG exhaust delivered efficiently (without significant dilution) to fire.	0	0
B	GAG exhaust reaches fire but diluted and not fully effective. Fan change needed to allow inertisation stabilisation of fire.	7	20
C	GAG exhaust reaches fire only after fan change and potentially effective after local reversal of ventilation air (incl. fire fumes) across fire.	16	46
D	GAG exhaust will never reach fire even with fan changes.	5	14
E	GAG exhaust only reaches fire after fan change. Reversal of working section methane and ventilation air (incl. fire fumes) across fire.	7	20

- Category E covers priority fires in gassy mines in which section production gas make has been included in the simulation modelling. GAG exhaust will never reach the fire location without stopping of one or more main surface fans to rebalance ventilation within the pit. However this change in ventilation causes working section methane and ventilation air (incl. fire fumes) to reverse across the fire. This is clearly a potentially dangerous situation and this situation was found in 20 percent of the cases.

A total of 35 priority mine fire locations that have had scenarios simulated that were considered worthy of incorporating utilisation of the GAG as an exercise in recovery of a mine following a major fire were reviewed. Table 3 shows results of the outcome of the 35 scenarios from the study.

These simulation exercises undertaken at a wide range of Australian coal mines focuses attention to the situation that many potential underground mine fire sources cannot be successfully inerted with the GAG docked at the current specified point.

This inability to deliver GAG output is particularly so for fires in extended areas of workings or in panels. Two important conclusions are

- Successful delivery of GAG output from units on the surface must consider other (that is alternative to Mains Travel or Conveyor Heading portals) delivery conduits directly into workings near the fire through existing or purpose drilled boreholes.
- During a fire the stopping of the main surface fan or fans will lead to rebalancing of pit ventilation and in some cases potential explosions through air reversals bringing poorly diluted explosible seam gases or fire products across the fire site.

FIRE SCENARIO SIMULATION EXERCISE 4 - INERTISATION OF HIGHWALL PUNCH MINES AND USE OF BOREHOLES

A number of Australian mines have adopted "punch" mine layouts with access to workings through the highwall of a box cut. Many of these have no conventional Mains. Practical options for inertisation of punch mine longwall workings are required. Borehole docking and delivery of inert gases may be required for fires in some sections of the mine if the open cut is not available for GAG action because of

- Geometry of the open cut,
- Open cut road access issues,
- Open cut roads pass in front of open underground mine portals,
- Potential of fume build up in the box cut

There is a debate on whether a borehole into punch mine workings should be placed near the front of the mine workings (close to and within a few hundred metres of the highwall portal) or at the back of the mine behind the longwall installation road. These alternatives of use of a front or back borehole have various advantaged and disadvantages that are often mine layout specific. Figure 8 shows a typical punch mine layout and the possible inert points available.

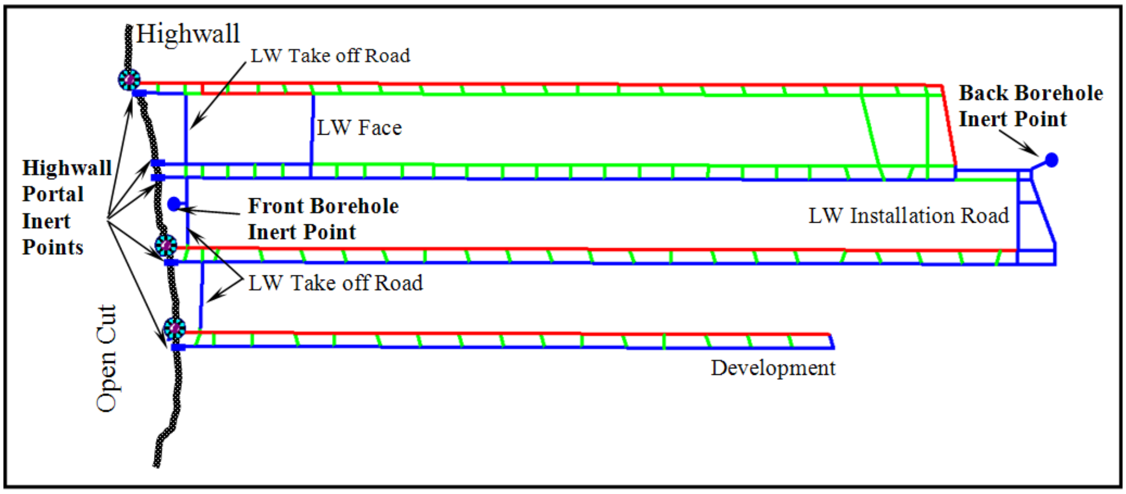

Figure 8 Typical punch mine layout and potential inert gas delivery points

The use of a back borehole to conventional longwall panels in Queensland is becoming very common. Examples are for instance in use or planned at Crinum, North Goonyella, Moranbah North, Grasstree, Oaky Creek No 1, and Kestrel collieries. Other mines such as Bundoora and Aquila have put in boreholes for potential inertisation use. The punch mines of Newlands North, Broadmeadow and Crinum East have examined the competing merits of use of different location boreholes for inertisation use. A back borehole in a punch mine can be useful for the following.

- Borehole downcast air can be used at start of extraction of LW panels to ventilate Main Gates if development slows over life of mine and there is no hole through to the next planned panel. It provides a form of ventilation insurance.
- Borehole downcasts clean air that provides some additional ventilation through LW panel life.
- Chilled air can be downcast through the borehole throughout LW panel lives with positional advantage for delivery when longwall face is farthest inbye and often at greatest depth.
- Borehole can be used for services and communication links.
- Borehole delivery of GAG inerts is generally equal to or advantageous (in terms of GAG operating time to inert a fire) for back half of mine compared with docking at front boreholes or highwall portals.
- Borehole can be used for emergency man escape if it is considered too far to walk from back of LW panels to open cut portals.

Front boreholes can be developed earlier than back boreholes. However they do not generally have the positional advantage in relation to providing extra production face air (chilled or normal temperature) or emergency man escape. Efficiency of inert gas delivery through a front borehole will partly depend on mine layout and whether the mine longwall panels are progressing from right to left or left to right. Extra overcasts or remote operation of a Ventilation Control Device door or regulator may be required to direct borehole inert gases to the fire site.

The use of highwall portals for delivery of GAG inerts to longwall panels is the simplest and most direct approach. No extra development of borehole drilling is needed. All new development immediately inbye a new Portal requires this approach for delivery of inert gases until a borehole (if one exists) is holed into. The docking approach is essential for the first part of any new Development headings. Many punch mines are currently being developed with provision for inertisation docking at both the highwall and through boreholes to allow efficient inertisation of fires across a variety of priority locations.

CONCLUSIONS

A study has examined the potential for simulation of the effects of inertisation on fires within a mine ventilation network. The project involved applying the VENTGRAPH mine fire simulation software to preplan for mine fires. Work undertaken to date at some Australian coal mines is discussed as examples. The effort has been built around the modelling of fire scenarios in selected different mine layouts.

Case studies have been developed to examine usage of inertisation units and particularly application of the GAG unit. One section has focused on selection of the surface portal location for placement of the GAG for effective fire suppression. The difficulties that some current approaches present are highlighted. Another section has looked at issues involved with delivery of GAG output through boreholes. A third examines inertisation and dilution issues in Mains headings. These present a complex ventilation network and with additional interference from a fire, maintaining control of the movement of inert gas is more difficult than elsewhere in the mine. A final section has examined considerations presented by “punch” mines layouts.

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