



# Arnot's readiness to prevent a Pike River disaster

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## Synopsis

Methane explosions in underground coal mines are a major concern across the mining industry. After the Pike River disaster, Arnot Coal became even more aware of the explosion risk. To determine whether Arnot has adequate precautions against a methane explosion, such as the one that led to the Pike River disaster, a literature survey covering the causes of the incident and what preventative measures should have been in place was conducted. Many different methane explosion prevention methods were evaluated, as well as codes of practice. Based on the findings, Arnot's measures to prevent conditions favourable for a methane explosion were evaluated.

## Keywords

methane explosion, code of practice, dominoes, ventilation, LTR (last through road).

## Project background

### What is coal seam methane?

Methane ( $\text{CH}_4$ ) is formed as part of the process of coal formation. When coal is mined methane is eventually released from the freshly broken coal face. Methane can also be released as a result of natural erosion or faulting. The depth of the seam predicts the amount of methane content present. Methane is directly exposed to fresh air when mining takes place on surface and is confined when mining takes place underground..

### Methane gas in coal mines

Methane gas in underground coal mining is a big concern. Methane explosions are devastating, causing significant loss of life and damage to property, and there is a significant industry effort to prevent these accidents from occurring.

Methane becomes explosive only if it is diluted to between 5%–15% by volume in air. Failure to provide adequate ventilation to

dilute the methane to less than 5% by volume increases the threat of an explosion.

Following the Pike River disaster in New Zealand in November 2010, it became a major concern at Arnot 10 Shaft to manage its methane levels so as to avoid a similar incident.

### The Pike River disaster

The Pike River disaster shocked the world. On 19 November 2010 at 3:45 pm there was an underground methane explosion at the Pike River coal mine which resulted in the loss of 29 lives. Daniel Rockhouse and Russel Smith were the only two people underground that survived the explosion. The emergency response was led by the New Zealand police. A rescue attempt was prevented by a lack of information regarding the conditions underground. On 24 November a second explosion occurred, and all hopes of finding the 29 miners underground alive were abandoned. The focus moved to the recovering of the bodies. However, conditions underground made this impossible. Two further explosions occurred, the second of which ignited the coal underground. The mine entrances were sealed in January 2011. This event raised concerns throughout the coal mining industry to prevent methane explosions. (Royal Commission of the Pike River Coal Mine Tragedy, October 2012)

### Scope of study

The aim of the study at Arnot was the prevention of methane explosions and not preventing a methane explosion from leading to a coal dust explosion. Thus the project's main emphasis was on what happened at Pike River, how the tragedy could have been prevented; what measures Arnot already has

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Table 1

Depth vs. methane content (Van der Merwe, 2013)	
Depth interval (metres)	Mean methane content (cubic metres per ton of coal)
100	0.02
500	0.99
1000	3.73
1500	4.89
2000	7.09

in place, and what further measures it needs to take in order to prevent a similar disaster. There was no emphasis on actions to be taken in the event of a methane explosion, only on prevention. The project also did not consider rescue procedures or assistance to the bereaved families.

### Methodology

A survey was conducted and a hierarchy of information on methane explosions built up by using methods such as consulting with experts in the field and contacting other mines that had suffered methane explosions. From the hierarchy the most relevant information was selected. Underground visits were conducted during December 2012 and June 2013. The visits were scheduled so as to ensure that enough time was spent at each installation to ensure the effectiveness of Arnot's methane management and explosion preventative measures. Following the evaluation, conclusions were drawn and the necessary measures put into place to make Arnot 'Pike -River ready'.

### Results and analysis

#### Ventilation requirements

- *COP requirement*—Barrier pillars should be spaced 15 m apart.
- *Actual*—From Figure 1 it can be seen that the barrier pillar spacing separating panels averages 23.35 m, thus complying with the COP
- *COP requirement*—Each section should have its own ventilation district with a separate set of ventilation controls
- *Actual*—It can be seen from Figure 2 that Section 4 and Section 12 have separate ventilation districts, which means each section has separate intakes as well as return airways. The air flows are kept separate by making use of walls and air crossings, thus complying with the COP
- *COP requirement*—Under normal conditions 0.25 m<sup>3</sup>/s of fresh air should be supplied in the last through-road, and 0.3 m<sup>3</sup>/s under high-risk conditions
- *Actual*—Taking the average bord height and width as 3 m and 6.5 m respectively, the following air flows were calculated:  
 Normal conditions = 7 faces \* 3 m \* 6.5 m \* 0.25 m<sup>3</sup>/s = 43.2 m<sup>3</sup>/s  
 High- risk conditions = 7 faces \* 3 m \* 6.5 m \* 0.3 m<sup>3</sup>/s = 41 m<sup>3</sup>/s

From Figure 3 it can be seen that that sections 4 and 12 comply with the COP. The air flow in Section 3 was measured as 46.9 m<sup>3</sup>/s, thus also complying with the COP.

#### Abandoned panel ventilation

- *COP requirement*—Abandoned panels should be sealed off or ventilated until they are sealed off. Where they are still ventilated, the air flow velocity in the LTR should be greater than 0.5 m/s
- *Actual*—From Figure 4 it can be seen that panel N31 is abandoned and thus sealed off as required by the COP. Figure 5 shows an abandoned panel that is still being ventilated prior to sealing off. The air flow velocity is 1.1 m/s, thus complying with COP.

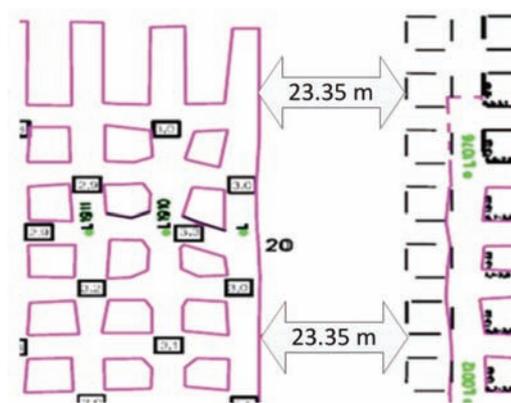


Figure 1—Mining layout showing barrier pillars

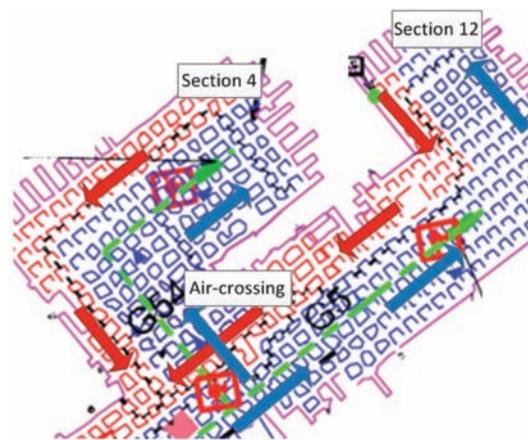


Figure 2—Air-crossing separating ventilation districts

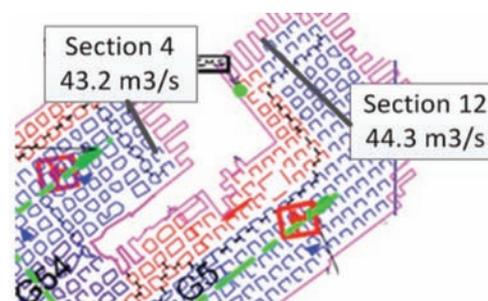


Figure 3—Section 4 and Section 12 layout and air flow rates

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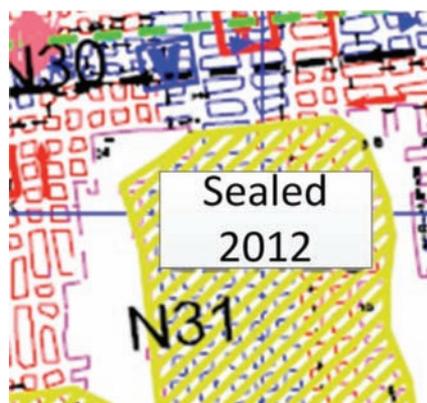


Figure 4—Example of sealed and unsealed abandoned panels

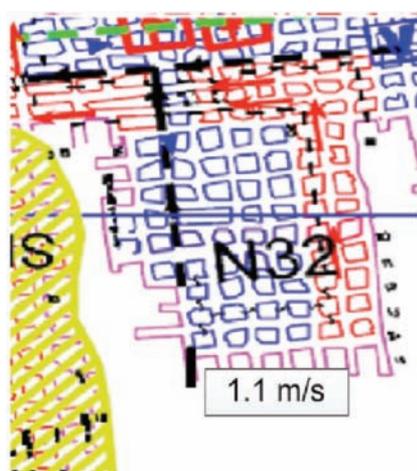


Figure 5—Air velocity in last through-road of abandoned panel

### Intakes and returns roads minimum velocities

Table II and Table III show the average intake and return velocities for each section. All of the readings can be seen to comply with the COP requirement of 0.5 m/s.

### Schedule of checks

Table IV shows the inspection intervals prescribed by the COP, together with the actual inspection intervals noted during underground visits. It must be noted that the inspection intervals are those prescribed under normal conditions, although there could be exceptions.

### Analysis of results

#### 'Swiss cheese' model of causation

Each layer in a 'Swiss cheese model' (Figure 6) represents a defensive system labelled by type (at the top). The holes in each layer represent gaps in the defensive system. These gaps can be created by active failures, human error, violations etc. Once these gaps line up there is no defence and an accident such as the Pike River disaster is likely to occur.

For example, if the ventilation at Pike River had been adequate and if there had been no ignition sources, then the accident would not have occurred. However, both the ventilation and the spark prevention measures were inadequate. The more defensive systems in place, the better the chances that not all of the holes in the model will line up (the probability of an incident decreases).

It is thus of great importance to have as many defensive systems as possible. If the critical systems fail, the secondary or ancillary systems must kick.

#### Dominoes at Pike vs. Arnot mandatory Code of Practice

From Table V it can be seen that 24 dominoes were identified that led to the Pike River disaster. Visual inspections, calculations, and interviews with employees indicated that Arnot is able to prevent all 24 of these dominoes.

### Conclusion

Failure to control the methane levels resulted in led to the inevitable explosion at Pike River during 19 November 2010, which resulted in the unnecessary loss of 29 lives. By

Table II

Intake velocities			
Section	COP intake requirement (m/s)	Section minimum measurement (m/s)	Average intake velocity (m/s)
3	0.5	1	1.3
4	0.5	1	1.2
12	0.5	1	1.1

Table III

Return velocities			
Section	COP return requirement (m/s)	Section minimum measurement (m/s)	Average return velocity (m/s)
3	0.5	1.2	1.7
4	0.5	1.3	1.9
12	0.5	1.3	1.7

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Table IV

**Inspection intervals**

Inspected	According to COP	Inspections interval measured	Compliance with COP?
Main ventilation to section	Start of shift and then every three hours	Start of shift and then every three hours. Deviations were less than 10 minutes.	✓
Last through-road velocity	Start of shift and then every three hours	Start of shift and then every three hours. Deviations were less than 10 minutes.	✓
Positive ventilation of faces	Start of shift and then every three hours	Start of shift and then every three hours. Deviations were less than 10 minutes.	✓
Scrubber screen and fan on the mechanical miner	Start of shift and when changing picks	Start of shift and every time picks are changed	✓
Ventilation brattices and section walls installed according to standard	Start of shift	Start of shift	✓
Trailing cables	Start of shift and at least once during shift	Start of shift and mostly once, sometimes twice.	✓
Flame proofing	Start of shift visual inspection	Start of shift	✓
Operating conditions of spray nozzles	Start of shift and when changing picks	Start of shift and mostly once, sometimes twice.	✓
Mechanical miner onboard flammable gas monitor tested	Start of shift	Start of shift	✓
Test for flammable gas in each heading up to second-last row of support	Start of shift and then every three hours	Start of shift and then every three hours. Deviations were less than 10 minutes	✓

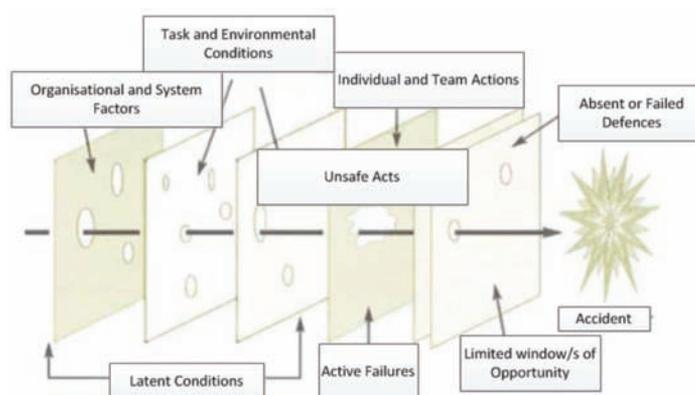


Figure 6—Swiss cheese model (Bredel, 2013)

thoroughly working through the Pike River disaster, 24 main dominoes contributing to the Pike River disaster incident as were identified listed. It can be seen that ventilation practices was the main issue involved.

Following up on a review of Arnot's methane control systems, which were obtained and data of which included obtaining from the ventilation readings, conducting visual underground inspections, and exercising to communicate with the interviews with relevant persons at the mine itself, Arnot's practices were compared to those of Pike River. From these comparisons it can be seen that Arnot can prevent all of the twenty four 24 main dominoes that played a role at Pike River.

The fact that Pike River was 150 m deep, compared with only 60 m at Arnot, could also have played a role. The mean

methane content measured in cubic metres per ton of coal increases with increasing depth of the mine. The methane emission rate would therefore have been higher at Pike River than at Arnot. (This can be seen from Table I).

### Recommendations

#### ***Increase the scoop/line brattice efficiency***

The scoop/line brattice efficiency can be calculated by comparing the quantity of air entering the section (point 1, Figure 7) to the quantity of air leaving the section (point 2). As an example, if the amount of air entering is 1.6 m/s and the amount leaving is 1.6 m/s, the efficiency will amount to 100 per cent.

## Arnot's readiness to prevent a Pike River disaster

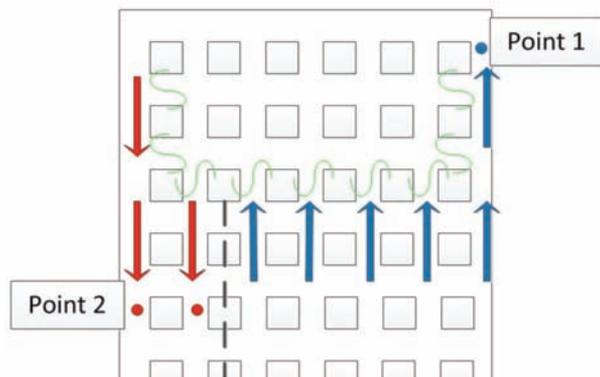


Figure 7—Layout of a basic section at Arnot

Domino	Complies with COP	
	Pike River	Arnot
Proper ventilation of goaf area	✗	✓
Sealing of the hydro panel	✗	✓
Unrealistic drive towards coal production	✗	✓
Main fan placed underground	✗	✓
In-bye ventilation fragile	✗	✓
Ventilation engineer	✗	✓
Second intake	✗	✓
Assessing of Health and Safety reports	✗	✓
Free venting of drained methane	✗	✓
Tripping of machines	✗	✓
Sensor bypassing	✗	✓
Experience of mine management/ constant change	✗ ✓	
Sensor at bottom of vent shaft	✗	✓
Placement of the sensors and reporting	✗	✓
Sufficient sensors	✗	✓
Voltage cables near pipes transporting methane creating a hazard	✗	✓
Stoppings separating intake air from return air	✗	✓
Diverting air away from face and shutting down of air while work continuous	✗	✓
Risk assessment conducted when fixing restricted and nonrestricted areas.	✗	✓
Variable-speed drives	✗	✓
Training of employees	✗	✓
Widening of the panel from 30m to 45m	✗	✓
High methane readings reported	✗	✓
Main fan flameproof	✗	✓

Table VI

### Efficiency table

Section	Above 70%	Below 70%	Average%
3	36	18	75
4	8	46	64
12	24	30	68

It is recommended that the efficiency be maintained equal to or greater than 70 per cent.

From Table VI it can be recommended that the scoop/line brattice efficiency on Section 4 must be drastically increased, since this low efficiency results in less air being supplied in the last through-road. Section 12 can also consider improving their efficiency. Section 3 has the highest efficiency, but it is still nevertheless recommended that more effort be put into minimizing the number of readings below 70 per cent efficiency.

### Reporting format

It is recommended that I.O (in order) and O.O.O (out of order) should not be used to report on ventilation readings in the shift overseer's daily logbook. The quantity of the readings should rather be recorded so as to build up a record of ventilation readings underground.

### Suggestions for further work

As we have learned, by placing the main fan at the PR in the underground vicinity was 'a major error'. It appears that the safety measures similar in Australia (but not legal requirements in NZ) were not enforced nor instituted to begin with. It is thus suggested that the aforementioned and vital legislation in different countries regarding the prevention of methane explosions be investigated. In addition, investigations should be extended to the prevention of coal dust explosions, and not only methane explosions. As with main fans that are not banned underground within the New-Zealand laws it is suggest that there could be further looked into the role the laws of the different countries play when it comes to the prevention of methane explosions. It can also be suggested that it must be further looked at the prevention of a coal dust explosion and not only that of a methane explosion

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