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AN ANALYSIS OF CURRENT AUSTRALIAN LONGWALL VENTILATION METHODS

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ABSTRACT

A study has been undertaken into the mine ventilation systems currently in use within modern Australian longwall extraction mines. The paper reviews current systems and discusses evolving changes being adopted to address the more complex problems.

The analysis of current Australian longwall ventilation methods is based on a review of current practice. An analysis of the ventilation techniques used to manage the critical ventilation issues experienced provides an understanding of the engineering solutions currently utilised. With a greater understanding of the dependent nature of these issues and the existing solutions a methodology can be established for the optimisation of longwall ventilation system. These techniques when combined with a working knowledge of existing or anticipated ventilation constraints facilitate ventilation network optimisation and allow for improved management methods through increased understanding.

The review was completed by visiting and surveying 16 large longwall mining operations in Australia. The selection of longwall mines was based on encompassing most pits with pronounced ventilation challenges while focusing on larger operations facing issues related to higher production. Details are given of ventilation techniques used including number of gateroads developed, longwall ventilation patterns, use of monitoring systems, methods for sealing goafs, seal and stopping practices, pressure balancing of goafs and ventilation structures.

KEYWORDS

Ventilation, Mining, Coal, Longwall, Australia, Mine Layout, Homotropal Ventilation, Seals, Stoppings

INTRODUCTION

The purpose of this paper is to establish the state-of-the-art of Australian underground longwall mining ventilation methods. Within Australia the two states where almost all underground coal mining activities take place are Queensland and New South Wales (NSW). The mining history, geology and regulations vary between these two states. This current study demonstrated significant change from a similar review by Schaller and Savidis (1983) almost two decades ago. At that time it could be seen that collieries almost exclusively used an "R" or "Z" ventilation approach similar to European practice whereas this recent study has shown that collieries now almost exclusively use the "U" ventilation approach or a variation of this method to ventilate their longwalls.

The core of this review is based on visiting and surveying 16 large longwall mining operations in Australia. In total there were 34 operating longwalls in Australia in 1999 producing approximately 66.7 Mtpa, 11 of which operated within the Queensland Bowen Basin and the remaining 23 were within the Western, Southern, Hunter and Newcastle regions of the NSW Sydney Basin. All of these collieries operated a single retreat longwall except for one colliery that operated two retreat longwalls with a one week dual operation or overlap to ensure continuity of production.

INDUSTRY SURVEY

Survey Format

The survey was divided into a number of major sections including colliery statistics, physical mine environment, main ventilation environment, development ventilation, longwall ventilation, ventilation network analysis, ventilation monitoring and future considerations. The physical mine environment section dealt with the physical parameters of the mine including seam cross section, roadway dimensions and physical layout of the pit. The main ventilation environment dealt with main fan installations, issues affecting ventilation and related incidents and location of the critical or open split. The development ventilation dealt with ventilation layout in development and most importantly considerations for breaking through in development. The longwall ventilation dealt with extraction method and equipment, ventilation method and sealing practices behind the active longwall face. Ventilation network analysis and monitoring dealt with the level of monitoring of ventilation parameters within the pit and how computerised network analysis was being utilised. Future considerations allowed issues expected to affect future production and ventilation of the pit to be noted.

<u>Summary</u>

Of the 16 mines visited 14 longwalls were ventilated using a variation of the traditional U ventilation approach. The two exceptions were a Z ventilation method and a variation on the Z ventilation method. The typical longwall block dimensions were in the order of 2000m long with 250m face lengths. The face quantities varied from 25m³/s up to approximately 100m³/s with face velocities up to 4m/s. The seam conditions varied greatly with a variation in working section thicknesses from 1.8 to 5.5m within seam thicknesses from 1.8m to 24m. The gas content of these seams varies in content from 0.1m³/t up to 22m³/t in-situ with concentrations of methane and carbon dioxide, the two main seam gases present in Australian seams, each varying from 0 to 100%.

Gas drainage was used in pits with gas contents high enough to cause development and/or longwall ventilation issues. In most cases a method of in-seam horizontal pre-drainage was used ahead of the mining activities to reduce in-situ gas contents. In two mines visited a system of in-seam horizontal and inclined post-drainage was used. This system was designed to capture gas liberated in underlying seams during and after longwall retreat. Two of the mines visited used a method of goaf drainage using vertical wells from the surface placed under suction pressure.

Production from these longwalls varies from about 1Mtpa up to 5.5Mtpa for the newer "thick seam" mines. All collieries had a combination of shaft and/or drift access for personnel, materials and ventilation. The production method on the face was predominantly uni directional cutting due to gas and/or explosive or respirable concentrations of dust.

Currently all Australian longwall collieries have two heading maingate development. Panel headings are designed without a yielding pillar to maintain a boundary between two adjacent goafs. Some collieries are planning to lengthen their longwall blocks and are considering alternative methods for ventilating gateroad development including three heading development in line with North American practice. The development method is predominantly "in place" mining, however "place changing" operations currently operate in a few collieries.

Sealing practice varied between the two states based on new Queensland regulations requiring rated ventilation structures. However, NSW practice was to some degree falling in line with Queensland regulations and evolving practices.

Monitoring of gases within collieries was provided by tube bundle and/or telemetry systems. Typically carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4) and oxygen (O_2) were monitored using these systems. Those collieries with ventilation issues involving gas typically had a gas chromatograph to assist with the analysis of bag samples for other indicator gases. Network analysis was in most cases facilitated through the use of a mine ventilation computer network simulation program. The operation of these computer models was generally supported by consultants that had assisted in the creation of up to date models.

LONGWALL VENTILATION CASE STUDIES

<u>Typical Aspects of Australian Longwall Mining</u>

The typical layout of an Australian longwall mine is shown in Figure 1. In terms of ventilation nomenclature intake roadways are shown as solid, single arrow roadways where as return roadways are shown as dashed, double arrow roadways. In this case a raisebore exists behind the current goaf and is shown as a circle with an intake roadway connecting to the longwall face roadway.

Australian longwalls at present use only two roadway maingate development and have typically between five and seven Mains roadways. In development, A Heading (as shown in Figure 1) is an intake roadway with B Heading the return roadway through which the panel conveyor runs. In the Mains, B, C, and D Headings are typically intake with flanking return roadways, A and E Headings. When all longwalls are being extracted on one side of the Mains only, D and E Headings may be used as return roadways with A, B and C Headings as intake roadways. The conveyor runs in the intake headings typically in C Heading. In Queensland this roadway is segregated from either one or both of the other intake roadways. In NSW segregation is generally not undertaken. The previous goaf's are sealed from both the tailgate of the current longwall and where the previous maingate/tailgate join the Mains. The current goaf is progressively sealed as the longwall retreats.

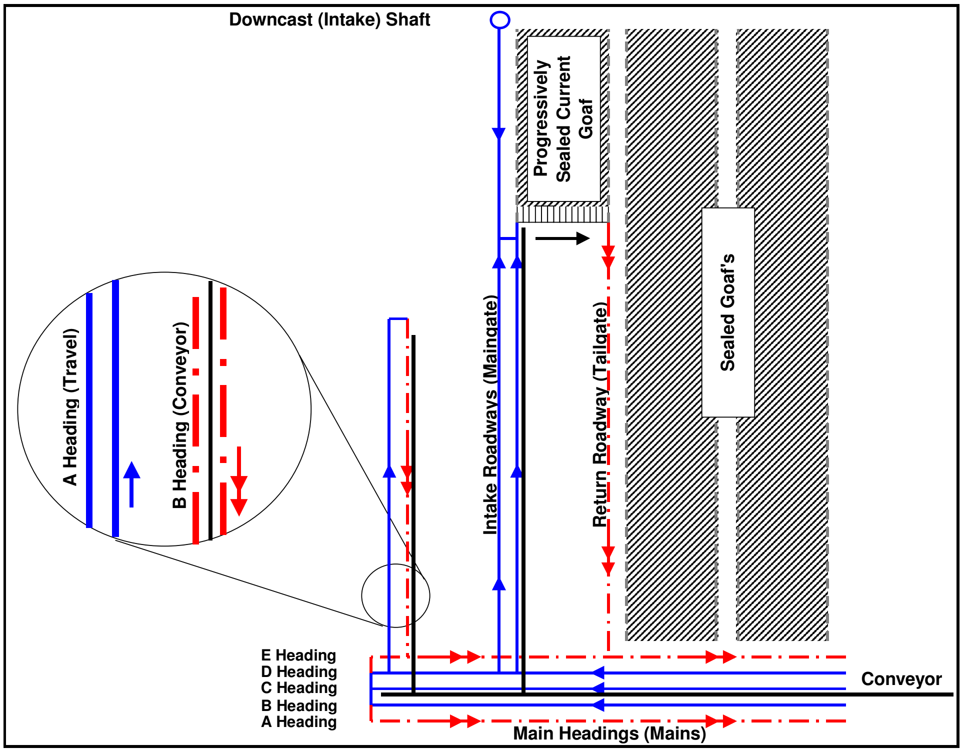

Figure 1. Typical Layout Aspects of Australian Longwall Mining

Case Study A

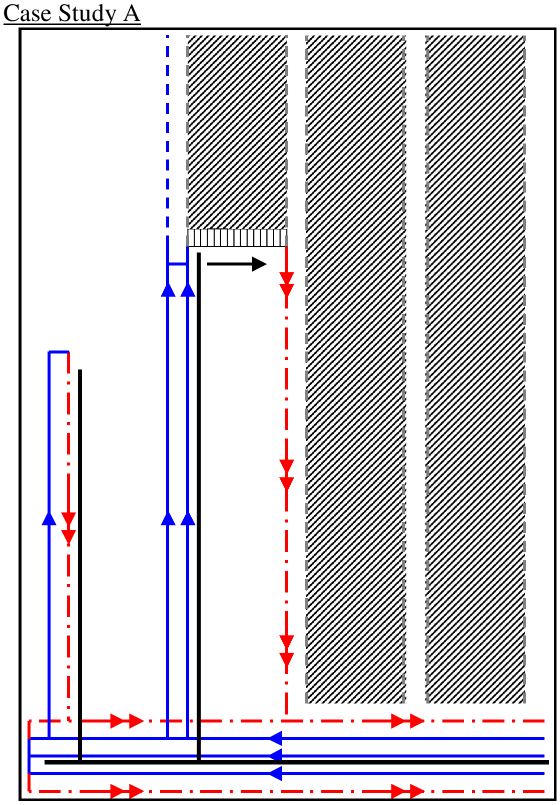

Figure 2. Case Study A

Case Study A, shown in Figure 2, is an example of a traditional U ventilation approach. This is the most commonly used longwall ventilation base model in Australia. This method minimises the induced ventilation pressure difference over both the current goaf and sealed goaf's. This aspect is important when considering ventilation engineering design for operations in coal seam that have been demonstrated to have some propensity for spontaneous combustion. Under U ventilation the need to pressure balance the sealed goaf is minimised because of bordering returns.

Recent practice has been to install a rated seal or some form of ventilation structure as the longwall retreats in the cut throughs behind the longwall. This has replaced a historic practice of segregating the old goaf with less substantial structures including ply wood stoppings. With more substantial structures present seal sites must first be accessible for installation and ongoing access for inspection and maintenance. The installation of these seals is increasingly undertaken by contractors or non-pit labour.

To provide access to the A Heading roadway in the maingate in this ventilation method auxiliary ducting ventilation is utilised. The use of auxiliary ventilation over increasingly longer distances as the longwall retreats is problematic and hence this pure form of U ventilation is not employed without some variation. These variations are discussed in later case studies.

Case Study B

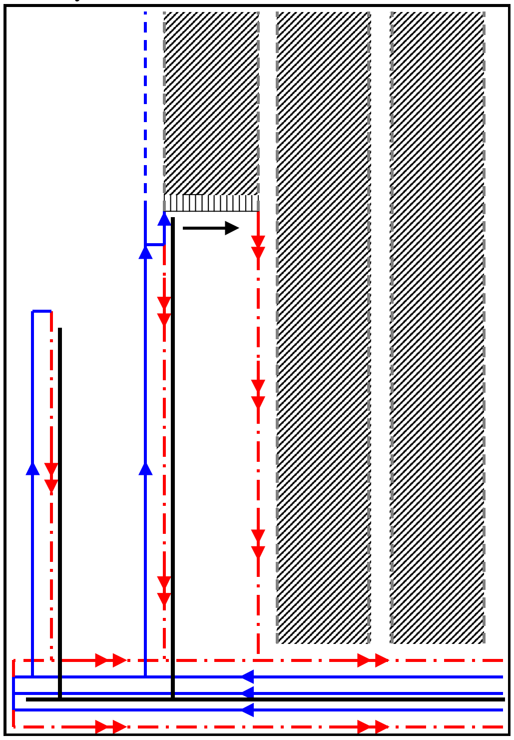

Figure 3. Case Study B

Case Study C

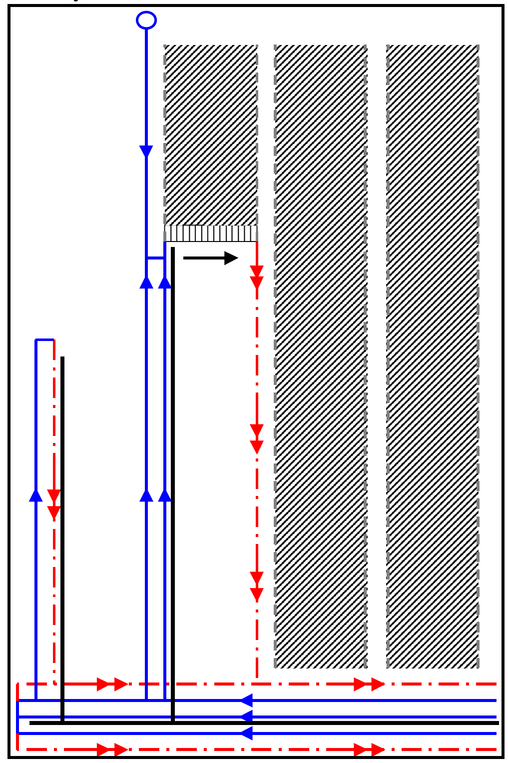

Figure 4. Case Study C

Case Study B, shown in Figure 3, is a variation on the traditional U ventilation approach where the panel belt road (B Heading) is operated in a homotropal mode. This homotropal mode of operation has been used for toxic seam gas management, heat management and for dust management with consideration for the open split location. This method allows for a split of intake air to return via the B Heading beltroad to remove some form of ventilation contaminant away from the longwall face. This is possible as the B Heading belt road usually ventilates the longwall pantec, breaker-stage-loader (or part there of), any tripper drives present and the flow of coal along the conveyor itself. By locating the start of the split inbye of the location of the contaminant source the contaminated air is not directed onto the longwall face.

The management of this homotropal split location can then represent an operational issue as this location is effected by a constantly moving longwall face/support equipment and discrete cut through locations. Typically a longwall face is ventilated with approximately $30m^3/s$ if no overriding contaminant levels are present. The homotropal split is typically ventilated with approximately $10\text{-}15m^3/s$. The split can be seen to significantly reduce the ability to provide the longwall face with all intake air available.

Again in this example auxiliary ducting air allows access to the A Heading roadway in the maingate.

Case Study C, shown in Figure 4, is a variation on the traditional U ventilation approach where a small diameter raise (typically 1.0m diameter) has been bored behind the current longwall. In this case study the raisebore is being operated in a downcasting mode. This free ventilating raisebore is only capable of providing small quantities of intake air in the order of $10m^3/s$.

This raisebore will facilitate a small drop in the overall mine resistance and an increase in airflow on the longwall face. This airflow however may be contaminated by gas as the goaf breathes out diurnally. This contamination may be considerable when installing some of the last panel seals.

Currently the legislation on this issue varies between states with Queensland not permitting intake air past old workings. This is probably more so directed towards bringing intake air past the previously sealed goaf via the existing longwall's tailgate roadway. However there is an applicability to this situation that may prevent the method being used or operated under exemption.

For these reasons this method may be difficult to operate.

This method does allow for access to the next longwall's tailgate roadway which is a requirement for seal installation, inspection and maintenance.

Case Study D

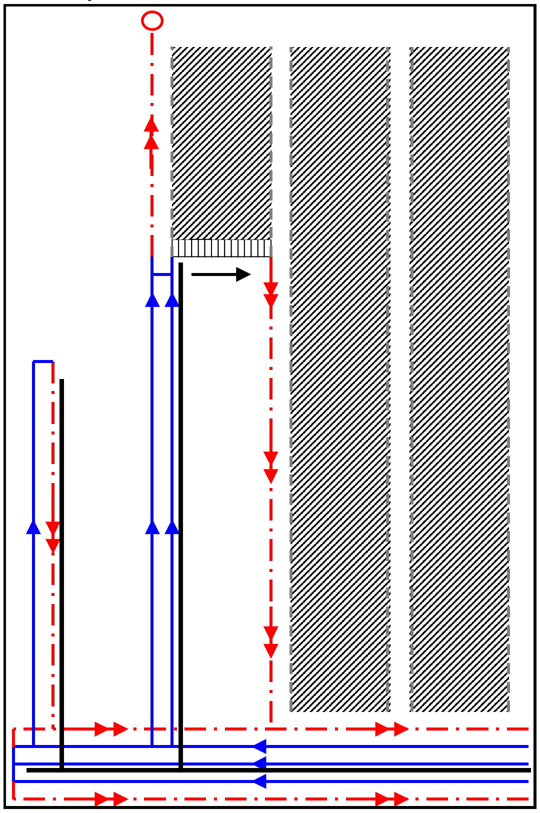

Figure 5. Case Study D

Case Study D, shown in Figure 5, is another variation on the U ventilation approach with a small diameter raisebore (typically 1.0m diameter) behind the current longwall operating in an upcasting mode. This method requires the installation of a fan on the raisebore to provide the necessary pressure drop against the induced main fan ventilating pressures. This additional fan increases the number of operational issues when considering the running of multiple surface fan installations.

The quantity provided by this additional fan is dependant on the sizing of the fan. Typically the quantities involved are approximately 15 m^3/s. The distribution of pressures in the ventilation circuit has to be considered especially if considering exhausting large volumes of air with associated higher pressures for spontaneous combustion reasons. However, most of the pressure loss will be in the raisebore itself and not in the working horizon. This raisebore would be lined as a result to prevent air leaking through cracks in the strata.

This method removes potential contamination from the seal installation site but can reduce the available quantity of air on the longwall face. This method might also serve to offload some of the Mains return requirements.

Case Study E

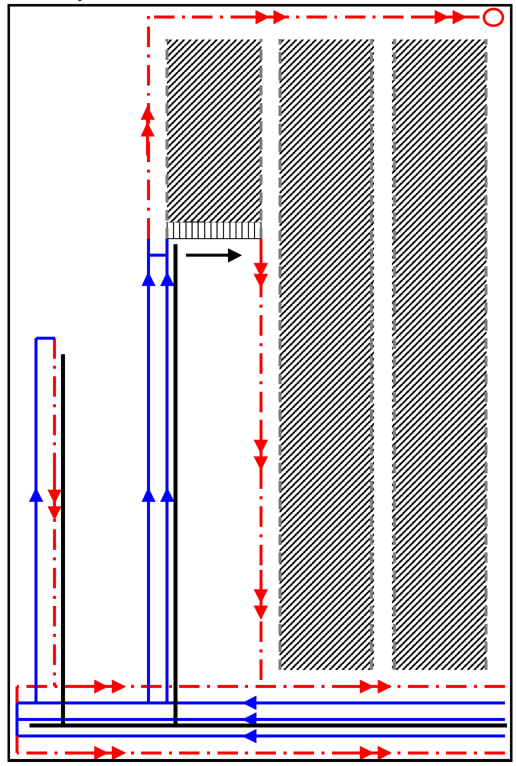

Figure 6. Case Study E

Case Study E, shown in Figure 6, is similar to the previous example where air is returned along the next longwall's tailgate roadway. Air is exhausted via a small diameter shaft (typically minimum of 2.0m diameter) along a back return roadway. This installation allows for a significant increase in the amount of air that can be returned via this back roadway as the shaft diameter increase allows for a significant drop in pressure loss in the shaft. The cost per m^3/s for this installation is significantly less than for the smaller diameter raisebore in the previous case study. Additional costs are acquired through the necessary installation of significant seals behind the longwall goaf's to assist in distributing pressure gradients and for ongoing inspections and maintenance. However the cost of this installation can be amortised over a number of longwall panels as opposed to one panel in the previous case.

The issue of spontaneous combustion has to be considered in terms of the induced ventilation pressures. The distribution of these pressures has to be understood to minimise the risk of creating the correct conditions for spontaneous combustion. The additional perceived risk in this case may arise from induced pressures across previously sealed goafs. This method, with its inherent advantages of contaminant removal has the potential to increase in air quantity in the pit by removing some of the load on Main returns. An another fan installation is required for the additional shaft location.

Case Study F

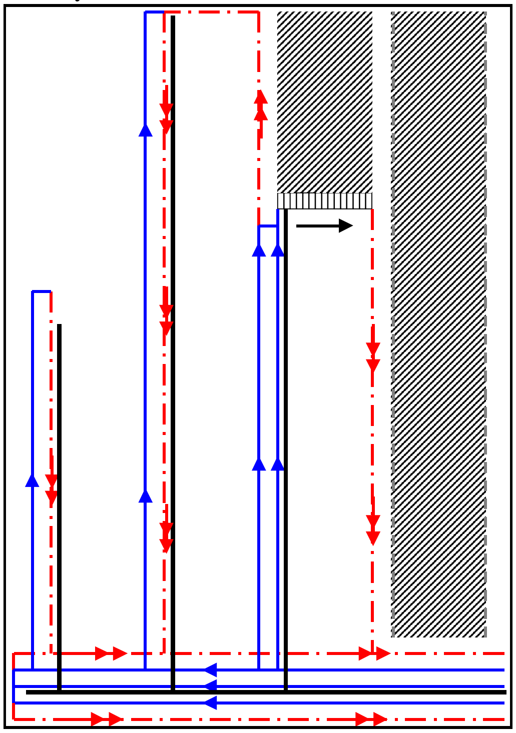

Figure 7. Case Study F

Case Study F, shown in Figure 7, is based on the U longwall ventilation approach. This method brings intake air up the maingate of the current longwall panel and across the longwall face. Air then returns via the tailgate to the Mains return. Air is also returned via the A Heading in the maingate around the next longwall's installation road and returned to the mains return via the B Heading beltroad. This return is also diluted with intake air from the A Heading the next longwall's maingate. The air provided inbye of the longwall face in A Heading would be classed as return to satisfy the legislative requirement in some cases but would only carry contaminant sourced from the current goaf's breathing.

This ventilation method eliminates the need for raisebore/small diameter shafts and associated capital costs behind the longwall panels to provide ventilation to A Heading in the maingate for seal installation, maintenance and inspections. The added cost of this method is the development in advance of the next longwall panel. Again in allowing ventilating of A Heading this approaches requires that seal installation follow closely behind longwall operations. If the last open cut through inbye of the longwall face is not sealed immediately following the longwall retreat intake air may course indirectly behind the longwall face through the goaf to the maingate or tailgate return. The introduction of air into the new goaf may have spontaneous combustion and/or face dust implications.

Case Study G

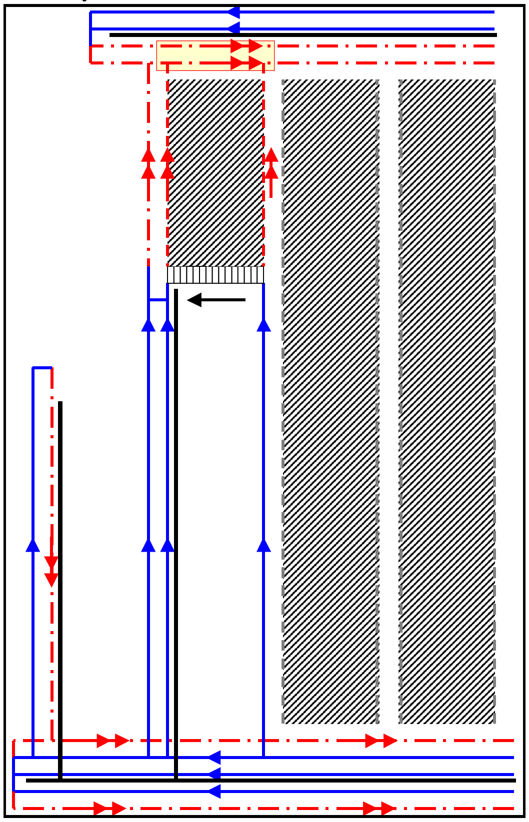

Figure 8. Case Study G

Case Study G, shown in Figure 8, is based on the Z longwall ventilation approach. This method brings intake air up the tailgate (beside old workings) and across the longwall face. Air then exhausts behind the longwall through the goaf. This method allows air to be coursed through the two caved roadways (maingate and tailgate) and through the next longwall's tailgate roadway. All air is exhausted via a set of Submain bleeders behind the longwall panel.

This ventilation method allows for significantly increased airflow in the pit. This air is not necessarily directed onto the longwall face ($30m^3/s$) due to ventilation induced face dust problems with excessive face velocities. The increased air available in the pit is used to dilute excessive quantities of gas present in the working section. Significantly increased ventilation pressures can also be achieved and directed across current workings and an incompletely sealed old group of goaf's. This aids in draining seam gas from the goaf's acting as gas reservoirs. This method would obviously only be used in a seam that had demonstrated no propensity for spontaneous combustion.

A mixing chamber (restricted access/barricaded zone) is utilised to allow high concentration goaf gas to be diluted by uncontaminated air behind the current goaf.

Case Study H

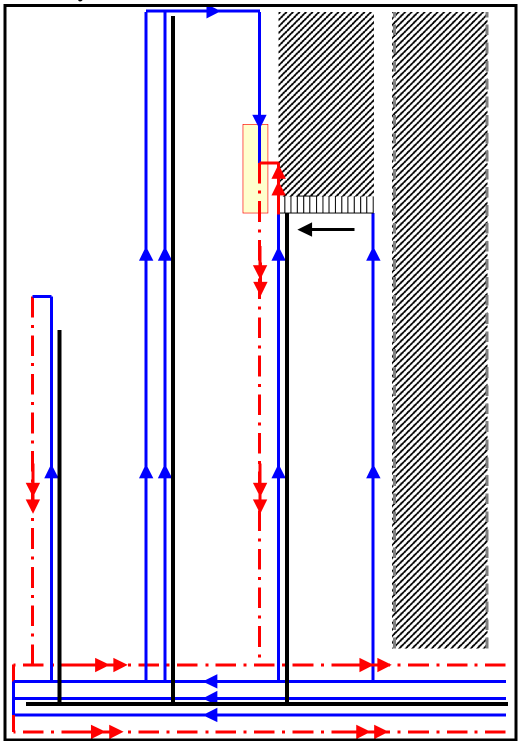

Figure 9. Case Study H

Case Study H, shown in Figure 9, is a hybrid ventilation method utilising aspects of both U and Z ventilation approaches. Intake air is coursed towards the longwall face along the tailgate roadway and panel belt roadway. Intake air is also sourced from the next completely developed longwall panel and brought against the sealed current goaf. Air returns from the longwall face through the goaf to the last open cut through behind the face. At this point return air mixes with intake air from the next panel and is returned through a single roadway to the Mains. This single roadway is barricaded, has restricted access and can be considered a "sewer" roadway. This ventilation method is being used to remove excessive quantities of gas present in the working section with consideration given to a moderately propensive seam to spontaneous combustion.

In this method the mixing chamber concept is utilised in the location where return air from the longwall face is mixed with the intake airflow from the next longwall panel. Due to the reorientation of the sewer roadway, development can be reversed from the traditional to minimise seal preparation and stopping destruction.

Again in this method pressure distributions are very important due to face air intentionally passing through the immediate goaf to A Heading in the maingate. Seal installations have to be undertaken and monitored as soon as practicable coordinated with longwall retreat.

LONGWALL VENTILATION ISSUES

Maingate Development

The development of maingate entries using two headings is the standard method of development within Australian collieries. However, due to concerns over development face gas, dust and heat issues three heading development is being considered as collieries move further underground extracting reserves at greater depth.

Choice of development method is another issue that continues to be addressed from a productivity standpoint. "In place" mining methods are used commonly with a few examples of "place changing" being used. The use of the "place changing" method is based on apparent gains in productivity. Irrespective of whether there is actually an increase in productivity the mining cycle is based on providing enough "places" for mining activities to occur. This results in a greater number of cut throughs. The larger number of cut throughs has two ventilation implications. The first is during the development phase where leakage through stoppings becomes a critical aspect of the development panel ventilation. The second issue appears as the longwall is retreating, seals are erected behind the active face in the open cut throughs to prevent oxygen migration into the goaf and goaf gas migration into the ventilation airflow. The increased number of seals to be erected presents both an increase in cost and more leakage paths between the general body of air and the goaf atmosphere.

Bleeder Ventilation

Within Australia there is currently limited use of true bleeder ventilation due to the propensity of Australian coal to spontaneous combustion. Of the 16 mines visited only two mines employed a variation of bleeder ventilation to ventilate the current and previous goaf's due to excessive gas accumulations.

Raisebore Utilisation

The issue of ventilating future tailgate entries and other blind entries has been addressed in a number of ways. The most apparent solution is to maintain development at least a full longwall panel ahead of the operating longwall. This way intake air can be directed though the next panel entries, across the installation face and down the future tailgate entry to be returned possibly across the working longwall face. This method provides access to the installed seals behind the current longwall face for inspection and maintenance. However, this additional development does not usually exist due to factors including economic and productivity focus.

To provide ventilated access to the current goaf seals some collieries are boring raises behind the longwall panels and used in a downcasting mode for intake to the longwall face or upcasting mode providing return capabilities. These raises can be utilised for other purposes during longwall installation (eg; concrete drophole) or during emergency scenarios as another means of access to the working seam and/or surface.

CONCLUSION

From the case studies discussed it can be seen that there are several underlying themes that are common within Australian longwall mines. At the same time, however, there are also some extreme variations of ventilation approaches utilised to facilitate management of severe ventilation issues. Each of the 34 operating longwalls in Australia manages a combination of issues including spontaneous combustion, total and respirable dust, heat and explosible and toxic gases. The increasing depth of operations exacerbates most of these issues.

The utilisation of two headings in maingate development is common across all operations. This limits the number of different longwall ventilation methods possible and hence most operations use a variation of the traditional U ventilation approach. This method is also utilised to assist with the minimisation of pressure differential induced across the current and previous goaf's for spontaneous combustion reasons. A limited number of operations use a variation of the Z ventilation approach but only to facilitate the ventilation management of extreme quantities of gas in a seam with little or no potential for spontaneous combustion.

The use of raisebores and small diameter shafts is becoming more common assisting with reducing mine resistances in some instances and allowing the ventilation of blind headings subject to gas inundation and development breakthroughs.

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