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Queensland mine emergency level exercises assisted by fire simulation

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ABSTRACT: A mine's safety and health management system must provide for managing emergencies in Queensland coal mines under the Coal Mining Safety and Health Regulations 2001. The system must include provision for carrying out aided rescue and self-escape of persons from the mine in an emergency and also auditing and reviewing the emergency exercises. For a number of years mines have been participating in what are termed Level 1, 2, 3 and 4 evacuation exercises on a regular basis. Examples of work undertaken focused on mine fire incidents in each of these categories are described. Meeting requirements for annual involvement in and management of these Level exercises is a significant effort for underground mines. The type of work that has been undertaken in assisting mines with "fire" based exercises and management approaches to development and implementation is discussed.

1 INTRODUCTION

Many people consider that mine fires remain among the most serious hazards in underground mining. The threat fire presents depends on aspects such as the nature and amount of flammable material, the ventilation system arrangement, the duration of the fire, the extent of the spread of combustion products, the ignition location and the reaction of personnel present.

An Australian Coal Association Research Program supported project incorporating a number of mine site exercises, as described by Gillies et al. (2004a) and Wu et al. (2004) has been undertaken focused on the application of mine fire and ventilation software packages for contaminate tracing and fire modeling in coal mines. This paper in particular examines the type of work that has been undertaken in assisting mines with "fire" based exercises and management approaches to development and implementation of these.

The study into this complex area has utilized the recently upgraded Polish mine fire simulation software, "Ventgraph". There is a need to understand the theory behind the simulation program and to allow mine site use by those already familiar with the main existing mine ventilation analysis computer programs currently popular within the Australian, United States and South African industries such as "Ventsim", "VnetPC" and "Vuma". "Ventsim", "VnetPC" and "Vuma" were not designed to handle fire effects on mine networks. Under the project a small subroutine has been written to transfer the input data from the existing mine ventilation network simulation programs to "Ventgraph".

It is difficult to predict the pressure imbalance and leakage created by a mine fire due to the complex interrelationships between the mine ventilation system and a mine fire situation. Depending on the rate and direction of dip of the entries (dip or rise), reversal or recirculation of the airflow could occur because of convection currents (buoyancy effect) and constrictions (throttling effect) caused by the fire. This reversal jeopardizes the functioning of the ventilation system. Stability of the ventilation system is critical for maintaining escapeways free from contamination and therefore available for travel. Reversal of air following fires can have a tragic outcome (Wala 1999).

Simulation software has the great advantage that underground mine fire scenarios can be analyzed and visualized. A number of fire simulation packages have been developed to allow numerical modeling of mine fires, such as Greuer (1984), Stefanov et al. (1984), Deliac et al. (1985), Greuer (1988), (Dziurzyński et al. (1988). The Ventgraph fire simulation program has been described in detail by Trutwin et al. (1992). The software provides a dynamic representation of a fire's progress in real time and utilizes a color-graphic visualization of the spread of combustion products, O_2 and temperature throughout the ventilation system. During the simulation session the user can interact with the ventilation systems (e.g. 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).

The primary objective of the part of the study described in this paper is to use mine fire simulation software to assist in the design of emergency training evacuation exercises. This paper examines work undertaken to assist mines in the planning and undertaking of emergency training exercises and related workforce training.

Work undertaken with appropriate bodies during preplanning and subsequently during the course of mine emergency exercises is discussed. Some comments have been made on the ventilation aspects of the emergency exercise from observations made during the course of the incidents. Some of these are set down as observations and some were personal comments from participating individuals. A key aspect of the software is the ability to model fires in a mine and the consequent effects of control measures such as ventilation changes and the introduction of means of atmosphere inertisation. Management is provided with a pre-emptive tool that gives ability to have control measures such as emergency seals or doors in place, as well as a predictive tool for analyzing actions prior to implementation in the event of a fire.

Broad conclusions from work undertaken at individual Australian coal mines are discussed as examples. The effort is built around the introduction of the fire simulation computer program "Ventgraph" to the Australian mining industry and the consequent modeling of fire scenarios in selected different mine layouts. In Queensland coal mines are requires to participate in what are termed Level 1, 2, 3 and 4 evacuation exercises on a regular basis. Similar systems are in place in other states. Examples of work undertaken across different categories of evacuation exercises are described.

2 EMERGENCY EXERCISES

Emergency training exercises have been undertaken in Queensland since implementation of the recommendations of the Inquiry Report from the Moura No 2 coalmine disaster of August 1994. Under the state's Coal Mining Safety and Health Regulations 2001, the mine's safety and health management system must provide for managing emergencies at the mine. The system must include provision for carrying out aided rescue and self-escape of persons from the mine in an emergency and also auditing and reviewing the emergency exercises. For a number of years mines have been participating in what are termed Level 1, 2, 3 and 4 evacuation exercises on a regular basis. The categories of exercises are:

– Level 1. Whole industry exercise organized by Mines Inspectorate and from which a report on outcome is widely circulated.
– Level 2. Once a year full mine simulated evacuation followed by de-brief.
– Level 3. Done every six months for each section crew. Crews presented with a scenario and undertake evacuation followed by de-brief.
– Level 4. One hour training on emergency scenario.

Reece (2005) summarized aspects of these exercises:

– Every Queensland underground coal mine has a mandatory requirement for a range of emergency exercise simulations each year.
– At least one full mine evacuation must be undertaken.
– Everyone must participate in at least one exercise each year.
– Two Mines Inspectorate state run exercises are organized each year.
– One of these includes a full mine evacuation.
– One targets management and inertisation and is largely a desktop exercise.

Scenarios are generally simple and:

– Require escape using self contained self rescuers in limited visibility.
– Focus on fire, explosion or major energy release that must be controlled.
– Need formation and response by a formal Incident Management Team.
– Showcase emerging technology.
– Employ borehole cameras and remote monitoring.
– May include use of automated unmanned surveillance vehicles.
– Have a need for Incident Control Systems and Dynamic Decision Making techniques.
– Utilize of the order of 15 industry assessors.

The outcome is the production of a report for industry with recommendations for the individual mine and general industry. Generally results have been good, but individual testing reveals that many miners could not escape. Of mine employees present 20 percent know what to do and take the lead while the remaining are not as focused. There has been a reluctance to mitigate an incident even from a safe location, the emphasis being on escape.

Queensland emergency exercises are not just to test that a mine has a system and to satisfy a gazetted regulation or to embarrass mine management and make them feel uncomfortable. They are to assist in improving responses, provide learning opportunities, reinforce good practice and showcase emerging technology.

The paper briefly examines a number of exercises that have recently been constructed and run.

3 LEVEL 1 DESK TOP 2004: MAINS FIRE WITH TWO MINERS TRAPPED

Under this exercise a simulated fire was burning in a Mains intake airway with two miners trapped inbye the fire. They were barricaded in a cut-through where a 500 mm ballast borehole was providing fresh air from the surface. The scenario has been described in detail by Gillies et al. (2004b).

The Ventgraph ventilation and fire simulation software was used to model the fire and mine conditions as various mitigation strategies were assessed. This assisted in determining the ultimate best solution to the problem. The mine used the GAG inertisation unit to reduce the intensity of the fire, whilst theoretically extricating the miners via the borehole and single rope and harness rescue. A borehole camera was used to view the men and the surrounding area. At the same time actions were taken to control the fire by drilling a series of boreholes from the surface to seam level, just outbye (in the same roadway) the last known position of the fire as well as in cut-throughs around the expected perimeter; then dropping flyash into the roadways. This was to be undertaken to block off the air to these roadways and starve the fire of O_2.

The incident tested the mines aided response capability. That is, following on from first response principles, personnel had been evacuated, as far as possible and the Incident Management Team (IMT) must bring the situation under control utilizing any resources that may be available.

The scenario commenced with a fire burning 10 pillars outbye from where two miners were trapped and barricaded below a ballast borehole site. The GAG inertisation unit was at the mine site but had not been connected or activated. Mines rescue teams were also on site but not operational, due to the mine measured gas levels from products of combustion approaching 80% of the Lower Explosive Limit (LEL).

For the purposes of the exercise, the mine was advised of these details three days prior to the event, in order to replicate some degree of preparation – as if the incident had happened a day or so beforehand. The mine were also advised that the IMT would be utilizing the Ventgraph software and that as the mine also had access to this software it would be able to utilize both the model and expert operators who were present at the mine to model the situation.

This description focuses only on the fire simulation modeling during the exercise. Examples from the concise scenario development and simulation results are set down.

3.1 *Scenario*

As illustrated in Figure 1 the fire is in the Mains inbye 51c/t B Heading caused by collision of two diesel vehicles with acetylene diesel ignition and subsequently ignition of standing coal. The mine has been evacuated except for two miners (one with a suspected broken lower arm) who have barricaded themselves at 61c/t A-B Hdg at the (600 mm) ballast borehole. Attempts had been made by evacuating personnel and a mine rescue team (using high expansion foam) to extinguish the fire but these were unsuccessful.

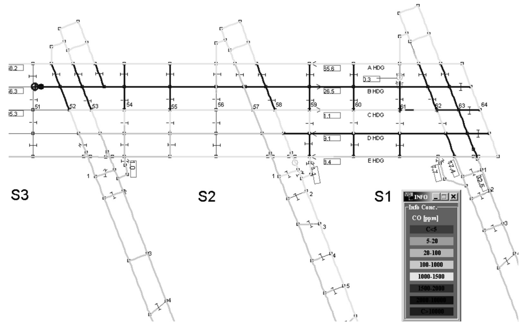

Figure 1. Ventgraph simulation of part of pit inbye fire (red dot) showing CO levels after 6 hours of fire burning. This shows air quantity inbye the fire of 26.5 m^3/s, 0.3 m^3/s of fresh air flowing down the borehole and contaminated air is leaking into the refuge from B Heading.

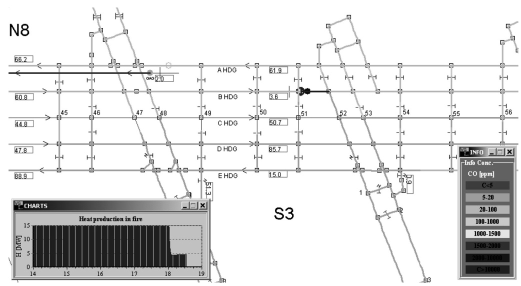

Figure 2. Ventgraph simulation of part of pit 12 hours after placement of flyash outbye fire GAG operating at Drift Portal showing CO levels. Air quantity outbye the fire is reduced to 3.6 m^3/s (O_2 is 12%, very high CO levels) and the heat output from fire reduced to 5 MW.

3.2 *Control action*

Drilling of borehole into B Heading outbye of the fire is proposed with fly ash used to obstruct the airway (R = 5). Figure 2 shows Ventgraph simulation of part of the pit after flyash placement outbye fire. GAG operating at Drift Portal showing CO levels. Air quantity in B heading outbye the fire is reduced to 3.6 m^3/s (O_2 is 12%) and the heat output from fire reduced to around 5 MW. The fire is now controlled and small enough to fight with foam or water.

3.3 *Alternative rescue approaches simulated*

A number of alternative scenarios were simulated. The mine normally has three fans running.

After starting up the GAG, an attempt was made to gradually shut off fans to reduce the O_2 supply to the fire. It was found that after shutting off the second fan (with the third fan still running), the airflow is reversed at the fire site and an explosion may occur. This is an unsatisfactory solution.

After starting up the GAG, an attempt was made to shut off one fan and then progressively close off two of the highwall entries to reduce the O_2 supply to the fire. Shutting off one fan successfully reduced the airflow to the fire but due to a lack of segregation, closing off the highwall entries had no effect in further reducing the flow to the fire. This alternative approach did not appear to cause a situation under which a gas explosion would be likely. However it is not effective as the fire would not be starved from lack of air.

3.4 *Observations on the emergency exercise*

The following comments can be made on the ventilation aspects of the emergency exercise from observations made during the course of the incident. Some comments are set down as observations and some were personal comments from participating individuals.

1. The Ventilation Officer (VO) was directed to analyze a number of potential solution options, utilizing Ventgraph, for the IMT. This process took significant time mainly due to the need to carefully document each step as it was modeled, so that an effective plan was generated and key activities were not missed.
2. VO was close to the IMT (in an adjacent room) but in effect was sufficiently removed from view that the IMT didn't adequately utilize the Ventgraph model.
3. The Ventgraph model was not well understood and as a result was very underutilized as a conceptual aid and management tool.
4. The ventilation models and options being run in another room was effective in that it allowed ventilation experts to concentrate on developing options unencumbered. However, the drawback was that it became disconnected from the IMT processes.
5. A number of key functions such as data entry and validation were under resourced. Time had not been devoted to understanding Ventgraph or preparing the IMT room for operation. Ventgraph is a very recent addition to site capabilities and therefore no doubt will take time to be assimilated. The assimilation process may require much more extensive training by the providers including scenario training.
6. It was clear that the purpose, capabilities and limitations of Ventgraph were not fully understood by pit staff. This may in part be due to the short lead time and also limited training in its operation by the software supplier.
7. A lot more work needs to be done to adequately incorporate Ventgraph into mine ventilation analysis system and current ventilation models should be integrated into Queensland Mines Rescue Service functions as part of GAG operations. Difficult to evaluate operation of GAG without this. There is no doubt that using Ventgraph will significantly enhance the IMT's ability to deal with mine fires.
8. There is a need to refresh key personnel understanding of mine fires and their characteristics, – for example the effect of reducing O_2 whilst maintaining airflow and effects of recirculation. This should be interfaced with actual examples of mine fires and successful and unsuccessful treatment of them.
9. There is a need to objectively demonstrate the behavior of mine fires including their products and how they are influenced – effects of air flow, O_2 concentration and inert gas.
10. Ventgraph modeling was a valuable tool but became intense due to the number of options being run – the IMT with more experience should ask for a prioritized assessment of the key options.

A comprehensive emergency training exercise held at an operating colliery incorporating a fire incident has been examined. The Ventgraph simulation software was used to model the fire and mine conditions as various mitigation strategies were assessed. This assisted in determining the ultimate best solution to the problem. Use of the Ventgraph simulation approach highlights actions that mine management can undertake to improve their position in the event of a fire. Examples of these include the following.

- Many fires occur associated with conveyor belts. Segregation of belt headings assists in preventing fumes ingressing escape intake roadways. Ventgraph gives a clear indication of poor or non-existent segregation stoppings.
- Short circuiting of fire fumes to return can keep escape ways open. This could be achieved by opening stopping man doors or vehicle doors. This can be very difficult if these are inbye a fire source. Remote control of these doors from a surface mine control room can overcome this difficulty.
- Many mines have change over locations (or refuge chambers in metalliferous mines). Ventgraph simulation can assist in determining the optimum location for these.

4 LEVEL 2 DESK TOP 2004: SIMULATION OF A SPONTANEOUS COMBUSTION INDUCED MINE FIRE

Ventgraph fire simulation software has been used to examine and illustrate the effects on the mine ventilation network of an open fire on a pillar sidewall rib induced by a spontaneous combustion heating developed from within the pillar. The simulation illustrates the effects of the fire on the whole mine ventilation network after an incubation period of about 700 hours following the outbreak of the pillar fire following a long incipient period and a migration phase upwind. The pillar under examination is positioned separating a mains intake heading from a return heading and so the heating has initially migrated toward the intake air. A fire development is examined in two stages within the case study mine.

1. An open fire that has broken out on the intake side of the pillar.
2. A subsequent stage when an open fire has broken out on the return side of the pillar (the charring phase, when the heating has continued to develop until the hotspot and charline encounter the pillar rib on the return side).

This hypothetical spontaneous combustion incident is reported as a simulation scenario that focuses on effects across the whole mine network. It is written up as a series of developments against time from the outbreak of the open fire in the pillar rib. The scenario has been described in detail by Gillies & Wu (2005).

All spontaneous heatings require that certain conditions are satisfied for the coal temperature to continue to rise. Primary amongst these conditions is that, at some point within the pile or solid mass of coal, the rate of heat generation from oxidation exceeds the rate of heat loss due to conduction and convection. If ever this condition is not fulfilled, the heating will have reached a maximum temperature and there will be no further increase. The temperature in the pile or mass of coal will henceforth begin to decrease. Whilst the requirement for this condition is well known, it is difficult to predict the characteristics of coal mass or size, coal reactivity, airflow flux and other parameters that will allow the development of a high temperature heating.

Humphreys (2004) developed a numerical model to examine the development of a heating within a coal mass, pillar or pile. For the purposes of modeling, it has been assumed that the starting conditions in the coal pile are homogenous; that is with all coal at the same particle size, reactivity and initial temperature. An underground coal pillar or solid mass will have a permeability that allows passage of air as controlled by the mine ventilation air pressure across the pillar. This permeability is likely to be lower than that exhibited by loose coal in a pile although the spontaneous

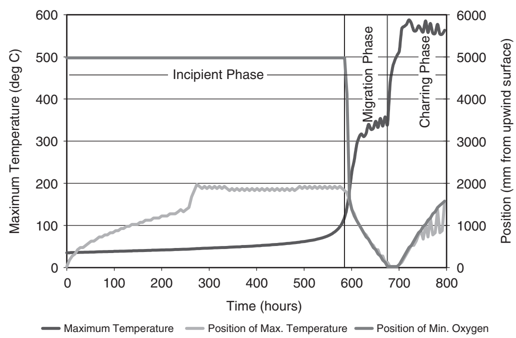

Figure 3. Spontaneous combustion heating development – temperature, time and position of minimum oxygen (Humphreys 2004).

combustion development characteristics will follow the same trend. In Humphreys' analysis the airflow flux is constant across the model although obviously there is consumption of oxygen as air passes through the model. For the purposes of examining the nature of a spontaneous heating as it occurs in a pile of coal, a quasi three dimensional model has been run for a representative coal.

The development of this heating can be summarized in Figure 3. The peak temperature in the pile, the position of the peak temperature (the hotspot) and the position of the minimum oxygen concentration in the pile are shown. At the very start of the heating, there is a moderately rapid increase in temperature, with the "hotspot" located at the upwind surface of the pile and the minimum oxygen concentration at the back surface. The rate of temperature rise moderates and the position of the peak temperature moves gradually downwind.

The position of the minimum oxygen remains at the back surface of the pile, although the minimum oxygen concentration is decreasing. After 275 hours, the peak temperature has moved to the furthest downwind position at about 1900 mm. The hotspot remains in this position until its temperature exceeds 125°C. This triggers a change in the behavior of the heating and the hotspot begins to migrate forward. Shortly afterwards, the minimum oxygen concentration in the pile falls to zero, as does the oxygen concentration at the hotspot. Despite this, the peak pile temperature is increasing rapidly, at approximately 8°C/hour.

Once the positions of the peak temperature and minimum oxygen concentration coincide, they begin to migrate together toward the upwind surface. This can only begin when the temperature profile in the coal ahead of the hotspot is sufficient to consume all the oxygen entering that part of the pile. The forward migration of the heating is limited by the upwind surface which triggers another increase in the coal temperature. A short while after this, the temperature of

the coal is sufficient to cause charring and a charline is formed in the pile. The final phase of the heating is the lateral expansion and downwind migration of the charline, as all the reactive elements in the coal are consumed by oxidation.

From this analysis, it is possible to divide the development of this heating into three distinct phases:

1. The incipient phase characterized by peak temperatures up to about 125°C. During this phase a hotspot develops from the upwind surface, migrates downwind to a maximum depth and remains static in that position.
2. The migration phase characterized by the forward migration of the hotspot. During this phase the oxygen concentration falls to 0 percent and there is a very rapid increase in the peak coal temperature. Without remedial action, the heating continues to develop and could lead to the outbreak of fire at the upwind surface of the pile.
3. The charring phase, when the temperature in the pile is sufficient to cause the formation of unreactive char. Without remedial action the heating will continue to develop until the hotspot and charline encounter the downwind surface when an open fire could break out.

The fire scenario developed for the emergency exercises focuses on stages 2 and 3 above during which an open fire may be in existence.

4.1 *Fire scenario development*

Spontaneous combustion fire in fractured pillar coal in the rib of a Mains Heading. There is a very high pressure of about 1200 Pa across the adjacent (Intake/Return) pillar. Heating started as deep-seated oxidation. In the initial stages of heating, moisture transfer and coal oxidation predominate.

4.2 *Intake side fire following the migratory phase*

As the coal dries out, a substantial local hot spot develops and begins to migrate upwind. The heating front has moved upstream in search of oxygen to the Heading pillar rib. It has just developed to the point of an open fire as simulation begins. Some highlight points are set down.

Smoke first reaches the development face at 22 minutes as shown in Figure 4.

Hypothetical actions of Development face crew are predicted. Crew see smoke and phone Outbye Deputy at 30 minutes. Crew contact Control Room Operator and commence to evacuate mine. Crews drive out in smoke. Crews reach surface at time since fire outbreak of 45 minutes.

Hypothetical actions of Deputy are predicted. Deputy finds fire source at 45 minutes after fire start.

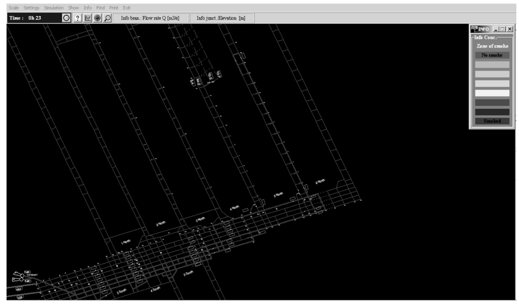

Figure 4. Smoke distribution after 22 minutes. Some smoke is reaching surface exhausting main fans outlets.

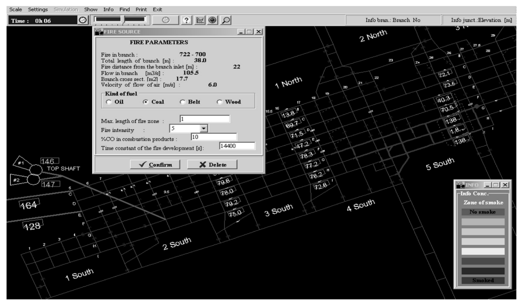

Figure 5. Smoke distribution after 5 minutes.

Deputy has hose ready to fight by 60 minutes. Coal fire grows. Deputy cannot extinguish fire at 90 minutes and drives out reaching the surface at 105 minutes. Fire is out of control. Decision reached that underground ventilation control will be ineffective. Decision made to shut down the two underground booster fans and one of the two Main fans.

At 120 minutes point no CO sensors in mine have alarmed (exceeded 8 ppm) yet.

Coal fire continues to grow. CO sensor on Development Dog Leg return first alarms at 130 minutes. Coal fire continues to grow past 150 minute point. Seam methane is present in mine. CH_4 never reaches the fire zone during the simulation. CO sensor at Longwall Dog Leg return has not alarmed after 180 minutes.

4.3 *Return side fire following the charring phase*

Following the charring phase, when the heating has continued to develop until the hotspot and charline encounter the pillar rib on the return side an open fire has broken out on the downwind side of the pillar.

A spontaneous combustion initiated fire is present in fractured rib pillar coal in the Mains Heading return near the No 2 booster fan. There are no electronic sensors inbye the fire.

Figure 5 shows location of fire and smoke distribution.

4.4 *Summary*

Both these intake and return side scenario simulation could be undertaken for much longer on the assumption that coal within the mine continues to burn and no remedial action such as flooding or introduction of gas inertisation occurs. It has shown how a relatively common form of mine fire, a spontaneous combustion initiated coal pillar fire (with the pillar separating intake and return air and with substantial pressure differences) can affect the mine workings. It can be shown how CO levels in mine airways increase over time for a specific fire build up scenario.

In the intake side fire significant CO levels reach the Mains and Development faces early but also eventually reach the longwall face if the fire is not stabilized and extinguished. The fumes from the fire have only limited effect on the Longwall face as it receives most of its intake air from unaffected airways.

In the return side fire significant CO levels build up. However these pollutants are restricted to the return airways and so do not directly imperil miners who are evacuating the mine.

5 LEVEL 3/4 2005: SECTION EVACUATION AND TRAINING

Ventgraph fire simulation software has been used to examine and illustrate the effects on the mine ventilation network of an open fires caused by vehicle accidents leading to fuel ignition. The example illustrated here was developed for a mine with three working crews. The assignment was to develop three separate PowerPoint training sequences, namely one for each working place. These form Level 4 training packages that can be delivered by a company trainer. Following training of all crews the company will implement a Level 3 exercise under which the same incident is used and a mine evacuation is required.

Some sequences from one example are given for illustration.

The scenario presented is of a vehicle fire in a longwall Maingate. Driver is stunned and observing but not fighting fire. Face seam methane gas source is illustrated by use of measured mine monitored readings. Figure 6 shows fire after 5 minutes.

The crew on the longwall face smell smoke within 10 minutes and raise the alarm by phoning Control. Men stop work, don 30 minute self rescuers and move to MG first rescuer cache. Men don 50 minute self rescuers at cache and proceed to crib room at 25 minute point. Evacuate at 35 minute point, drive up intake for 300 m in smoke. Deputy is continuously monitoring atmosphere with Personal Gas Detector. Smoke is too thick at 300 m outbye face and they continue on foot.

Deputy reads CO at 300 m point from face and finds CO in excess of 100 ppm in intake roadway, he checks Panel antitropal beltway and finds CO less than 100 ppm. Crew continue on foot via Panel antitropal intake beltway having passed through stopping man door.

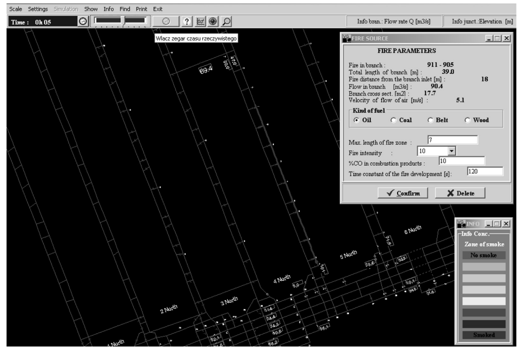

Figure 6. Smoke distribution at 5 minutes.

While face crew evacuating up Panel antitropal beltway, CO levels of 20 to 100 ppm will be experienced while they walk out. Distance dictates that next cache of rescuers is outbye fire. (Normal rate in smoke is 1000 m walk in 60 minutes.)

Longwall tailgate return Dog leg CO sensor alarms at 30 to 35 minutes. Control room phones or PEDs the Outbye Deputy if not done already. Control room can interrogate and see rising CO level. Control room phones the Shift Coordinator if not done already.

As time moves on face crew are evacuating using Maingate antitropal belt road checking stopping doors for fresh air in travel road (gas reading taken). At each DAC along the belt they buzz Mine Control. CO levels continuously dangerous at 20 to 100 ppm while they walk out. Outbye Deputy will have arrived at intake side of fire by about 45 minutes or earlier if he has a vehicle. Otherwise his arrival is a little later. Panel intakes inbye the fire is greater than 100 ppm CO.

Conclusion points highlighted in the training are

- Evacuating face crew in belt air should pass through to intake air outbye the fire and then exit mine through any intake Mains headings. Time escaping walking up beltway may be almost an hour.
- Smoke reaches face within 5 to 10 minutes and completely fills panel within 15 minutes.
- CO levels rise rapidly and so movement out of LW panel into clear intake air in the mains should be as fast as possible.
- Preference to evacuate through Beltway as contaminant level is lower. Man doors and segregation stoppings must be kept closed and in good order to achieve segregation.
- Escape headings should be kept clear to assist evacuation which may be over a long distance (up to full panel length).

– Seam methane vents through returns and so should not pass near fire.
– Fight fire as soon as possible to stabilize atmosphere and assist the men to escape.
– Evacuation exercises allow crews to become familiar with the self escape equipment and procedures and experience an escape in potentially non clear and difficult conditions.

Fire incidents cause many important mine emergencies. Training for section crews and "practice" evacuation exercises are important. Planning of exercises and production of training material using mine fire simulation software is valuable. This approach is being adopted by an increasing number of mines.

6 CONCLUSIONS

A study has examined the potential for simulation of the effects of a variety of relatively common forms of mine fires in developing level 1, 2, 3 and 4 emergency exercises. The approach emphasizes the ability of "Ventgraph" mine fire simulation software to be productively used to preplan for mine fires and possible emergency evacuations.

The background to this approach to simulating the effects of mine fires on the mine ventilation network has been examined. The anatomy of a number of fires have been analyzed. Mine fires are recognized across the world as a major hazard issue. New approaches allowing improvement in understanding their consequences have been developed as an aid in handling this complex area.

The mine fire simulator Ventgraph has been shown to be an important tool in planning for mine fires developed from spontaneous combustion heatings. The capability to visually display the spread of effects of a fire quickly and reliably provides a strong aid to those involved in developing emergency plans or contributing to emergency management. The active use of mine fire simulation in emergency planning should continue to be encouraged.

ACKNOWLEDGEMENT

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REFERENCES

Deliac, E.P., Chorosz, G. & D'Albrand, N. 1985. Development of Ventilation Software on Personal Computers in France and the Application to the Simulation of Mine Fires. In P. Mousset-Jones (ed.), *Proceedings 2nd US Mine Vent. Symp.*: 19–27. Littleton, Colorado: Society of Mining Engineers.

Dziurzyński, W., Tracz, J. & Trutwin, W. 1988. Simulation of Mine Fires. In A.D.S. Gillies (ed.), *Proceedings 4th Int. Mine Vent. Cong.*: 357–363. Melbourne: The Australasian Institute of Mining and Metallurgy.

Gillies, A.D.S., Wala, A.M. & Wu, H.W. 2004a. Mine fire simulation in Australian mines using computer software. *Australian Coal Association Research Program Grant C12026, Final Report, November.*

Gillies, A.D.S., Wu, H.W., Reece, D. & Hosking, R.S. 2004b. Use of mine fire simulation for emergency preparedness. *Queensland Mining Industry Health and Safety Conference, Townsville*, 13–22 August.

Gillies, A.D.S. & Wu, H.W. 2005. Spontaneous combustion and simulation of mine fires and their effects on mine ventilation systems. *Coal Operators' Conference, Aus.*: 225–236. Melbourne: The Australasian Institute of Mining and Metallurgy.

Greuer, R.E. 1984. Transient-State Simulation of Ventilation Systems in Fire Conditions. In M.J. Howes & M.J. Jones (eds), *Proceedings 3rd Int. Mine Vent. Cong.*: 407–410. London: Institute of Mining and Metallurgy.

Greuer, R.E. 1988. Computer Models of Underground Mine Ventilation and Fires. *US Bureau of Mines Information Circular: IC 9206 (Recent Developments in Metal and Non-Metal Mine Fire Protection*: 6–14.

Humphreys, D. 2004. The Application of Numerical Modeling to the Assessment of the Potential for, and the Detection of, Spontaneous Combustion. *Underground coal Mines. Ph.D thesis (unpublished), University of Queensland, 2004.*

Reece, D. 2005. Lessons Learnt from Emergency Exercises. Mine fires Simulation Workshop. In A.D.S. Gillies (ed.), *Eighth International Mine Ventilation Congress*. Melbourne: The Australasian Institute of Mining and Metallurgy.

Stefanov, T.P., Asenyan, E.E. & Vlasseva, E.D. 1984. Unsteady-state Processes during An Open Fire in a Ventilation Network. In M.J. Howes & M.J. Jones (eds), *Proceedings 3rd Int. Mine Vent.*: 417–420. London: Institute of Mining and Metallurgy.

Trutwin, W., Dziurzyński, W. & Tracz, J. 1992. Computer Simulation of Transients in Mine Ventilation. In R. Hemp (ed.), *Proceedings 5th Int. Mine Vent. Cong.*: 193–200. Johannesburg: Mine Ventilation Society of South Africa.

Wala, A.M., Dziurzyński, W., Tracz, J. & Wooton, D. 1995. Validation Study of the Mine Fire Simulation In A.M. Wala (ed.), *Model. Proceedings 7th US Mine Vent. Symp.*: 199–206. Littleton, Colorado: Society of Mining Engineers.

Wala, A.M. 1999. Three Underground Coal MineExplosions – Twenty Miners Killed – One Reason. In J. Tien (ed.), *Proceedings 8th US Mine Vent. Symp.*: 395–404. Rolla, Missouri: University of Missouri.

Wu, H.W., Gillies, A.D.S. & Wala, A.M. 2004. Case Studies from Application of Numerical Simulation Software to examining the effects of fires on mine ventilation systems. In R. Ganguli & S. Bandopadhyhy (eds). *Proceedings 10th US Mine Vent. Symp.*: 445-455. Rotterdam: Balkema.