Effective response to an emergency at an underground coal mine

David Cliff
Key questions

• What do recent events tell us about our capacity to react effectively to an emergency?
• What are the problems identified at these incidents?
• Are we different/better than them?
Emergency Response
Key things to remember

- Ideal gas law
- Conservation of mass
- How big atmospheric pressure is compared to the mine differential pressure
- You can't get negative gas concentrations
- Air moves from high pressure to low pressure
- A mixed gas atmosphere does not unmix
- Buoyancy is as much influence by the temperature of the gas as its density at RTP
- The ventilation officer is a very important role
Summary

- Computers are wonderful aids but there is no substitution for knowledge and the capacity to think.
Treat an underground coal mine just like a chemical processing plant.

- Exercise the same level of control and real time monitoring over key chemicals, i.e. flow and concentration
  - Air quality in returns
  - Real time velocity/differential pressure at key points in the mine
  - Temperature and humidity
  - Air quality in the intakes
  - Smoke detection
Ways forward and challenges

• Reliable personnel location in mines
• Explosion resistant communications systems
• The ability to assess the air quality at key locations in a mine after an explosion/incident where there is loss of underground power
• Robust self escape systems
• Better resourced ventilation management departments
• Better resourced and organised control rooms
• The ability to rapidly isolate part of a mine
• The ability to rapidly seal a mine
• The ability to inert part or all of a mine quickly
Window of opportunity
From available monitoring data we must be able to:

- determine current status throughout mine
- Predict future atmospheres, including:
  - rates of change
  - key influences on atmospheres including:
    - Air leakage
    - Flammable gas movement
    - Effect of barometer
- Estimate uncertainty in determinations so that margins for error and margin of safety can be established
- Find evidence of ignition source, absence of evidence is different to evidence of no ignition source
- Know how representative of the mine environment is the monitoring data
CAMGAS Operator 1992

CO > 10 ppm
H₂ > 50 ppm
Runtime 30 – 45 minutes
SMARTGAS

CO and H₂ < 1 ppm
Runtime < 60 seconds
SAFEGAS System with Realtime Sensors

WORKSTATION PCs RUNNING SAFEGAS

Backup of SAFEGAS files via Network Backup

Printing Via Network Printers

Modem link to SIMTARS for Maintenance and advice on trends

Printing Via Network Printers

GAS MONITORING ROOM

Network File Server Running Novell Netware

Radio or Fibre Optic link to Novell Network

Local Printer for daily alarm reports and trending

Modem link to SIMTARS for Maintenance and advice on trends

PLC & Analysers

SAFEGAS PC

Computer Software

Converter

DH+

RS232

RS485

U/G

Gas Sensors (CO & CH4)

Remotes

2x Analog In
2x Relay Out
8x Digital In

Other PLCs

Workstation running SAFEGAS

Alarm Panel

(c) Copyright SIMTARS 1995
SMARTGAS - CONNECT
Ventilation simulation
Models never lie
<table>
<thead>
<tr>
<th></th>
<th>CORE Sample gas % (AF)</th>
<th>As received</th>
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<tbody>
<tr>
<td>Helium</td>
<td>1.8876</td>
<td>0.006</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.3146</td>
<td>0.001</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0</td>
<td>20.9</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>28.6914</td>
<td>78.0</td>
</tr>
<tr>
<td>Methane</td>
<td>72.3561</td>
<td>0.23</td>
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<tr>
<td>Carbon Monoxide</td>
<td>0.1573</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>5.3714</td>
<td>0.05</td>
</tr>
<tr>
<td>Ethylene</td>
<td>0.6292</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Ethane</td>
<td>0.6292</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Argon (calculated)</td>
<td>-10.0369</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Key features:

• LW 400m wide (2.6-3.6m H) (LW1 325m)

• Development (min 3.2m x 5.4m)
  - 3 hdg gateroads
  - 7 hdgs mains

• Force / Exhaust Primary Ventilation System

• Used as access for Glen Munro, Woodlands Hill & Piercefield seams
General Information

• Mine opened September 1, 1994
• Eagle coal seam
  – High Volatile Bituminous Coal
  – Average coal thickness 54 inches
  – Average mining height 84 inches
• Four producing sections
  – 3 continuous miner (CM) sections
  – 1 LW
  – LW moved to Logan’s Fork Mine in 2006, returned to UBB in 2009
• Workforce
  – 234 underground, 2 surface
  – Numerous contractors
• Overlapping and staggered shift schedules
  – Two production shifts, one maintenance shift (midnight)
Description of the Accident

• At approximately 3:02 PM
  – Electrical power at the Ellis Portal went off
    • Power cable ran through mine
  – Dust and debris blown out of the portals
  – Mine fans at the UBB portal stalled
  – CO monitoring system started alarming (belt monitoring)
• Several miners near the portals evacuated the mine
• Surface personnel began notifying underground (UG) personnel to evacuate
• 29 miners unaccounted for
Victim Locations

Ricky L. Workman
Howard D. Payne
Ronald L. Maynor
James E. Mooney
Kenneth A. Chapman
William I. Griffith

Joe Marcum
Gregory S. Brock

Edward D. Jones

Rex L. Mullins

Nicolas D. McCroskey
Richard K. Lane
Grover D. Skeens

Joel R. Price
Gary W. Quarles, Jr.
Christopher L. Bell, Sr.
Dillard E. Persinger

Cory T. Davis
Joshua S. Napper
Charles T. Davis

Adam K. Morgan

Michael L. Elswick

William R. Lynch
Carl C. Acord
Benny R. Willingham
Robert E. Clark
Jason M. Atkins
Steven J. Harrah
Deward A. Scott
UBB actions

- Rescuers went straight into mine – got all the way to LW face
- Rescuers report over range CO and methane at HG22
- Boreholes drilled
- Thursday - borehole reports explosive atmosphere – rescue abandoned
- Rescuers re-enter mine Friday find high CO and smoke – ordered to exit mine – evidence of an active fire
UBB actions

- Nitrogen inertisation used to render atmosphere non flammable
- Rescuers brave high CO concentrations to rescue bodies
- Once all bodies retrieved mine declared too dangerous for persons to remain underground.
- Investigators have to wait over two months before it is deemed safe to re-enter
Pike River Coal Mine November 2010
Pike River November 2010

- Most workers in this area
- Second emergency shaft planned for here
- 4 or 5 workers
- Emergency shaft being drilled to this point
- Ventilation shaft
- Approx six workers
- 2.3km to mine entrance
After the 3\textsuperscript{rd} explosion
The issues

• In each case:
  – Explosion has occurred
  – People still underground
  – No gas monitoring in place
  – No communications with underground
  – Methane seam gas
  – Unknown ventilation circuits
  – In all cases fires found after explosion
Emergency Response
INADEQUATE INFORMATION TO MAKE INFORMED DECISIONS
Mine entry during or after an incident

- An explosive atmosphere with ignition source
  - Ventilation failure
  - Accumulation of fuel
  - Presence of an ignition source

- An explosive atmosphere without a confirmed ignition source
  - Ventilation failure
  - Accumulation of fuel
  - Unable to identify an ignition source

- Unstable environmental conditions
  - Fire burning or reduced ventilation quantity
  - Unable to determine visibility conditions
  - Unable to determine the effect of casual water
  - Unable to determine the presence and extent of debris

- Unknown status of mine ventilation
  - Unable to substantiate strata failure and stability
  - Unable to determine thermal conditions
  - Fire burning or reduced ventilation quantity
  - Unable to determine visibility conditions
  - Unable to determine the effect of casual water
  - Unable to determine the presence and extent of debris

- Unknown overpressure event
  - Unable to determine type of event
  - Unable to determine type of explosion

- Secondary explosion
  - Unable to determine likelihood of subsequent explosion and when.

- Unknown post inrush conditions
  - Unable to substantiate impact of inrush of material (water or mud)

- Unknown post outburst conditions
  - Unable to determine strata damage

- Unknown current and post fire conditions
  - Unable to substantiate location, type and size of fire.
Guideline for:

EMERGENCY MINE ENTRY OR RE-ENTRY

Produced by the Queensland Mines Rescue Service and NSW Mines Rescue Service

Queensland Mines Rescue Service Limited
49 Garnham Drive, Dysart QLD 4745
Phone 07 49582244
Fax 07 495827401
www.qmrs.com.au

Mines Rescue Pty Ltd
533 Lake Road, Argenton 2284
(PO Box 41 Boolaroo NSW 2284)
Ph: (02) 4922 4452
Fax: (02) 4950 6629
Email: info@rescue.coalservices.com.au

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<th>Date</th>
<th>Description</th>
<th>Initiated by</th>
<th>Checked by</th>
<th>Approved by</th>
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<tr>
<td>1</td>
<td>16/06/2010</td>
<td>Original</td>
<td>Geoff Nugent</td>
<td>Darren Brady</td>
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Printed: 17/02/2011 11:35 AM
Page 1 of 22
Username: Geoff Nugent
Site: Carborough Downs Mine
Document date: 2010-11-16
Scope of document:
- Site Information
- Incident Information

Please choose the site from the list or create a new site.
Click to select a date for the document.
1. Firefighting

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the fire fighting resources on site documented?</td>
<td></td>
</tr>
<tr>
<td>Is all site fire fighting equipment compatible both underground and on the surface?</td>
<td>Yes</td>
</tr>
<tr>
<td>Notes:</td>
<td></td>
</tr>
<tr>
<td>Is information readily available on the type of fire fighting equipment available on the mine site?</td>
<td>No</td>
</tr>
<tr>
<td>Is information readily available on the quantity of fire fighting equipment available on the mine site?</td>
<td>No</td>
</tr>
<tr>
<td>Is the mine self sufficient for all relevant fire fighting media for at least two hours?</td>
<td>No</td>
</tr>
<tr>
<td>Are the expected water pressures for fire fighting known?</td>
<td>No</td>
</tr>
<tr>
<td>Is the Mines Rescue Service aware of the capability and type of equipment used?</td>
<td>No</td>
</tr>
<tr>
<td>Are there adequate numbers of competency based trained persons to conduct fire fighting operations available on all shifts?</td>
<td>No</td>
</tr>
<tr>
<td>Are the mine fire fighting plans up to date?</td>
<td>No</td>
</tr>
<tr>
<td>Do the mine fire fighting plans conform to AS 4368 - 1996?</td>
<td>No</td>
</tr>
<tr>
<td>Do MSDS exist on the mine site in readily accessible locations for all fire fighting media?</td>
<td>No</td>
</tr>
</tbody>
</table>
Control Rooms
Control Rooms

• Properly trained operators
  – Front line in an emergency
  – Ability to detect abnormality

• Simplify displays

• Simplify alarms

• Discriminate between process alarms and safety alarms

• Know where people are underground
Ventilation management system requirements

• Quality of information
• Capacity to interpret information
• Calibrated ventilation model – understand the ventilation system of the mine and what influences it
• Properly calibrated and maintained monitoring systems
Ventilation management system requirements

- Understanding of mine environment monitoring system
  - Lag times for tubes
  - Ranges of analysers/sensors
  - Integrity checks
- Understanding of the sources of gas in the mine
- Understanding of what is normal anywhere in the mine
- Understand the limits of what you know
- Understand what you don’t know
The Future

- High operating efficiency longwalls > 100 hours per week
- 7 kilometre gate-roads
- 500 m wide faces
- Top coal caving
- 10 million tonne per year mines
- 1000 m$^3$/sec mine ventilation
Back to the Future

• The ability to seal parts of the mine in an emergency
• The ability to adjust the ventilation in a mine remotely
• The ability to rapidly inert parts of a mine

However:

• Massive skills shortage
• Loss of practical knowledge and experience in dealing with abnormal conditions
• Lack of recognition of the importance of VO skills
Mine Environment Monitoring in the 21st Century

• To move forward with MEMS we need to treat the underground mine the same or better than a chemical plant with the same level of process control and quality monitoring systems.

• Improved MEMS will:
  – Increase safety
  – Optimise ventilation
    • Create a better working environment
    • Minimise cost
    • Improve productivity
Key things to remember

- Ideal gas law
- Conservation of mass
- How big atmospheric pressure is compared to the mine differential pressure
- You can't get negative gas concentrations
- Air moves from high pressure to low pressure
- A mixed gas atmosphere does not unmix
- Buoyancy is as much influence by the temperature of the gas as its density at RTP
- The ventilation officer is a very important role
Computers are wonderful aids but there is no substitution for knowledge and the capacity to think.
Hughes and Raybould Diagram
Ellicott diagram
Mapping Coward onto Ellicott – CH4
CH₄, CO and H₂ mapped onto Ellicott
Buffer zones

80% LEL and 120% UEL

Graph showing the percentage of oxygen and flammable gas (% LEL and % UEL).
Mapping buffer zones onto Ellicott diagram

- 80% LEL 120% UEL
- Boundary of coward

The diagram shows a mapping of buffer zones onto an Ellicott diagram, indicating the boundary of coward with reference to LEL and UEL limits.
Time based Ellicott coordinates
Proposed QMRS/NSW MR P/L diagram