CHAPTER 8

Ventilation

Introduction

The purpose of mine ventilation

1. All underground coal mines require adequate ventilation. A mine's ventilation system must deal with the hazards of gas and dust, keep the temperature and humidity within acceptable limits, and ensure there is sufficient air for workers to breathe.[1] The ventilation system should form part of an overall gas management system, including gas monitoring, electrical safety procedures, measures to avoid sources of ignition and, in some cases, pre-drainage of methane.[2]

2. Poor ventilation is a serious hazard that creates a risk of a major explosion and loss of life. Multiple disasters over more than a century have shown the importance of robust ventilation, which has rightly been described as 'the life-blood of any operational mine'.[3]

Basic description of a ventilation circuit

3. The basic design of a ventilation system consists of an intake, which draws in fresh air, and a return, which expels contaminated air. This creates a ventilation circuit, with air flowing in, across a working face to collect gas and other contaminants, and out through the return. Mining consultant David Reece referred to the following diagram to explain the concept of a ventilation circuit:

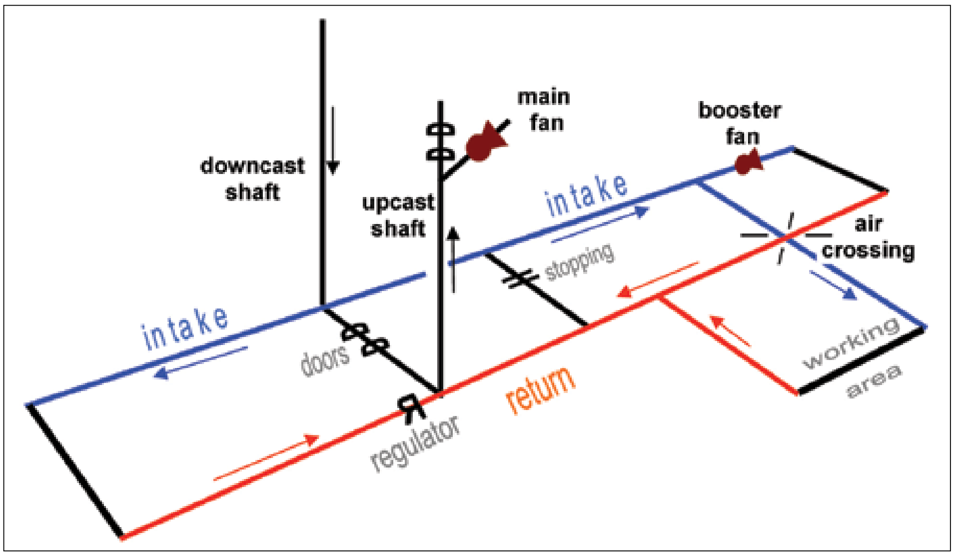


Figure 8.1: Typical elements of a main ventilation system[4]

4. Fresh air is drawn in through a downcast shaft, continues along the blue intake roadways, then across the mining faces shown in black. Contaminated air travels through the return airways, shown in red, and out the upcast shaft through the main fan. At Pike River, the intake was the 2.3km drift, and the main fan was at the base of the upcast shaft rather than on the surface, but the principle of a ventilation circuit was the same.

5. To create a ventilation circuit it is essential to direct air along the correct roadways and in the right direction. This is achieved with ventilation control devices. These consist of stoppings (solid barriers), overcasts or air crossings (which send air over a roadway) and other devices designed to direct or control the flow of air. Any leakage of air, through a poorly constructed stopping, for example, will make the ventilation circuit less effective.

6. The simplest ventilation circuit involves a U shape with the intake and return completely separated by solid walls. However, during development there will frequently be sections of one-way road, as well as dead-end stubs and other areas, that do not naturally fall within a circuit. One solution to ensure these areas are properly ventilated is to use an auxiliary fan, such as the one in the photograph.

Figure 8.2: Auxiliary fan

7. An exhausting auxiliary fan draws contaminated air away from the end of a stub or working face through a tube. A forcing fan may also help to send intake air in the correct direction towards the face. This is shown in the diagram, which shows an exhausting auxiliary fan drawing air away from the face through a ventilation tube, in red, with an additional forcing fan, in blue, on the right to help push fresh air up to the face.

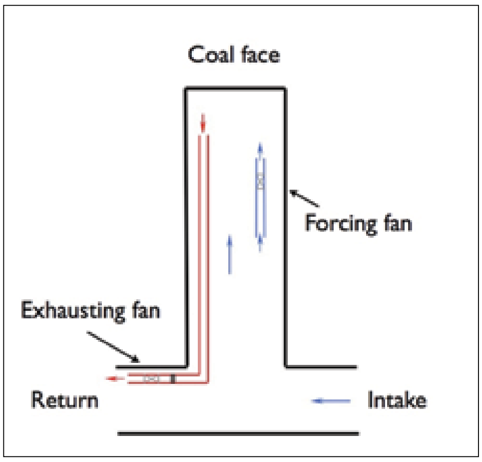


Figure 8.3: Right-hand diagram exhausting system with force overlap[5]

8. In order to function safely and effectively, an auxiliary fan must itself be located in sufficient air to keep it cool and to prevent recirculation of contaminated air. A standard requirement, which applied at Pike River, is that the main ventilation system must provide at least 30% more air to the auxiliary fan than the fan itself draws.

Who designed the Pike River ventilation system?

9. It was clear from an early stage that the Pike River ventilation system would need to deal with significant quantities of methane. As the next chapter describes in more detail, estimates of the methane content in the coal seam varied, and the Minarco Asia Pacific Pty Ltd ventilation report in June 2006 predicted a 'medium to high gas content throughout the resource area, particularly within close proximity to the Brunner fault.'[6] As a result, Pike River was expected to need about twice the ventilation of a typical high-production longwall mine.[7] Given the gassiness of

the coal seam, and the other challenges facing the design of the ventilation system, including the rugged surface terrain and complex geology, Pike should have had a dedicated ventilation officer[8] to oversee the system's design.[9]

10. However, no one person assumed responsibility for designing the ventilation system. When Peter Whittall was asked who designed it, he referred to four different ventilation consultants providing specific advice at different times.[10] It was appropriate for Pike to obtain advice from independent consultants, but the company did not establish clear responsibility and accountability for the overall design of the ventilation system.

Location of the main fan

Suggestions for an underground fan

11. On 31 October 2006 Pike invited four contractors to tender for the design, supply and installation of its main ventilation fans. The invitation stated that the fans were to be located on the surface. That is standard practice in the industry for a number of reasons, including the need for ready maintenance access, a secure power supply and access in an emergency. However, Pike faced significant challenges in installing fans on the surface. The proposed location was in mountainous conservation land, the only access was on foot by a bush track or by helicopter, there was no surface electricity supply and weather conditions on the surface were often harsh.

12. Two contractors ultimately proposed underground fans in addition to the conventional surface fans. It is unclear how the idea of underground main fans originated,[11] but Pike decided in favour of and developed the idea jointly with the preferred tenderer, Fläkt Woods Fan (Australia) Pty Ltd, in late 2006.[12]

Unique in the world

13. Pike ultimately decided to install its main fans underground, with a back-up fan on the surface. That situation is unique. Although underground booster fans are common in many countries, there is no evidence of any other coal mine in the world with a main fan underground.

The hazards of underground installation

14. Three main risks arise from locating a main fan underground.[13] First, it is more difficult to re-establish ventilation after an explosion, which could compromise the survival chances for anyone underground. Second, an underground fan is more likely to be damaged by an explosion. Third, an underground fan is closer to explosive material such as methane and coal dust, and a malfunction of the fan or its motor can be a source of ignition.

15. No doubt for these reasons, legislation in other countries either expressly bans main underground fans in coal mines,[14] or assumes they are installed on the surface and that only booster and auxiliary fans are installed underground.[15] The International Labour Organisation (ILO) code of practice issued in 2006 also assumes main ventilation fans are installed on the surface.[16] New Zealand law does not specifically prohibit the installation of main fans underground, and there is no mention of the location of main fans in the guidelines issued by the national health and safety council for the New Zealand minerals industry (MinEx), in October 2009.

16. Given the risks and the unique nature of the proposal, Pike should have insisted on a robust risk assessment and decision-making process to assess the proposal for an underground main fan. Three aspects of the process adopted by Pike are worthy of analysis: the risk assessment process, the level of oversight by Pike's board and the management's response to concerns raised.

Underground fan risk assessment

17. At the time of the tender process, Pike intended the ventilation shaft would be in stone measures, at a location east of the Hawera Fault. In February 2007 Pike held a professionally facilitated risk assessment into the placement of main fans underground. The risk assessment was led by two facilitators from Platinum Safety Ltd. Their role was specifically confined to facilitation of the assessment process as they had limited experience and knowledge of any

elements of mining.[17] The expert group comprised Pike's engineering manager (Tony Goodwin), technical services manager (Udo Renk), mechanical co-ordinator (Robb Ridl), senior mine engineer (Guy Boaz) and health and safety manager (Neville Rockhouse). The group also included a representative from Fläkt Woods, and Jim Rennie, an Australian ventilation consultant engaged by Pike. Mr Whittall participated in scoping the risk assessment.[18]

18. The group noted that installing main fans underground required a rigorous risk assessment process because of the risks to employee safety and business continuity.[19]

19. The scope of the risk assessment was described as 'high level', and the facilitators described the process as 'very challenging' and difficult to maintain within the agreed scope and context because people continually left and returned to the meeting. A large number of 'unknown factors' required further analysis by Pike.[20]

Problems with the underground fan risk assessment

20. In common with other risk assessments at Pike, the process rated the risks of various events and identified proposed controls. The risks were re-evaluated, and often reduced, in light of the controls.

21. For example, the hazard identified as '[b]oth main fans destroyed by explosion' involved the risks of 'destroyed fans', 'employee injury', 'business interruption' and 'suffocation from methane in the mine'. Two of these risks were initially rated as high in the 'red' or 'unacceptable' area, but revised into the 'green' or 'low' risk category in light of various controls, namely:

- *design and layout of the installation with built in explosion proofing*
- *protection of equipment by servicing and maintenance*
- *design consideration of the doors*
- *limit the sources of ignition*
- *installation of blast panels to protect the surface fan*
- *implement detailed Emergency Response Plans*
- *require supervisors to monitor specific hazardous processes and the installation*
- *install temperature and vibration sensing equipment*
- *site in a solid rock housing.*[21]

22. Some of these proposed controls never eventuated. For example, Pike did not install explosion proofing for the main underground fan, did not site the fans in rock and the blast panels on the surface fan proved inadequate during the explosion.

Relocation of the ventilation shaft

23. In September 2007 Pike moved the location of the ventilation shaft from stone into coal, west of the Hawera Fault, as discussed in Chapter 3, 'The promise of Pike', paragraph 47. The fan site moved with it, and despite material changes in the risks, there was no further risk assessment. Commissioning engineer Andrew Sanders, who began work at Pike as a consultant, drew this to Pike's attention in March 2010,[22] and listed three questions for the company:

- Was the risk assessment report ever finalised?
- Have resulting actions been followed up and signed off?
- Would it be appropriate to conduct another risk assessment on the latest proposed design and installation?

Mr Sanders' questions were never answered.

24. The risk assessment report was not finalised. There were four versions of the draft report, but despite attempts by Platinum Safety between March and July 2007, Pike never finalised the report. In June 2007 Neville Rockhouse apologised to Platinum Safety for Pike's 'unprofessional conduct with regard to this project',[23] after a third version

circulated to management to provide content had not been completed. The fourth version was distributed to managers in early July 2007 for completion,[24] but Platinum Safety had no further communication with Pike.[25] Mr Renk described trying several times with Mr Rockhouse to finalise it, but said Mr Whittall disagreed 'with some of the risk ratings and wording of the report and we were not able to finalise it'.[26] Mr Whittall does not recall any such approaches. He said he was not on the risk assessment team and it could finalise the assessment without reference to him.[27]

25. The failure to finalise the risk assessment, whatever the reasons, meant Pike had no adequate basis for deciding whether to proceed with the underground fan in light of the risks. That decision was critical, and should have been informed by a proper and final risk assessment.

Board oversight

26. Other than approving the expenditure required to enter into a contract with Fläkt Woods to manufacture and install the fans in July 2008,[28] neither the Pike board nor its health, safety and environment (HSE) committee took steps to ensure management had properly assessed the health and safety consequences of placing the main ventilation fans underground.

27. The board was informed in general terms of the underground fan risk assessment, but neither saw, nor asked for any audit of, the risk assessment report. The operations report to 23 February 2007 simply told the board there was 'no legislative or technical barrier to locating these fans underground with engineering solutions available to identified problems'.[29] From the board minutes, that advice appears to have been accepted without question.

28. Board chair John Dow was unaware of any other coal mine in the world with a similar arrangement,[30] but he said it was not a matter of particular concern for the board's HSE committee (which he chaired) to review the risks associated with having a main fan underground. He said he remembered having conversations about the location of the fan, but he saw it as a management issue.[31]

Management response to concerns

29. From early 2007, when the operational decision was made, numerous people at Pike raised concerns about locating the main fan underground.

30. In June 2007 Mr Rennie emailed Mr Whittall and proposed a forcing fan at the portal instead of an underground fan. He identified many advantages, including:

- ease of installation;
- immediate access to the fan for maintenance;
- power to the fan would not have to be routed underground and no secondary fan/generator system was required;
- minimal facilities would need to be maintained at the remote ventilation shaft surface with less environmental impact; and
- the long-term escapeway via the ventilation shaft would not be needed.

Mr Rennie stated that while his proposal for a forcing fan was 'somewhat unusual', it was 'by no means rare'.[32]

31. Mr Boaz was a participant in the February 2007 risk assessment. He left Pike later that year. He did not agree with the idea of putting fans underground and thought that the decision to do so was taken without full consideration of the risks involved.[33] Describing the concept as 'ground breaking', because he had not 'heard of it ever occurring in any other underground coal mine in the world', he raised his concerns with Mr Whittall.[34] However, Mr Whittall has 'absolutely no recollection' of this conversation.[35]

32. Mr Renk, the technical services manager from January 2007 to May 2008, emailed Mr Whittall in October 2007 to say he 'strongly believe[d]' a forcing fan at the portal was preferable to an underground fan and quoted a number of economic arguments to support his case.[36] Mr Renk says he was told it was too late as the decision had already

been made.[37] Mr Whittall does not recall saying this and also said that in any event a forcing fan was ruled out as impracticable at Pike River.[38]

33. Concerns continued to be expressed in 2009. Technical services manager Pieter van Rooyen recalled that in about February or March that year Mr Rennie expressed concerns about the placement of the main fans underground. Mr van Rooyen spoke to Mr Whittall, who said the decision had already been made, and one fan was already in New Zealand and the other partially constructed but on hold.[39]

Oversight by the regulator

34. Michael Firmin, the Department of Labour (DOL)'s health and safety inspector responsible for liaison and inspections of Pike River mine from 2007 to mid-2008, recognised that an underground main fan was unusual and would give rise to more hazards than a surface installation.[40] Mr Whittall told him, at a meeting on 13 February 2007,[41] that 'he looked at the regulations. And there was nothing that would stop Pike River doing this, and that's basically what he said.'[42] Pike's risk assessment meeting on placement of the main fans underground occurred two days later.

35. Mr Firmin checked the New Zealand regulations and concluded they 'did not appear to prevent the main fan being installed underground.'[43] He was concerned enough to conduct internet research into the regulatory regimes in other countries but said he did not find any regulation preventing an underground installation.[44]

The ventilation management plan

36. Pike had a ventilation management plan, which was signed off by mine manager Kobus Louw and Mr Rockhouse on 18 November 2008, soon after the main drift struck coal.[45] The ventilation management plan was a 78-page document, with 48 pages of appendices. It dealt with 11 major topics:

- ventilation design, plans and reports;
- ventilation fans;
- ventilation structures;
- underground environmental monitoring;
- mine inspections;
- prevention of ignitions;
- respirable dust;
- management of heat underground;
- wind blast;
- administration of the ventilation management plan; and
- responsibilities under the plan.

37. The plan required a ventilation engineer, a tube bundle system, explosion barriers, a permit to work system involving detailed sign-off by the ventilation engineer, and a full risk assessment to determine the non-restricted zone – none of which existed as contemplated by the plan.

38. The plan contained detailed and prescriptive responsibilities attached to 14 different roles at the mine. The mine manager was required to appoint a ventilation engineer,[46] and to receive reports from the ventilation engineer dealing with any defects in the ventilation or personnel.

Criticisms of the ventilation management plan

39. A number of staff members and contractors at Pike voiced concerns about the ventilation management plan. Mr Sanders produced a report dated 31 March 2010, which noted that the ventilation management plan was out of

date and contained numerous references to standard operating procedures that did not exist or had not been approved. He listed 54 items that required follow-up before the main ventilation fan was commissioned and hydro-monitor operations began. These included:[47]

- the appointment of a ventilation engineer;
- the lack of a tube bundle system;
- the risk of wind blast due to hydro mining;
- clarifying the various responsibilities under the plan;
- ensuring consistency between the ventilation management plan, the emergency response management plan and other plans and procedures at the mine;
- addressing inconsistencies in the definition of the restricted zone;
- confirming assumptions underlying the plan;
- completing an annual ventilation audit by an independent ventilation engineer;
- reviewing the actions to be taken when methane levels rose above set limits;
- creating a hydro monitor panel gas management plan;
- establishing special controls during initial operation of the hydro monitor;
- planning for safe access to the surface ventilation fan in the event of an emergency;
- reviewing of the ventilation management plan;
- carrying out a risk assessment before monitor start-up; and
- training and communication on the ventilation management plan.

40. Mr White accepted that he received a copy of Mr Sanders' report,[48] although he said he was not aware of the list of 54 things to be addressed before hydro-monitor extraction.[49] There was no process to check whether the items had been completed,[50] and many of them were not.

41. Mr van Rooyen, who arrived at Pike in February 2009, realised the ventilation management plan would need to be reviewed because it contained information he considered irrelevant and was sometimes 'too detailed and impracticable.'[51] As a result, he asked ventilation consultant John Rowland to review the plan.

42. Mr Rowland did so and reported: 'to be honest I don't like it either!!'. He described it as an all-encompassing plan covering ventilation management, explosion suppression, monitoring and other topics. It was 'gargantuan to be blunt and far too specific in my opinion in a lot of areas'. It would be difficult for him to adjust the plan in isolation: he would need to review the other management plans to see how they dovetailed together, and he would need to see a risk assessment. In his view the plan should be split up into various documents and this would take considerable thought. He said, 'It is ugly and will require far more discerning thought from you guys than you possibly realise.'[52] Mr Rowland received no further instructions in relation to this matter.

Compliance auditing

43. Australian and New Zealand Standard 4801 provides for safety management systems to be regularly audited.[53] There was no process at Pike to audit compliance with the ventilation management plan, and no external auditing.

44. Mr Rowland was not asked to audit compliance with the ventilation management plan.[54] When David Stewart of MinServ International carried out a series of compliance audits at Pike in February to April 2010, he did not look at the ventilation management plan. Indeed, he 'deliberately stayed away from looking at the documentation as such',[55] because he believed the plan was to be reviewed and updated. Mr Stewart said it is not easy for any mine to ensure that management plans are complied with, and he expected Pike was typical in this respect.[56]

45. Mr Dow said the HSE committee did not consider asking to see evidence of compliance with the ventilation management plan.[57] He said those were 'onsite activities',[58] and he did not accept that the HSE committee of the board should have ensured that the things required by the ventilation management plan were in fact happening at Pike River.[59]

The Pike ventilation system as built

46. Pike's early planning contemplated multiple intakes beyond the first year of development.[60] In November 2010 the Pike River ventilation system was still a one intake and one return system, as shown in the following diagram:

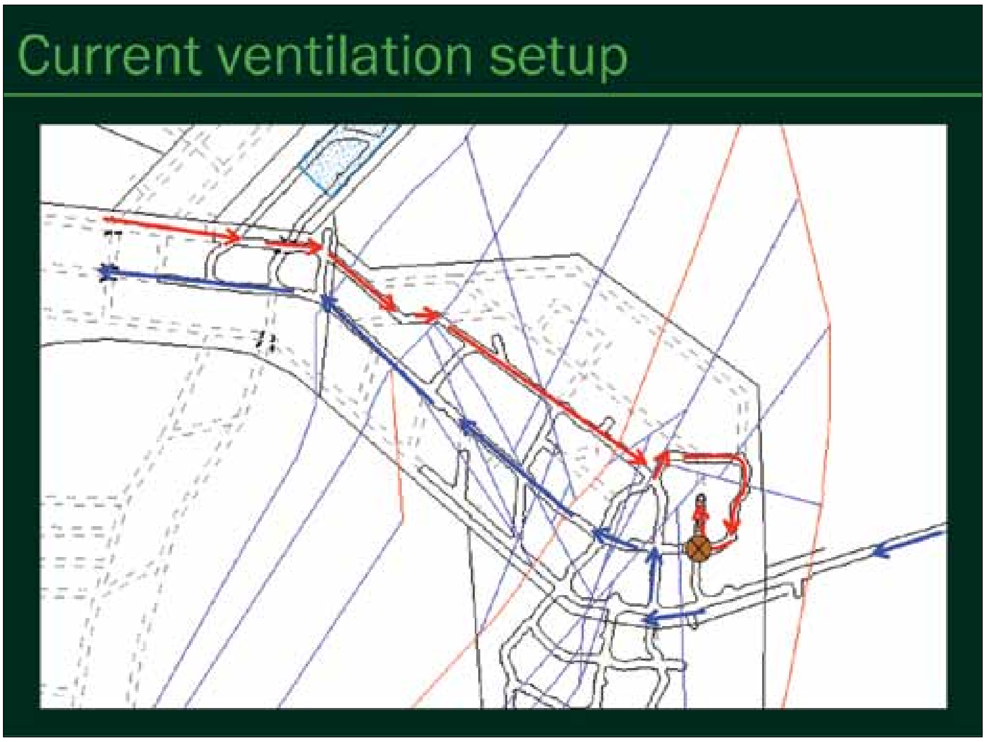


Figure 8.4 : Current ventilation setup[61]

47. The blue arrows depict fresh air entering through the intake (main drift), circulating through the workings and exiting through the return, shown in red. The main underground fan is depicted as a circled X towards the bottom right of the diagram, at the base of the ventilation shaft. Mr van Rooyen presented this simplified diagram of the Pike ventilation system to the Pike board in August 2010.

48. Mr Reece told the commission a single intake and return system is quite unusual for a mine with four or five working areas extending from it.[62] The DOL experts' report states that a one intake and one return system is not uncommon in New Zealand coal mines but would not be considered acceptable for anything but initial development in Australia. The report notes that Pike did plan to establish a second intake but it appeared that the mine would always be restricted to a single return system. The report said this might be acceptable, given the difficult geographical environment, but from a ventilation perspective it left no room for error. Any compromise to the main return would become a very serious event. [63]

49. The second intake was still planned. Mr van Rooyen presented the Pike board with a number of options in August 2010.[64] He estimated that it would have taken about a year for Pike to reach the recommended location of the second intake from the time he left in November 2010.[65]

The surface fan

Design and installation

50. Pike installed the surface back-up fan at the top of the ventilation shaft in June 2009. The exhaust structure (evasé) for the surface fan is on the left in the photograph, and the larger evasé is for the main underground fan.

Figure 8.5: The surface back-up fan

51. Fläkt Woods designed, built and installed the surface fan. It was powered by a 132kW electric motor with a capacity of 90m^3/s air flow at 0.4kPa (kilopascals) pressure.[66] The fan acted as the primary fan until the first main fan was commissioned underground.

52. The diagram below shows a bird's-eye view of the surface fan as installed. In the centre was the main underground fan evasé, designed to direct the air flow horizontally and prevent rain or snow entering the ventilation shaft.[67] The surface fan impeller (blades) and motor were to the right. To the left was an airlock entrance allowing access to the fan housing. Anyone climbing the ladder in the ventilation shaft would also exit through the airlock.

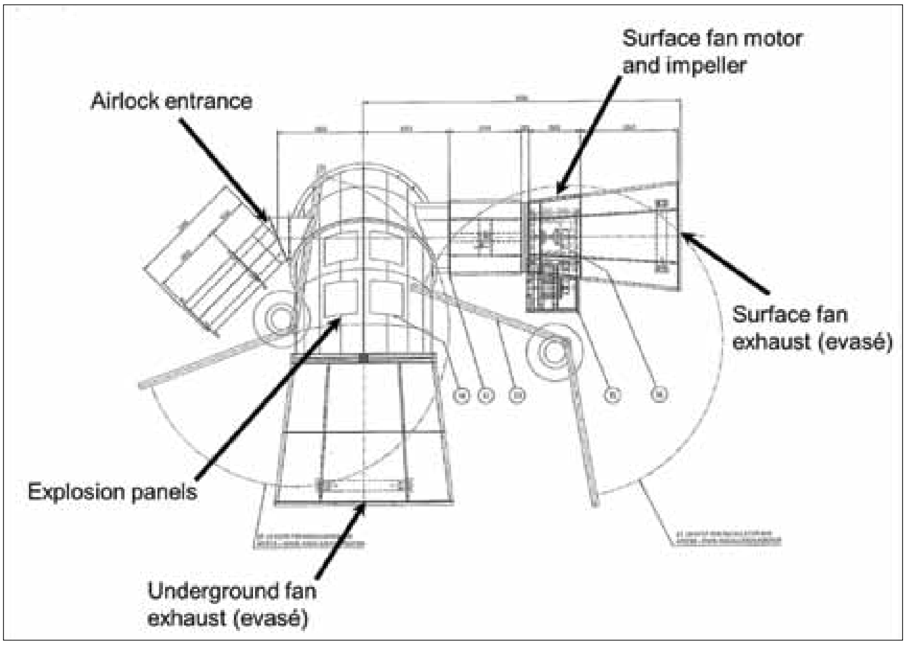


Figure 8.6: Surface fan as installed[68]

53. On the top of the housing were four explosion panels, designed to allow a pressure wave of air and debris following an explosion to go straight through the top of the housing and minimise damage to the fan. The explosion panels are seen in black in Figure 8.5.

54. Because both the surface fan and main underground fan were connected to the same ventilation shaft, a system was needed to block off air flow through one or other evasé, depending which was in use. Initially Fläkt Woods designed a butterfly damper for that purpose, but this was damaged and not repaired for 12 months or more.[69] During commissioning of the underground fan a few weeks before the explosion, Pike installed a set of louvres at the end of the main fan evasé as shown below. These were designed to close if the main fan stopped and the surface fan started up to ventilate the mine.

Figure 8.7: Evasé showing louvres being installed

55. The surface fan was powered by electrical cabling that ran from the portal substation up the main drift and then to the surface via the shaft. This was unusual. It meant that if power was tripped to the main fan at the portal, for example because of methane in excess of 0.25% in the vicinity of the fan motor, power would also be unavailable to the surface fan. Accordingly, diesel generators were installed to start automatically if the main fan stopped, enabling the surface fan to operate.[70]

Surface fan failures

56. On the evening of 5 October 2010, about three weeks before the commissioning of the underground fan, the surface fan failed after a blade sheared off.[71] Methane levels rose, power tripped to the underground workings and all personnel underground were evacuated from the mine. The mine gassed out, and on 6 October drops in barometric pressure and temperature caused methane levels in pit bottom to rise to such a level that Pike was unable to send a Mines Rescue Service (MRS) team underground to degas.[72] The daily volume of methane make peaked at 102,000m^3 during degassing on 7 October.[73] Pike conducted a risk assessment together with MRS personnel,[74] and repaired and ran the surface fan using the damper door to 'gradually introduce ventilation underground diluting the gas levels until normal historical gas levels were reached'.[75]

57. A similar event had occurred in July 2009 due to vibration.[76] Project manager Terence Moynihan believed that changes to underground ventilation and surface conditions meant the fan sometimes operated within the stall zone, leading to high levels of vibration and causing fan blade failure.[77] Given the changes from the original

ventilation shaft design, including the smaller Alimak raise installation, and based on an April 2010 ventilation survey conducted by Mr Rowland indicating high pressure losses between the shaft collar and the fan itself,[78] Mr Moynihan considered the surface fan was operating at significantly higher pressures than the instrumentation was recording. He felt that with the mine expanding, and increasing resistance, the surface fan would not have been able to meet its objective as a back-up ventilation fan.

58. Pike reviewed the surface fan failure in a meeting on 7 October.[79] The reason for the failure had yet to be determined by the engineering department,[80] and the review did not focus on preventing a repeat event. Rather, the meeting identified a number of improvements required to Pike's immediate response.[81] It is unclear how many of the identified improvements had been achieved by 19 November 2010. [82]

59. This failure occurred when the surface fan was about to take on a crucial back-up role to the underground main fan. Pike's ability to reventilate the mine in the event of a gassing out or an explosion underground was dependent on the surface fan, as the main ventilation fan could not be restarted in high methane levels. This incident was a near miss that should have led to more robust investigation and action.

The main underground fan

Installation of the fan

60. Pike's first main underground fan was installed in August and September 2010. Its size and configuration are shown in the photograph below. The fan motor (grey) is in the foreground, with the drive shaft (orange) connecting to the fan impeller (white).

Figure 8.8: Underground fan being assembled in factory

61. The bird's-eye diagram below shows the orientation and operation of the underground fan.

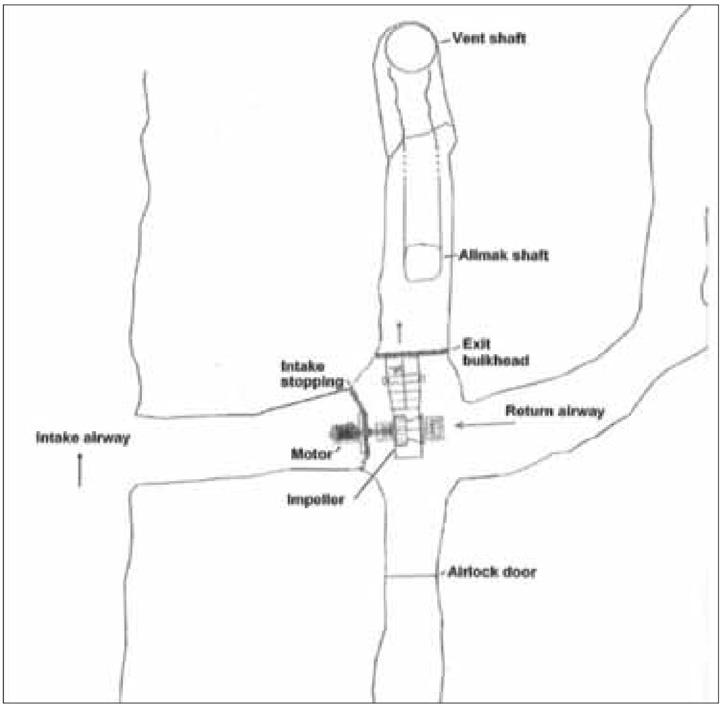


Figure 8.9: Orientation and operation of underground fan

62. Air entered from the return airway to the right of the diagram, then passed through the impeller and up the Alimak shaft. The non-flameproof motor was in fresh air on the intake side and sealed off from the fan impeller by a stopping, through which the drive shaft passed. The exit bulkhead was partly fitted with louvres, which were closed when the fan was working, but opened when it tripped. This enabled the surface fan to draw air more easily up the ventilation shaft to maintain mine ventilation. The airlock doors prevented return air from entering the mine intake system.

63. The main fan was designed to shut down in the event of a methane concentration in excess of 0.25% near the fan motor or when temperature or vibration cut-off points were reached, at which point the back-up surface fan was designed to start automatically.

64. The fan's maximum capacity was 128m^3/s,[83] from the 375kW motor that was controlled by a variable speed drive (VSD) located about 94m away in pit bottom south.[84]

Commissioning and operation of the fan

65. The main fan was first operated on 4 October 2010, but sparks came from the fan shaft at the junction with the intake stopping through which it passed.[85] To resolve the problem Pike removed a brass bush, which formed a seal between the drive shaft and the stopping.[86] This left a gap which Mr Sanders estimated was at least 20mm.[87] Mr White accepted there was potential for methane-contaminated air to leak through the gap if the fan was not operating.[88]

66. Further testing continued and on 22 October 2010 the underground main fan came online and the surface fan switched to standby duty.[89] Almost immediately the main fan suffered problems associated with the VSD power supply and other issues. At first neither the supplier, Rockwell Automation (NZ) Ltd, nor the installer, iPower Ltd, could identify the problem. In late October Rockwell agreed to replace the liquid-cooled 700L VSD with an air-cooled and larger capacity 700H model.[90] Problems continued as the new model was installed in the same VSD cabinet but had a different thermal requirement, and to avoid rising temperatures tripping the power, the mine installed ducting to direct air over the VSD. An air conditioning unit was also ordered, but had not arrived at the time of the explosion.[91]

67. Testing of the fan was completed on 10 November 2010 and the fan was finally commissioned for operation.[92] After installing the replacement 700H VSD, the main fan ran continuously until the explosion, apart from one problem caused by an auxiliary fan motor. [93]

Explosion protection of the fans

The proposed explosion path and explosion proofing of the underground fan

68. In 2007 Mr Renk designed twin underground fans to be housed in a separate heading, offset at 90° from the main return.[94] This was an attempt to create an explosion path to mitigate the risk of damage to the underground installations in an explosion.[95]

69. When the ventilation shaft was relocated into coal west of the Hawera Fault, Mr Renk redesigned the fans to remain offset from the shaft, with stoppings designed to fail in a pressure concussion event so a blast overpressure would bypass the fan and go directly into and up the shaft to the surface. He intended to install additional explosion-proof standard stoppings reinforced with steel to protect the fans.[96]

70. After the collapse of the ventilation shaft and the installation of the Alimak raise, the technical services department had to review and redesign the underground fan installation, and Mr Renk's earlier explosion path design was no longer possible.[97] By that time he had left Pike and no one in the department, including the new manager Mr van Rooyen, had prior experience with the concept. In June 2009 Mr van Rooyen looked at trying to maintain an explosion path to protect the fan but, after some research,[98] that issue, and the decision over design of a second connection to join the ventilation shaft, were deferred until further geological information was available. It was noted the mine would be without an explosion path until the second connection to the shaft was completed, but the surface fan was considered to be a sufficient contingency, along with other methods, including installation of explosion barriers 'to reduce the potential damage of an explosion'. [99]

71. Discussions in June 2009 (including with Jim Rennie and another consultant Steve Beikoff)[100] and again in September 2010 led to a consensus that explosion paths would not necessarily work as intended in an underground explosion,[101] and were not proven to be effective.[102]

72. The 2007 underground fan risk assessment had identified 'built-in explosion proofing' and protection as a control for placement of the main fan underground,[103] and Pike told insurance risk assessors in 2010 the underground fan would be located in 'explosion protected panels',[104] but no protection was in place.

73. This was described as 'somewhat deficient' by the joint investigation expert panel, who noted protection was a standard requirement in underground booster fan installations 'albeit in the form of a bypass mechanism'. Installation of explosion protection by means of a bypass in the underground workings near the fan 'may have contributed to reducing the extent or even the level of damage to the mine; as well as providing potential survivability of the ventilation system for later operation'. [105]

Stone dusting

74. Stone dusting helps to mitigate the effect of an explosion by mixing an inert limestone dust, also known as stone dust, with the coal dust on the floor, roof and ribs of the mine.

75. New Zealand regulations require employers to take all practicable steps to ensure the roof, floor and sides of every accessible part of the mine were treated with stone dust so combustible matter did not exceed 30%.[106] Pike's ventilation management plan set out a stone dust monitoring plan, and required the production deputy and undermanager to ensure that stone dusting was maintained daily in all roadways to within 10m of any working heading.[107]

76. Pike's stone dusting was inconsistent. When Mr White implemented a process in mid-2010 to test the standard of roadway dust, all samples failed the standard in Pike's draft standard operating procedure.[108] Although Pike was a

relatively wet mine, which would have mitigated the risk, the stone dusting was below standard and the problem had been raised during inspections and in writing twice by the DOL mines inspector in 2010.[109]

Explosion barriers

77. Regulations also require employers to take all practicable steps to ensure water or stone dust barriers were erected at suitable sites to limit the effects of an explosion.[110]

78. The ventilation management plan stated that 'stone dust barriers of the bag type will be used',[111] and Pike advised the Hawcroft Consulting International insurance risk assessor, in 2009 and 2010,[112] that explosion barriers would be installed to 'provide added defences in the event of a gas ignition, preventing development of a coal dust explosion'. However, as at 19 November 2010, Pike had not installed any explosion barriers underground. The equipment had been purchased and was stored on site from mid-2009.[113]

79. Deputies were required to complete a report every shift, and answer the query 'Are explosion barriers in order?' Deputies regularly answered 'no' or 'N/A [not applicable]'. Some Pike employees were concerned about the lack of explosion barriers and said so.[114]

80. Mr Stewart noted the absence of stone dust or water barriers in any of the roadways, in contravention of the regulations. When he spoke to the engineering staff and underviewers he was told there were no plans for barriers to be erected and they were waiting for a stone dusting machine.[115]

81. The expert panel considered that stone dust explosion barriers would have been useful.[116] Mr Reece accepted that stone dust barriers are not proven to extinguish a flame front from a methane ignition, but they can reduce the intensity of an explosion. Noting the common use of stone dust barriers within development panels of between 100 and 200m, and the relatively small size of the mine at the time of the explosion, Mr Reece said a stone dust barrier may have been appropriate in the main return to give some protection to the fan.[117]

The failure of explosion proofing of the surface installation

82. The surface fan failed in its vital back-up role. As shown in the photograph below, the explosion panels failed to divert the explosive air flow and debris from the first explosion, which damaged the fan, fan housing, shaft access doors, power generator and control infrastructure. Subsequent explosions propelled the fan and housing from their fixed positions.[118]

Figure 8.10: The surface fan after the first explosion

83. Gregory Borichevsky and an electrician examined the damage to the surface fan on 22 November 2010, before the second explosion on 24 November damaged it further. The airlock doors in the fan housing and the louvres installed on the evasé had been blown open and damaged. The fan was intact but three of the fan blades were damaged. The control panel had been blown over by the force of the blast coming out of the airlock doors and had fallen onto the emergency stop button of one of the generators.[119] The DOL investigation report concluded that the surface fan did not start at all, but it appeared that at least one of the diesel generators had started, since some fuel had been used.[120]

84. Mr Borichevsky believed the surface fan could and should have been restarted. Although damaged, his 22 November examination found the fan was intact, the second generator was running, the airlock doors could have been secured, the main cabling to the control panel appeared to be intact and could have been made safe to restart, the fan cowling, shutters and belts were slightly damaged but repairable, and the drive belts and motor on the fan appeared to be undamaged.[121] He says he told the production manager, Stephen Ellis, of his inspection and his view that the fan could be repaired and restarted to ventilate the mine, but that did not occur. Mr Ellis does not recall this, but comments that effecting repairs would have been too dangerous and restarting the surface fan was a decision for the mine manager Mr White.[122] Reventilating a mine following an explosion is an option that should always be available but can be dangerous and requires a risk assessment.

85. It is evident from the damage to the surface fan installation that the explosion panels could not cope with the explosion. The fan was too close to the ventilation shaft because of the limited space available at the site. The damage suffered meant the surface fan could not reventilate the mine.

86. Neither New Zealand or Australian mining legislation prescribes or provides guidance on the design of explosion panels. Pike provided no specifications to Fläkt Woods Fans. Fläkt Woods designed the explosion panels in accordance with a standard issued by the United States National Fire Protection Association (NFPA standard 68).[123] This standard requires complex calculations depending on analysis of several variables.[124] Fläkt Woods followed the design approach in this standard after it was specified for use by a Queensland mine for a surface fan installation Fläkt Woods completed in 2008, without comment from the Australian regulator.[125]

87. The commission considers that best design practice is reflected in the United States Code of Federal Regulations for underground mining. These regulations require explosion panels to have a cross-sectional area at least equal to that of the area (in Pike's case the ventilation shaft) through which an explosion would pass.[126] Under that approach, Pike's explosion panels were less than half the size they should have been to operate effectively.

88. The US regulations also provide that a main fan must be 'offset by at least 15 feet [5m] from the nearest side of the mine opening unless an alternative method of protecting the fan and its associated components is approved in the ventilation plan'.[127] Although the Pike surface fan was a back-up fan, a similar level of protection was necessary. However, the surface installation site was congested and the fan blades were installed only approximately 2.3m from the edge of the ventilation shaft. This site layout made it much more likely they would be damaged by explosion overpressure and debris.

Responsibility for ventilation at Pike

A dedicated ventilation officer

89. Since 1999 it has been a requirement for underground coal mines in Queensland and New South Wales to have a dedicated ventilation officer. That requirement arose from a recommendation of the inquiry into the 1994 Moura No. 2 mine disaster. The officer's functions are defined by statute and by regulations. They include ensuring adequate ventilation in the mine, ensuring proper ventilation measurements are taken and ensuring all ventilation control devices at the mine are properly constructed and maintained.[128] In New Zealand, a committee headed by the chief inspector of coal mines reviewed the Moura No. 2 recommendations in 1996, but did not recommend the

creation of a statutory ventilation officer position in this country because at that time only the largest company, Coal Corporation of New Zealand Ltd, had the economy of scale, or need, for such a person.[129]

90. In Australia, the ventilation officer's role is a full-time position. Queensland legislation does permit a ventilation officer to hold another role at the mine, but only if he or she can still carry out the functions of a ventilation officer. Mr Reece said a ventilation engineer would be 'constantly' looking into any methane issues in the mine and going underground every second or third day.[130]

91. In New Zealand, there is no statutory requirement for an underground mine to have a ventilation officer. Non-binding industry guidelines established by MinEx recommend that the mine manager appoints someone to carry out certain functions concerning ventilation, but they are much less exacting than the Queensland requirements.[131] Whereas in Queensland the ventilation officer must 'ensure' adequate ventilation and 'ensure' properly constructed ventilation control devices, the MinEx guidelines recommend that the relevant person carry out 'planning and design of ventilation systems and appliances' without reference to any particular standard.

92. From 2008 Pike's ventilation management plan required the mine to have a ventilation engineer, fulfilling the same role as a ventilation officer. However, no full-time ventilation engineer was ever appointed at Pike.

93. Mr Whittall said the role was subsumed within the mine manager's responsibilities. He thought Pike too small for a dedicated ventilation engineer and it might have been several years before the mine was large enough to merit a dedicated position.[132] Mr Whittall also said that the mine manager's responsibility for ventilation was 'supplemented by having a full-time, on-call ventilation or a designated on-call ventilation consultant available to us and they acted in that capacity'.[133] In particular, he indicated that Mr Rowland filled that role.[134]

94. However, Mr Rowland said he was never a 'full-time, on-call ventilation consultant' for the mine. He said he would not, under any circumstances, have accepted the ventilation engineer's responsibilities under the ventilation management plan as he was not permanently at the mine. Mr White accepted that Mr Rowland was not carrying out the role of ventilation engineer. He said it was never the intention to use Mr Rowland as a ventilation engineer but rather 'to seek his advice and have certain jobs done by him'.[135]

95. Mr White said that when he started in February 2010 he did not think Pike required a ventilation engineer. However, he accepted in hindsight it would have been desirable to have had a full-time person in this role from an early stage, even from the design phase.[136]

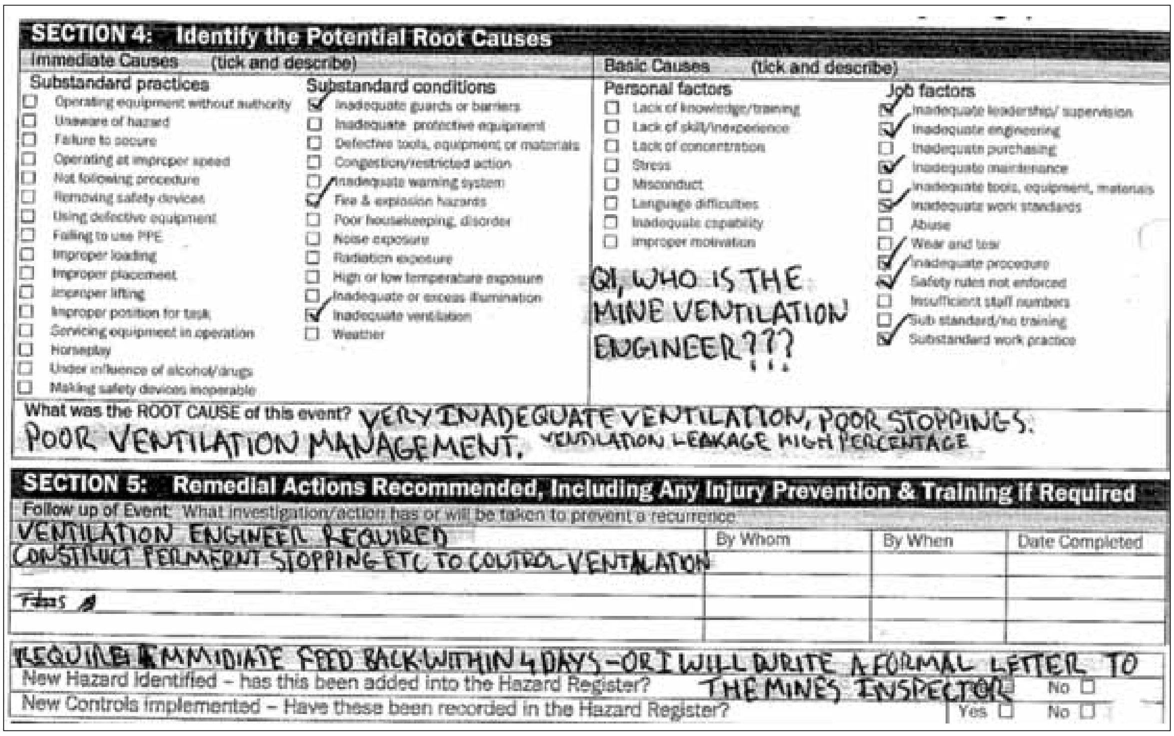
Concern at the lack of a ventilation engineer

96. A number of people at Pike raised the need for a ventilation engineer. Mr van Rooyen said that when he was appointed in February 2009 he assumed there would be a ventilation officer at the mine. He thought one was needed, particularly since he had very little ventilation experience. He suggested to Mr Whittall that Pike should send one of its engineers to New South Wales to complete a ventilation officer qualification. Mr Whittall said a ventilation officer was not required under New Zealand legislation, and not necessary owing to the size of the mine. Mr van Rooyen also raised this matter with Mr White.[137]

97. Mr Sanders raised the lack of a ventilation engineer among the 54 matters in his March 2010 report.[138] The following month, he prepared another report documenting key aspects of the ventilation system and detailing how it was to be controlled and operated. The draft document contained dozens of queries and gaps on critical issues. No final document seems to have been created, and responsibility for the ventilation system and ventilation management plan was never clarified. Mr Moynihan wrote on his copy of the report, 'Who is the ventilation engineer?', 'Who "owns" the ventilation management plan?' and 'Who "maintains" the ventilation management plan and its requirements?'.[139]

98. The subject was perhaps most stridently raised by Dene Murphy, one of the Pike deputies.[140] On 24 June 2010 he noted a problem with the ventilation system in an area containing two electrical substations. Mr Murphy filled out an incident form, noting, among other things, in capital letters, 'Who is the mine ventilation engineer?'. He went on to write, 'Ventilation engineer required', and 'Require immediate feedback within four days – or I will write a formal

letter to the mines inspector.'[141] Mr White signed off the incident on 7 July 2010, with the comment, 'This has been discussed with Dene. Vent structures being organised to be made permanent.'



SECTION 4: Identify the Potential Root Causes

Immediate Causes (tick and describe)

Substandard practices
- ☐ Operating equipment without authority
- ☐ Unaware of hazard
- ☐ Failure to secure
- ☐ Operating at improper speed
- ☐ Not following procedure
- ☐ Removing safety devices
- ☐ Using defective equipment
- ☐ Failing to use PPE
- ☐ Improper loading
- ☐ Improper placement
- ☐ Improper lifting
- ☐ Improper position for task
- ☐ Servicing equipment in operation
- ☐ Horseplay
- ☐ Under influence of alcohol/drugs
- ☐ Making safety devices inoperable

Substandard conditions
- ☑ Inadequate guards or barriers
- ☐ Inadequate protective equipment
- ☐ Defective tools, equipment or materials
- ☐ Congestion/restricted action
- ☑ Inadequate warning system
- ☑ Fire & explosion hazards
- ☐ Poor housekeeping, disorder
- ☐ Noise exposure
- ☐ Radiation exposure
- ☐ High or low temperature exposure
- ☑ Inadequate or excess illumination
- ☑ Inadequate ventilation
- ☐ Weather

Basic Causes (tick and describe)

Personal factors
- ☐ Lack of knowledge/training
- ☐ Lack of skill/inexperience
- ☐ Lack of concentration
- ☐ Stress
- ☐ Misconduct
- ☐ Language difficulties
- ☐ Inadequate capability
- ☐ Improper motivation

Q1, WHO IS THE MINE VENTILATION ENGINEER???

Job factors
- ☑ Inadequate leadership/ supervision
- ☑ Inadequate engineering
- ☐ Inadequate purchasing
- ☑ Inadequate maintenance
- ☑ Inadequate tools, equipment, materials
- ☑ Inadequate work standards
- ☐ Abuse
- ☑ Wear and tear
- ☑ Inadequate procedure
- ☑ Safety rules not enforced
- ☐ Insufficient staff numbers
- ☑ Sub standard/no training
- ☑ Substandard work practice

What was the ROOT CAUSE of this event? VERY INADEQUATE VENTILATION, POOR STOPPINGS. POOR VENTILATION MANAGEMENT. VENTILATION LEAKAGE HIGH PERCENTAGE

SECTION 5: Remedial Actions Recommended, Including Any Injury Prevention & Training if Required

Follow up of Event: What investigation/action has or will be taken to prevent a recurrence

	By Whom	By When	Date Completed
VENTILATION ENGINEER REQUIRED			
CONSTRUCT PERMERNT STOPPING ETC TO CONTROL VENTALATION			
Thanks			

REQUIRE IMMIDIATE FEED BACK WITHIN 4 DAYS - OR I WILL WRITE A FORMAL LETTER TO THE MINES INSPECTOR

New Hazard Identified – has this been added into the Hazard Register? No ☐

New Controls implemented – Have these been recorded in the Hazard Register? Yes ☐ No ☐

Figure 8.11: Extract from Dene Murphy's 24 June 2010 Incident/Accident Form

99. In the absence of a ventilation engineer, Mr White said he adopted the role of 'de facto ventilation engineer', adding he had 'no choice' because nobody else was available.[142] The ventilation management plan allocated more than 90 duties to the mine manager and ventilation engineer, and Mr White could not have fulfilled those while working as general manager.

100. Hydro-mining consultant Masaoki Nishioka said that when he arrived at Pike in July 2010 he found that 'nobody' was really taking care of ventilation at the mine.[143]

101. After Mr van Rooyen raised the lack of a ventilation officer with Mr White, it was agreed that Dean Jamieson, an underviewer, would be an appropriate person to train as a ventilation officer.[144] However, Mr Jamieson's training was delayed because of the resignation of another underviewer,[145] and he had not started formal training before November 2010.

Ventilation control devices

102. In any mine ventilation circuit it is essential that fresh air is delivered to the correct locations and in the right quantities, and that contaminated air is kept isolated from intake air and from any potential sources of ignition.[146] For that reason, ventilation control devices, including stoppings, overcasts, regulators and other devices, are used to ensure ventilation air continues on the correct path.

103. A stopping is a solid barrier that prevents air travelling through a roadway. A permanent stopping may be constructed from masonry, concrete blocks, fireproofed timber blocks or steel.[147] As a short-term measure, stoppings may be constructed from timber and brattice (a fire-resistant, anti-static cloth). The photograph below shows a low-pressure stopping constructed from timber and brattice.

Figure 8.12: Board and brattice stopping[148]

104. Stoppings must be constructed to a suitable standard to avoid leakage, which can compromise the performance of the ventilation system. Stoppings should also be built to withstand the pressures that may follow a roof fall or windblast within the mine.[149]

Construction standards

105. In Queensland and New South Wales the law requires stoppings to be 'rated', that is, built to withstand identified pressures. This followed a recommendation of the Moura No. 2 inquiry dealing with the design and installation requirements for seals. A seal is used to isolate a worked-out area of a mine from the rest of the mine infrastructure. It may consist of two or more stoppings, 5–10m apart, with the space between occupied by sand, stone dust or other non-flammable material.[150] The Moura No. 2 inquiry recommended that the chief inspector of coal mines should determine and enforce minimum requirements for the design and installation of seals.[151]

106. That recommendation is reflected in the current Queensland coal mining safety and health regulation, which requires the ventilation officer to ensure ventilation control devices are installed in compliance with specified ratings. For example, a stopping installed as part of the main ventilation system must be capable of withstanding an overpressure of 35kPa.[152]

107. Neither New Zealand law, nor the industry guidelines produced by MinEx, provide for stoppings to be built to any rated standard. The guidelines suggest temporary ventilation stoppings can be as many as four cross-cuts or 250m backbye of development headings.[153] Mr Reece told the commission this was 'significantly less of a standard' than Queensland regulators would accept.[154]

The ventilation control devices at Pike River

108. In 2006 the Minarco ventilation report noted there were no specific construction requirements in New Zealand for ventilation structures, except that they be constructed from non-flammable material. The ventilation devices nominated for Pike River included roadway stoppings of a 'nominal 14kPa rating'.[155] The suggested 14kPa rating was only 40% of the equivalent standard in Queensland and New South Wales of 35kPa. The 2006 report did not offer any justification for the proposed lower standard at Pike River. Ultimately, Pike did not implement even the lower standard.

109. Appendix 5 of the Pike ventilation management plan set out a procedure for the construction of ventilation structures.[156] The ventilation engineer was to advise the undermanager on standards for ventilation stopping construction, and stoppings were to be built to standards set out in the 'Pike River Mine Manager's Ventilation Rules'. Whereas Minarco's ventilation report in 2006 had contemplated stoppings with a nominal rating of 14kPa, the ventilation management plan left the issue of standards for ventilation control devices to the 'Pike Mine Manager's Ventilation Rules'. No such documentation was created.

110. When Mr Stewart carried out a statutory compliance audit in early 2010 he referred to stoppings being 'badly constructed and leaking hugely', contaminated air recirculating back into the … working place and overcasts with 'significant leakage'.[157] Improvements were made as a result of the audit, including the rebuilding of some stoppings. One report noted that an underviewer had been asked to develop designs for all the stopping types to form part of a construction template for Pike River. Mr Stewart also spoke to mechanical engineer Matthew Coll about stopping standards and gave him a copy of design and procedures for stopping construction for training purposes.[158]

111. When he left Pike in April 2010 Mr Stewart was not satisfied with the stoppings. Some had been improved, and he had done 'very basic things', for example, pushing stoppings to see whether they rocked.[159]

112. Responsibility for advising on standards for the construction of stoppings and other ventilation control devices rested with the ventilation engineer. When he arrived at Pike Mr White recognised that there were no permanent ventilation control structures, and he began organising a standard for building temporary stoppings and 'set about starting to talk to contractors in Australia with respect to the supply of equipment for building permanent stoppings'. Mr White added that it was 'difficult to nominate positions for permanent stoppings' because the mine plan changed so frequently.[160]

113. In May 2010 Pike issued a standard operating procedure document entitled 'Underground Standards', which set out the standard for both temporary and permanent stoppings.[161] The basic construction method was the same for both, namely board and brattice construction, as depicted in the diagram below and in Figure 8.12.

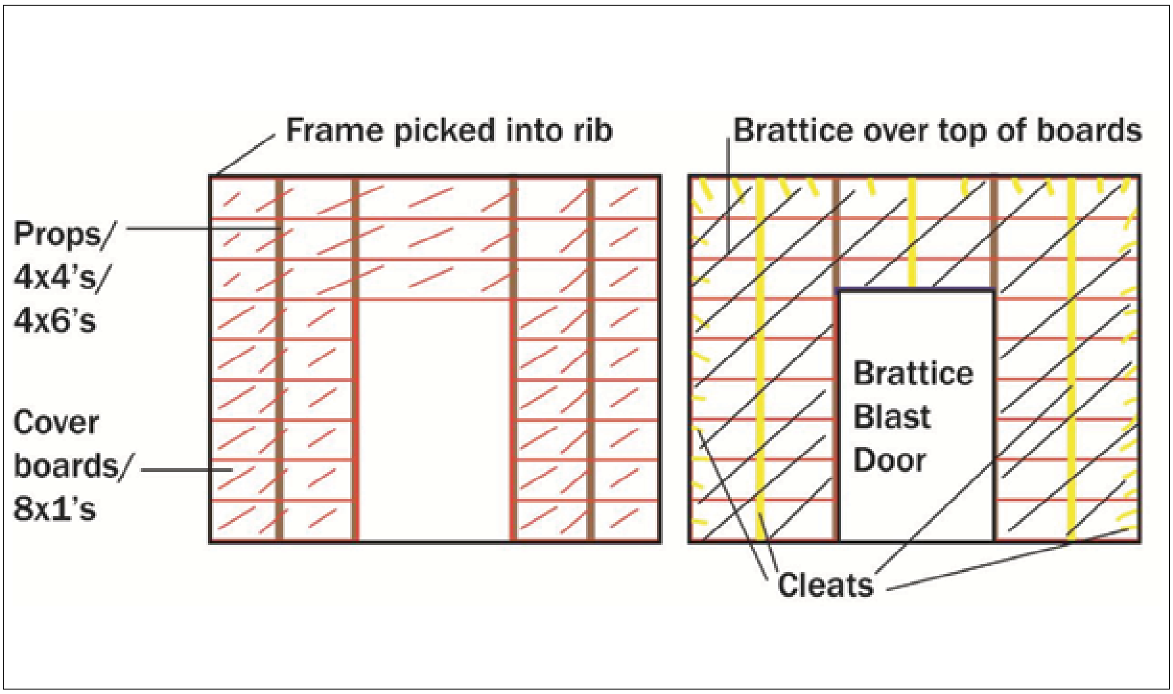


Figure 8.13: Board and brattice construction method[162]

114. The construction method was essentially to use standard timber covered by brattice. The main difference with permanent stoppings was that these were covered in mesh and sprayed with shotcrete (this is concrete or mortar

projected through a hose at high velocity). The underground standards document made no reference to pressure ratings.

115. Despite the underground standards document, problems with stoppings continued. On 20 September 2010 Mr Nishioka noted repeated problems with methane levels in the hydro panel. The hydro operation was stopped, and on investigation it was discovered that the ventilation stopping in the hydro panel was leaking air so badly that recirculation of air was allowing methane to accumulate in the explosive range.[163] The board and brattice system used to construct the stopping was not robust enough to prevent leakage, and this was the type of issue that would have been raised with the ventilation officer if there had been one at Pike.[164]

Roof fall on 30 October 2010

116. On 30 October 2010 there was a large roof fall in the goaf in the hydro panel. The roof fall generated a pressure wave that knocked over the stopping at cross-cut one in the hydro panel, marked in the diagram below.

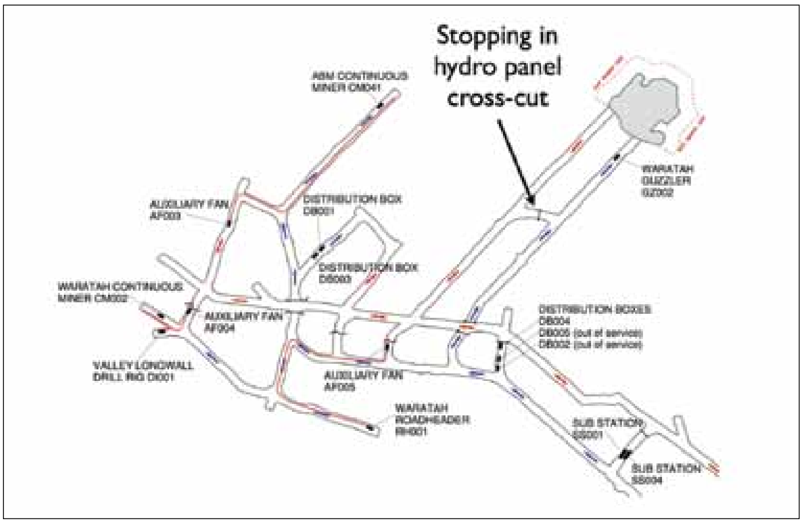


Figure 8.14: Stopping in hydro panel cross-cut[165]

117. The incident occurred around 4:00am on 30 October 2010. Steve Wylie was the deputy on duty. Just before the roof fall the crew had been cutting to the left of a stump of coal in the goaf. Slabs of coal had been falling from the side of the stump, most likely as a result of downward pressure from the roof of the goaf. Mr Wylie heard the roof collapse and saw that it had fallen in, covering the front of the monitor.[166]

118. He did not recall a significant windblast down the intake road, but the debris from the roof had blocked off the heading to the goaf and cut off ventilation. When he checked the stopping at cross-cut one he saw it had completely fallen over towards the intake roadway.[167] This indicated that a windblast had travelled down the return roadway and knocked the stopping over.[168] A gas reading showed greater than 5% methane in the return roadway at the intersection with cross-cut one.[169] Because his gas detector was not capable of reading greater than 5%, Mr Wylie could not tell the actual methane concentration, but there was clearly an explosive quantity of methane in the return.

119. Mr Wylie completed an incident report.[170] He attached a hand-drawn diagram showing the effects of the roof fall, including the blocked heading at the entry to the goaf and the damaged stopping in cross-cut one, with the words 'stopping blown over'.

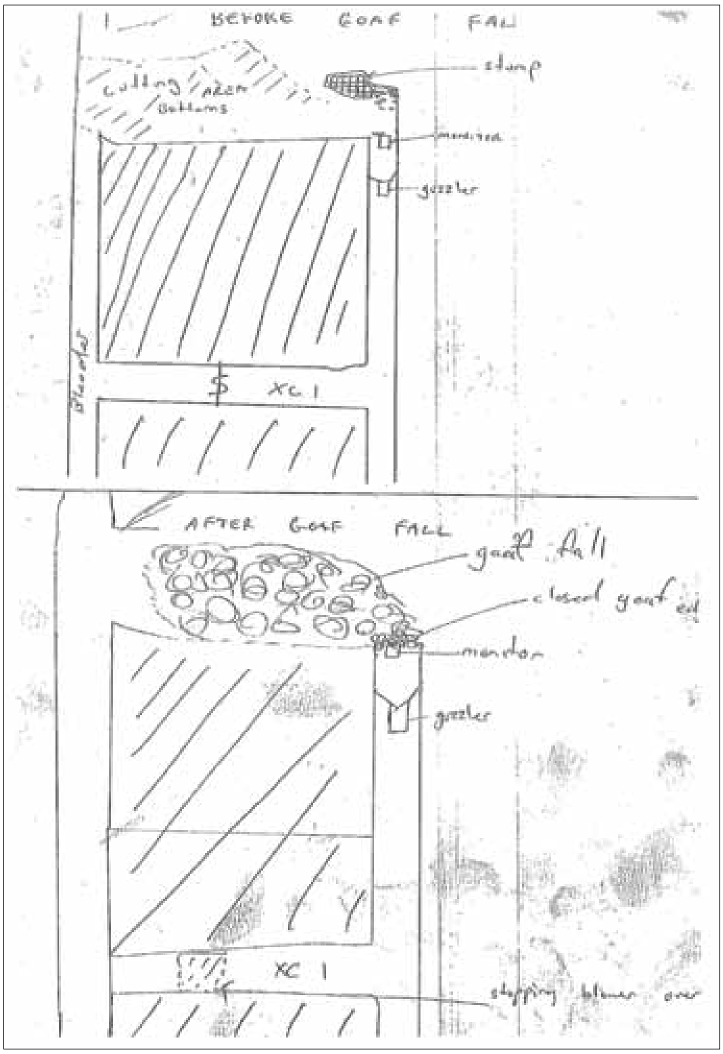


Figure 8.15: Effects of roof fall on 30 October 2010[171]

120. Mr Ellis signed off the incident form as 'closed' on 19 November 2010. The form stated the chance of this type of event happening again was 'occasional', and there had been 'extensive investigation and recovery'.[172] The commission has not been able to locate any evidence of that investigation. Mr Ellis said he would have expected the investigation to have been carried out by Mr Wylie or George Mason, but neither can recall it.[173] In a supplementary statement to the commission, Mr Ellis said he searched the company's electronic and hard copy records but had not been able to locate any material relating to the investigation. He said he would not have signed off the incident as closed without reading a report.[174] There is no evidence of such a report, other than a short, five-sentence note prepared shortly after the event.[175]

121. This incident provided a warning of a major hazard. It demonstrated the vulnerability of the mine's stoppings, as well as the potential for a roof fall in the hydro goaf to damage the ventilation system and lead to an explosive accumulation of methane.

122. Three aspects of the mine's response are significant. First, the incident was primarily categorised as property damage rather than as a safety issue. The original incident form noted that the incident had damaged a stab jack on the hydro monitor. The discussion at the weekly operations meeting focused on the cost of repair to the hydro monitor and the loss of production.[176] There is no indication that the broader significance of the event was discussed. When Mr Ellis signed off the incident on 19 November 2010 he did not answer the question whether any new hazard had been identified or new controls implemented, and he ticked the 'no' box in response to the question about a possible systematic failure.

123. Second, the incident highlighted the vulnerability at the mine caused by Pike's lack of a full-time ventilation engineer. The complete failure of a ventilation control device was a significant issue. Mr Rowland said he 'would expect the total failure of a ventilation appliance in a panel face area to be widely communicated to all persons on the site'.[177] Mr Reece agreed that, for a prudent mine operator, the roof fall would have signalled the urgent need to assess the integrity of all stoppings.[178] This task would have been the responsibility of the ventilation engineer, had there been one.

124. Third, the incident was not formally reported to DOL, despite the fact there was an uncontrolled accumulation of more than 5% methane. DOL inspector Kevin Poynter visited Pike three days after the roof fall, on 2 November 2010. Mr Ellis stated he discussed the roof fall with Mr Poynter, although he could not recall the specifics of the conversation.[179] Despite the seriousness of the incident, there was no formal notification and no investigation by the regulator.

The standard of ventilation control devices at Pike River in November 2010

125. The DOL investigation team carried out a detailed analysis of the ventilation control devices at Pike River, and concluded their quality was 'extremely variable'.[180] The stoppings near the main ventilation fan were made of steel and concrete, and rated to 35kPa. A number of stoppings were constructed using 'pogo sticks', expandable poles with an internal spring often used to hold up cables within the mine. Mr Reece described pogo sticks as 'very temporary arrangements',[181] not intended for any type of permanent construction. The mine was attempting to achieve a number of permanent stoppings in the months leading up to November 2010, although these would not necessarily be rated.[182] The stoppings in November 2010 would not have complied with Queensland standards.[183]

126. The DOL investigation stressed the significance of the stopping at cross-cut 3, marked with an arrow below.

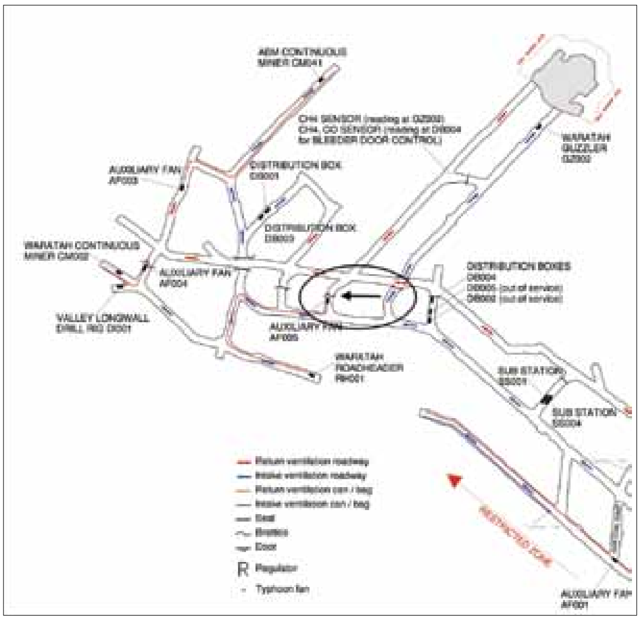


Figure 8.16: Hydro panel and cross-cut 3[184]

127. That stopping was directly in line with the return from the hydro-monitor panel. Any significant roof fall in the hydro goaf would create an overpressure down the return, and the stopping would need to withstand that pressure.

128. Despite that risk, the stoppings at cross-cuts 3 and 4 remained in a temporary state on 19 November 2010. The collapse of the stopping at cross-cut 1 in the hydro panel on 30 October 2010 had served as a warning of this vulnerability, but Mr White said it was 'not likely' any consideration was given to the matter, even following the 30 October incident.[185]

129. Mr van Rooyen agreed with the criticism of the stopping at cross-cut 3, and said it 'should have been made permanent preferably before or certainly early on in the excavation of the hydro panel'.[186] He agreed that the

increasing size of the goaf created a greater risk of a roof fall, resulting in damage to the temporary stopping in cross-cut 3, which could allow the short circuiting of air away from the inbye faces, and might also allow methane to enter the intake roadway.[187]

130. Mr White said the intention was to make that stopping permanent after a panel move, which took place from Friday 12 November to Monday 15 November 2010, but this was not done.[188]

131. There were three main problems with the ventilation control devices at Pike River in November 2010. First, there were too many temporary stoppings in light of the mining activity taking place. Second, with a few exceptions, the permanent stoppings that did exist were not rated to any particular standard. Third, there was insufficient oversight of the construction and maintenance of stoppings. The variable quality of stoppings at Pike River compromised the effectiveness of the ventilation system, and increased the risk of a catastrophic event. Rated stoppings may have assisted in an emergency, especially if combined with a functional surface fan, because they may have helped to re-establish a ventilation circuit to remove hazardous gases from the mine.

Sufficiency of ventilation at Pike River

132. Evidence before the commission indicated that Pike River had a 'serious lack of ventilation quantity for the number of faces being worked'.[189] At best the system was stretched to capacity, with no room for error.[190]

133. Mr Ridl, by then the engineering manager, said the ventilation was 'pretty shit' before the main underground fan began operating in October 2010.[191] Then 'there was a significant increase in ventilation and people were a lot happier'.[192] However, Mr Rowland advised the mine in early November 2010 it needed more ventilation capacity 'relatively urgently' because the total amount of air available (120m^3/s) was sufficient to run only four auxiliary fans on full speed while allowing standard margins for safety.[193] As at November 2010, the mine was running four auxiliary fans, with a fifth out of service. Mr Rowland's intention was to emphasise the importance of increasing the quantity of air available as soon as practicable and not 'resting on the apparent laurels of the new circuit capacity' provided by the underground fan.[194]

134. The DOL investigation included detailed ventilation modelling of the mine based on the available data. That modelling indicated there was less than 25m^3/s available for each place requiring ventilation, not allowing for leakage. That information, together with reports from mine officials, showed the ventilation system was struggling to cope with the gas quantity and the extent of mining operations.[195] DOL concluded that Pike had a ventilation shortfall, and should have been working one fewer place in the mine.[196] Pike considered the work was being managed within the limits of the ventilation system. As noted in paragraphs 139–144 methane problems persisted.

135. Ventilation inbye of the monitor panel was particularly fragile and struggling to cope with the extent of mining operations and gas load in the mine.[197] Those areas had a small amount of pressure (14Pa) and quantity (49m^3/s) available to ventilate the three working places and two standing places inbye of panel 1. That area is shaded yellow in the following diagram.

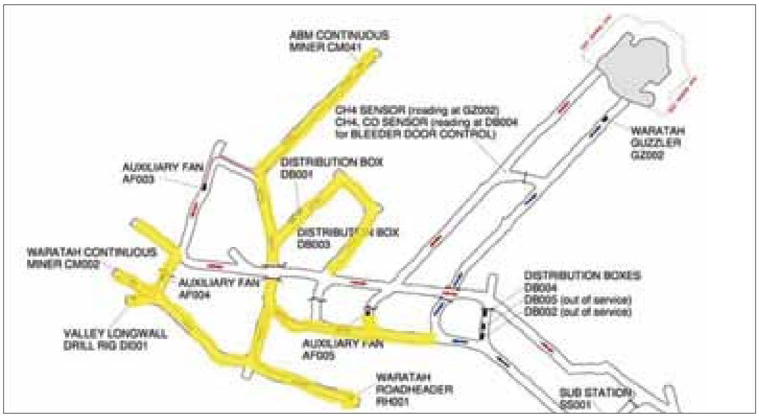


Figure 8.17: Ventilation inbye of the monitor panel[198]

136. DOL concluded that, given the gas make in the mine and the number of faces being worked, it should have been apparent that the ventilation system was stretched to its limit. Pike's approach allowed no factor of safety to deal with predictable hazards.[199]

137. Mr Reece also noted other deficiencies with the ventilation system, for example, the placement of an auxiliary fan (AF003) immediately next to a stopping,[200] which meant the fan did not have the necessary 30% of fresh air passing over it to ensure it did not overheat. The fan can be seen towards the left-hand side of the following diagram.

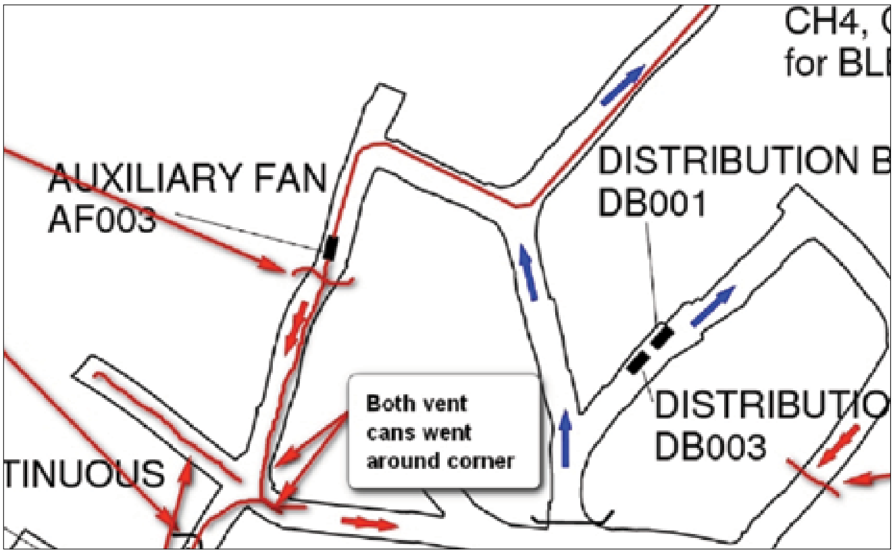
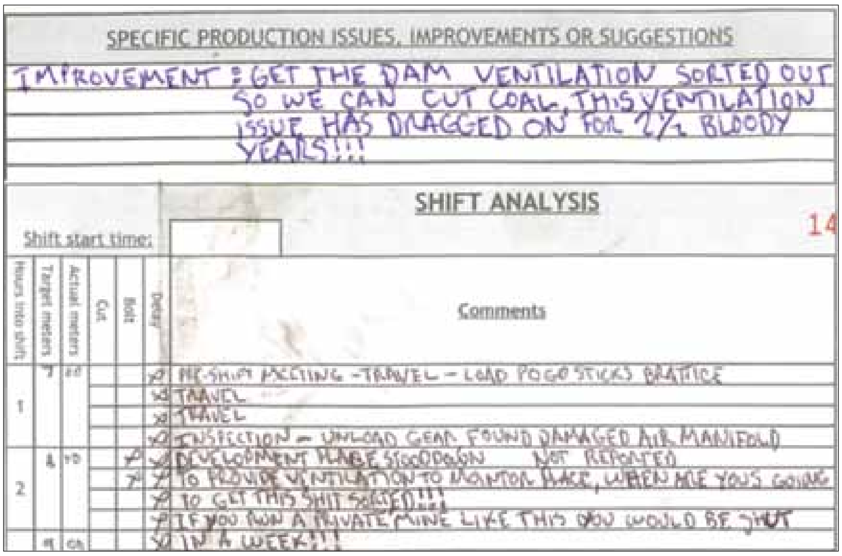


Figure 8.18: Location of the auxiliary fan[201]

138. Mr White accepted that the evidence used by DOL in its modelling was correct, but considered that there was sufficient air to run the number of faces being mined.[202] He said Pike managed the amount of work done within the ventilation available and did not work all faces at the same time.[203] However, Pike's own records, including incident reports and deputies statutory and production reports, show there were serious ventilation problems.



SPECIFIC PRODUCTION ISSUES, IMPROVEMENTS OR SUGGESTIONS

IMPROVEMENT : GET THE DAM VENTILATION SORTED OUT SO WE CAN CUT COAL, THIS VENTILATION ISSUE HAS DRAGGED ON FOR 2½ BLOODY YEARS!!!

SHIFT ANALYSIS

Shift start time:

Hours into shift	Target meters	Actual meters	Cut	Bolt	Delay	Comments
1						PRE-SHIFT MEETING – TRAVEL – LOAD POGO STICKS BRATTICE
						TRAVEL
						TRAVEL
						INSPECTION – UNLOAD GEAR FOUND DAMAGED AIR MANIFOLD
2						DEVELOPMENT PLACE STOOD DOWN NOT REPORTED
						TO PROVIDE VENTILATION TO MONITOR PLACE, WHEN ARE YOUS GOING
						TO GET THIS SHIT SORTED!!!
						IF YOU RUN A PRIVATE MINE LIKE THIS YOU WOULD BE SHUT
						IN A WEEK!!!

Figure 8.19: Extracts from Dene Murphy's 21 October 2010 Deputies Production Report[204]

Recorded methane spikes

139. Evidence before the commission indicated a large number of methane spikes in the weeks and months before the explosion, many in the explosive range of greater than 5% methane. Mr White agreed that any instance of 5%

methane or more within a mine, even in the return, would be classified as a high-potential incident.[205] The evidence indicates that methane greater than 2% were almost a daily event, both before and after the commissioning of the main underground fan.

Deputy statutory reports

140. Deputies' shift reports noted if they found greater than 1.25% methane in the general body of air. The reports between 3 October 2010 and 19 November 2010 contained recorded gas levels of 2% or higher on 48 occasions over 48 days. Concentrations of 5% were recorded within the mine 21 times during that period.[206] The gas detectors used by Pike were not capable of reading higher than 5%, so it is not possible to know the actual level of gas on these occasions. Pike should have notified DOL of these events, but did not. This was supported by accident/incident reports.

Masaoki Nishioka's work record

141. Hydro consultant Masaoki Nishioka kept a daily work record. He noted methane levels on 14 days between 20 September and 15 October 2010, and on nine occasions methane levels exceeded 5% in the return airway.[207] It was a safety hazard to continue monitor extraction with gas concentrations at that level.[208] On 1 October Pike agreed to stop the hydro-monitor operation until the main fan became operational.[209] During commissioning of the main fan, gas spikes in the hydro-monitor panel continued and Mr Nishioka's work record contained numerous references to methane levels above 5% and the 'poisoning' of the methane detectors.

142. When asked about these instances, Mr White said he believed the plugs of methane from the monitor panel would have been diluted below the explosive range in the main return.[210] Similarly, Mr Ridl's understanding was that the spikes of greater than 5% were present only in the hydro panel.[211] However, the sensor at the top of the ventilation shaft was not capable of generating a reading higher than 2.96% methane, and it is not possible to be sure about levels in the main return. For that reason Mr White accepted that levels of methane may have remained in an explosive state all the way to the top of the ventilation shaft. [212]

The gas monitoring system

143. DOL examined the records from the gas monitoring system for the period 25 October to 19 November 2010. Spikes over 1.25% were recorded 12 times. One of those spikes could be attributed to the calibration of the ventilation shaft gas detector, and a second to the restart of the main fan on 27 October 2010. Of the remaining 10, four events were of methane over 2.5% and a further two events were of methane over 1.8%. These were significant plugs of methane, and each one may have represented an explosive mixture if exposed to a source of ignition before dilution in the main return.[213] When asked about those conclusions Mr White said that number of spikes was a concern and, in hindsight, each should have been formally investigated. [214]

144. In a report written shortly after the explosion, Gregory Borichevsky noted that potentially explosive levels of methane would have been present in the mine workings on a number of occasions, because methane levels in the ventilation shaft routinely exceeded 1%, regularly exceeded 1.5%, occasionally exceeded 2% and had exceeded 3% more than once in the weeks before the disaster.[215] Mr White was asked whether, in light of the number of methane spikes coming through the ventilation shaft, there was a risk that this situation had become normalised. He said he would hesitate to say 'normalised', but it was 'certainly something that was happening frequently, more frequently than would be desired'. [216]

Accident/incident reports

145. Pike's accident and incident reports show other ventilation issues were reported often by workers. For example in October 2010 a typhoon fan ventilating a drill stub was not operating – the air hose had been disconnected and connected to other machinery. In June 2010 there was a higher pressure on the return side of a stopping near an electrical sub-station, leading to recirculation when the stopping door was open and the possibility of potentially flammable air in the presence of the substation. In January 2010 a blower fan was found on the floor 40 metres

from its original location, with the air hose disconnected. It was thought to have been hit by a passing vehicle. In April 2009 ventilation ducting was found damaged, resulting in an accumulation of flammable gas.

146. The reasons given for such incidents included lack of knowledge and training; lack of skill and experience; being unaware of hazards; inadequate work standards; safety rules not enforced; inadequate leadership/supervision, poor housekeeping and poor ventilation management.[217]

Ventilation monitoring

147. The effectiveness of a mine's ventilation system should be measured in a number of ways, including manual pressure and quantity surveys. Pike used hand-held anemometers (Kestrels) to measure ventilation quantity. These instruments are necessary to verify ventilation speeds underground, and essential in the degassing process.[218]

148. On at least 10 occasions during October 2010, deputies noted a lack of Kestrels underground. For example, on 20 October 2010 one deputy wrote: 'no Kestrel available for vent readings (5 wks now Hurry up and get em). Can't do job without the tools Bro.'[219]

149. When asked about this, Mr White said that 'as far as I was aware we had an adequate supply of Kestrels',[220] and that he would certainly have liked to have known this was an issue. He said it is not possible to start an auxiliary fan underground without measuring the air with a Kestrel, and he was disappointed to learn that someone had to wait five weeks to be given one.[221]

150. The commission received further evidence that Pike lacked appropriate equipment for ventilation measurements. On 12 October 2010 the Pike project manager Mr Moynihan emailed the Spring Creek mine's ventilation officer Robin Hughes and invited him to come to Pike. Mr Moynihan wanted someone to check air flow and pressure measurements for the underground fan. He said, 'Pike still does not have a [hand-held] electronic manometer and a good quality anemometer.'[222] A manometer is a pressure measuring instrument that should be available at an underground coal mine.[223]

Three key decisions

151. The initial plan for the development of the Pike River mine envisaged a two-intake/single return ventilation system powered by two main forcing fans located on the surface. Three separate decisions put paid to this plan:

- In late 2006 a proposal was made to locate the main fans underground, but in stone measures to the east of the Hawera Fault, and this was decided on after a risk assessment in February 2007.
- In late 2007, however, the location of the main ventilation shaft was moved from east of the Hawera Fault to its eventual position in pit bottom in coal. This meant also changing the location of the main fans so they would be adjacent to the shaft.
- In early 2010 Pike obtained approval to locate a bridging panel near pit bottom, which meant that hydro mining began before the development of a second intake.

Hence, as at 19 November 2010, Pike had a single intake/single return ventilation system, powered by an underground main fan at a time when hydro coal extraction had begun.

Conclusions

152. The ventilation system at Pike River was inadequate:

- The ventilation management plan was incomplete, largely ignored in practice and required the appointment of a ventilation engineer to be responsible for the ventilation system. No one was appointed to the role and the mine manager became the de facto ventilation engineer, without the time or resources to carry out the role adequately.

- The opportunity to improve ventilation capacity was lost when development of a second intake was deferred to accommodate the commencement of hydro mining in the bridging panel.
- The placement of the main fan underground was a major error, aggravated by the failure to adequately protect the fan motor against methane ingress.
- Aside from permanent stoppings erected at the location of the main fan, the mine stoppings were of variable quality and were not built to any rated standard. They compromised the effectiveness of the ventilation system, and created a safety hazard.
- The mine had a ventilation shortfall, with no factor of safety to meet foreseeable hazards, and one less mining or development area in the mine should have been worked.
- On 19 November 2010 the main and back-up fans were both damaged during the explosion, and the ventilation system failed. The mine was unventilated.

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[198] Plan highlighted by David Reece, MBIE3000010014/1.
[199] Department of Labour, Investigation Report, DOL3000130010/111, para. 3.11.12.
[200] The stopping is not shown in Figure 8.17 because it was not included in pre-explosion mine plans at Pike.
[201] Department of Labour, Plant Location and Ventilation Fan: Rescue 101119_181 (DOL Investigation Report, Appendix 8), 22 March 2011, DOL3000130008/1. (Extract of plan)
[202] Douglas White, transcript, p. 5144.

[203] Ibid., p. 4861.
[204] Pike River Coal Ltd, Pike River Coal Mine: Deputies Production Report, 21 October 2010, DAO.001.02459/1.
[205] Douglas White, transcript, p. 4930.
[206] Royal Commission on the Pike River Coal Mine Tragedy (Katherine Ivory), Summary of Pike River Coal Mine Deputies Production Reports for March and October 2010, November 2011, CAC0115/13–22; Royal Commission on the Pike River Coal Mine Tragedy (Katherine Ivory), Summary of Pike River Coal Mine Production Reports for November 2010, January 2012, CAC0115A/6–12.
[207] Masaoki Nishioka, work record, NISH0002/21–32.
[208] Ibid., NISH0002/22.
[209] Ibid., NISH0002/27.
[210] Douglas White, transcript, p. 4937.
[211] Robb Ridl, witness statement, 14 March 2012, DAO.041.00009/21, para. 84.
[212] Ibid., DAO.041.00009/21, para. 85.
[213] Department of Labour, Investigation Report, DOL3000130010/124, para. 3.16.4.
[214] Douglas White, transcript, p. 4937.
[215] Gregory Borichevsky, Pike River Coal Mine Disaster 19 November 2010, 2 December 2010, INV.04.00001/7.
[216] Douglas White, transcript, p. 4945.
[217] Royal Commission on the Pike River Coal Mine Tragedy (Katherine Ivory), Summary of the Reports of Certain Incidents and Accidents at the Pike River Coal Mine, November 2011, CAC0114/10–13.
[218] Douglas White, transcript, p. 5137.
[219] Pike River Coal Ltd, Pike River Coal – Deputy Statutory Report, 20 October 2010, DAO.001.02793/1.
[220] Douglas White, transcript, p. 4998.
[221] Ibid., p. 4999.
[222] Email, Terence Moynihan to Robin Hughes, 12 October 2010, EXH0036/1.
[223] Craig Smith, transcript, p. 3474.