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ECONOMIC INVESTIGATION OF AUSTRALIAN LONGWALL VENTILATION METHODS

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ABSTRACT

Ventilation is being given increasing attention with respect to both the importance of maintaining a safe operating environment in underground coal mines and minimisation of the costs associated with the operation of and capital required for air movement. In order to satisfactorily address these two requirements the real costs of ventilation must first be established. A economic investigation of longwall ventilation draws on previously established longwall ventilation methods and identifies and outlines a framework from which to evaluate the costs of a ventilation network.

The identified Australian longwall ventilation methods are 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 optimum design of a longwall ventilation system. When combined with a working knowledge of existing or anticipated ventilation constraints this process will facilitate ventilation network optimisation and allow for improved management methods through increased understanding.

While establishing a path to achieve a long term goal of optimum longwall ventilation design many issues can be identified as having both design and fundamental economic implications. One such issue is the utilisation of two or three (or more) headings in development. Analysis draws on a comparison of current Australian and North American and includes consideration of development method, number of stoppings, leakage over length of gateroad and anticipated development rates.

Through the analysis of current practices with a focus on various characteristics of ventilation methods an economic model can be constructed to provide important aspects of a more generic economic ventilation model. A generic district longwall ventilation model is used to establish the framework within which to identify and characterise the different costs associated with ventilation. From this model it is anticipated that existing longwall ventilation systems can be evaluated and compared. This generic model will also provide a base from which to identify, test and evaluate fundamentally new longwall ventilation models outside of current practice.

INTRODUCTION

The purpose of this paper is to establish basic economic factors that can be included in a comprehensive longwall district ventilation model. To achieve this typical Australian longwall ventilation practice is categorised using a series of case studies. From these case studies important operational features can be established in the context of design and operational economic planning.

The core of the categorisation 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. Eleven of these 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.

LONGWALL VENTILATION CASE STUDIES

Typical Aspects of Australian Longwall Mining

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.

In these case studies two roadway maingate development is only considered as recently introduced three heading development has not been utilised in longwall ventilation within Australia for some time. These case studies 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.

The case studies that follow are described using this nomenclature and describe some of the operational issues and procedures from which economic factors can be established.

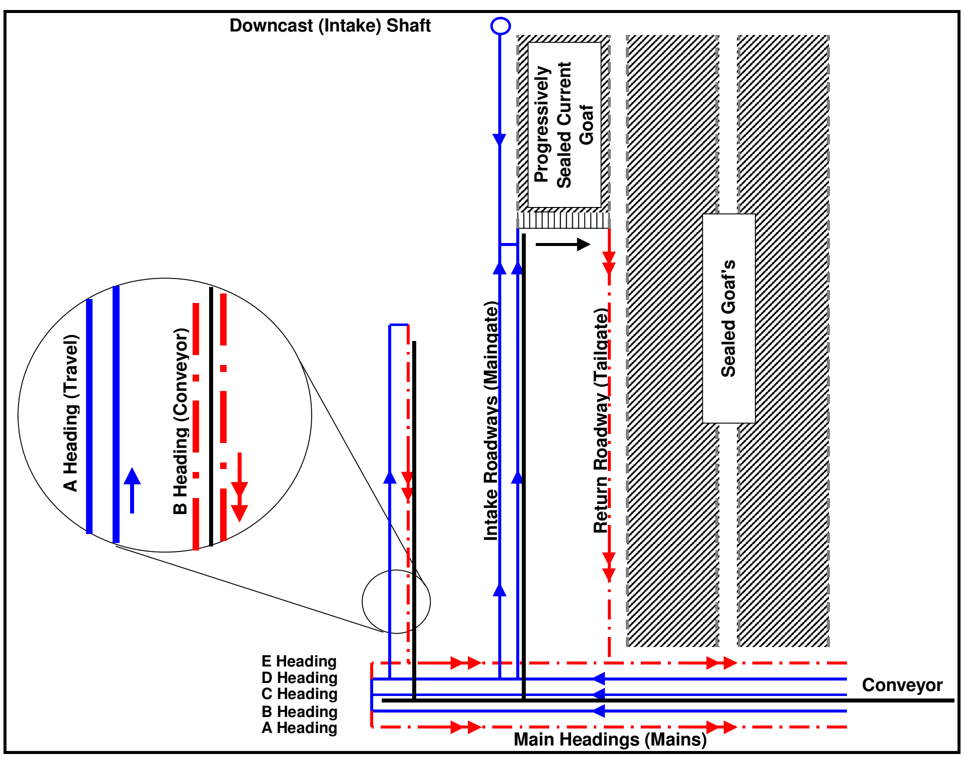

Figure 1. Typical Layout Aspects of Australian Longwall Mining

Case Study A

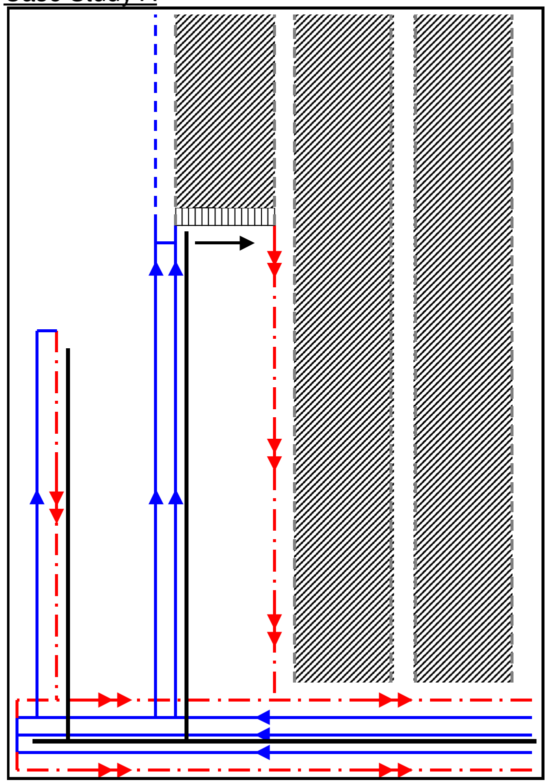

Figure 2. Case Study A

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.

The use of auxiliary ventilation in A heading over increasingly longer distances is problematic and hence this pure form of U ventilation is not employed without some variation.

Case Study B

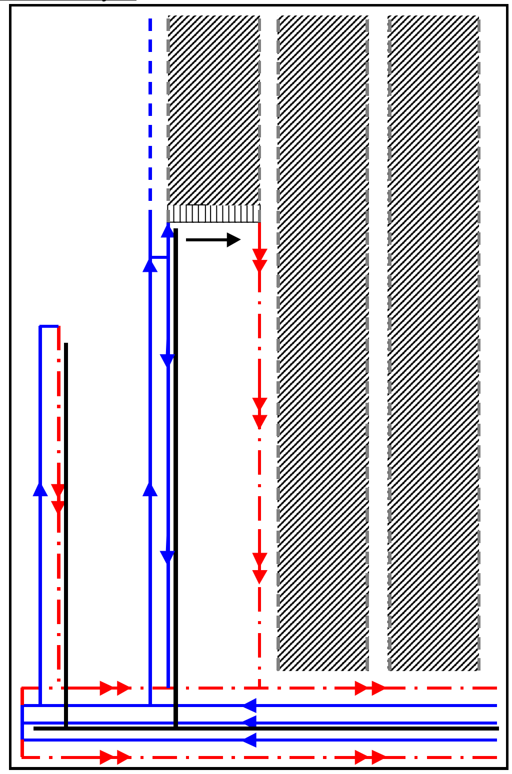

Figure 3. Case Study B

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 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 30m³/s if no overriding contaminant levels are present. The homotropal split is typically ventilated with approximately 10-15m³/s. The split can be seen to significantly reduce the ability to provide the longwall face with all available intake air.

Case Study C

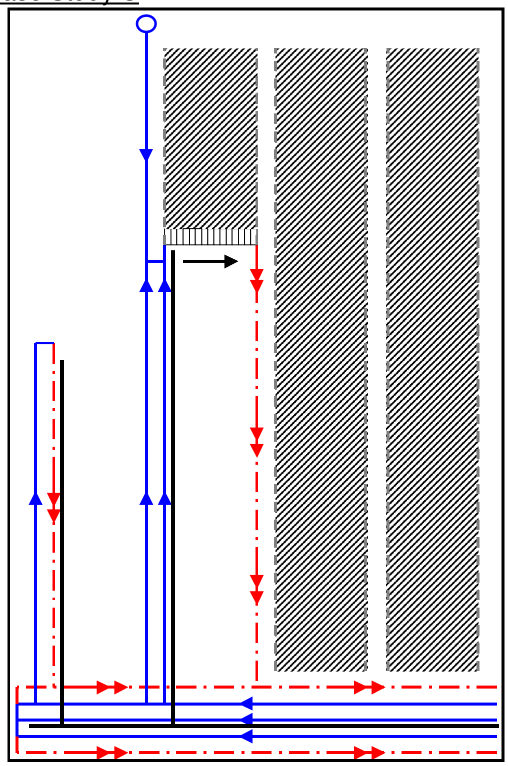

Figure 4. Case Study C

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 10m³/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

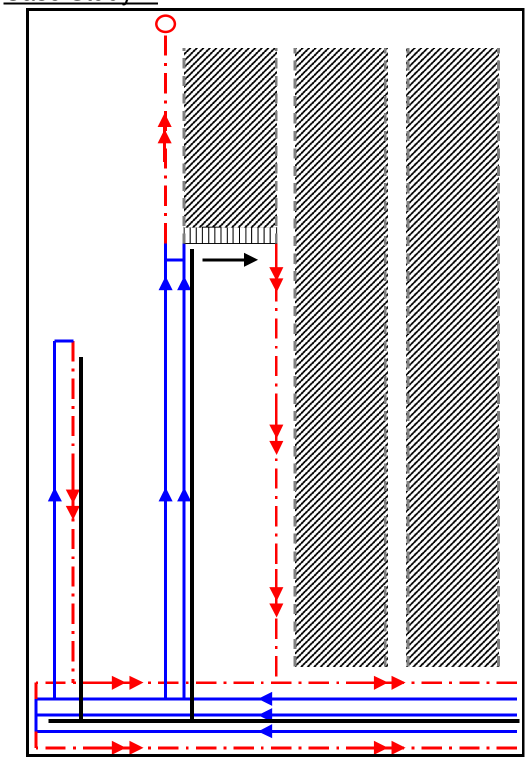

Figure 5. Case Study D

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 m³/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

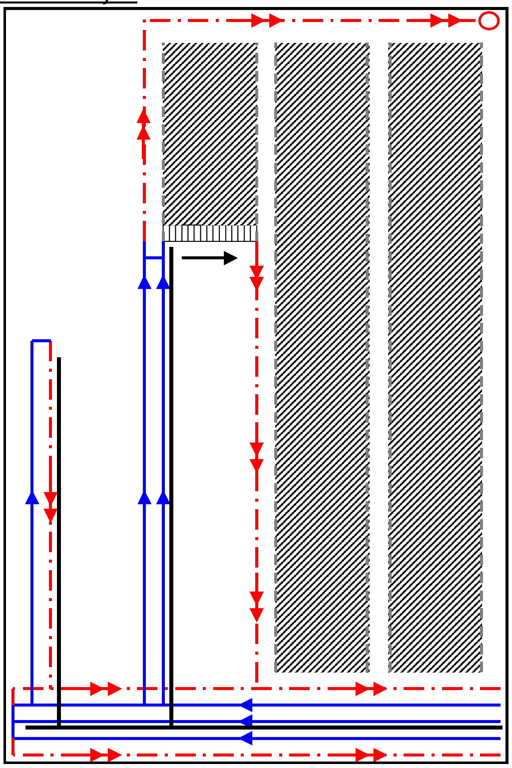

Figure 6. Case Study E

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 m³/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. This method, with its inherent advantages of contaminant removal, has the potential to increase air quantity in the pit by removing some of the load on Main returns.

Case Study F

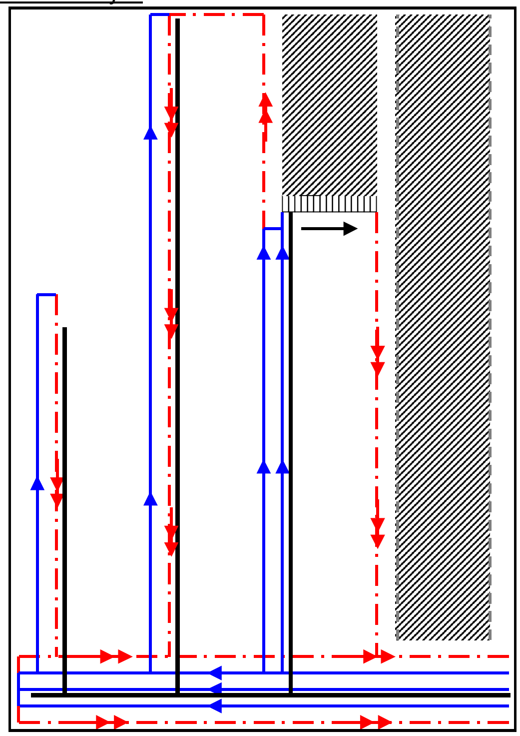

Figure 7. Case Study F

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. 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

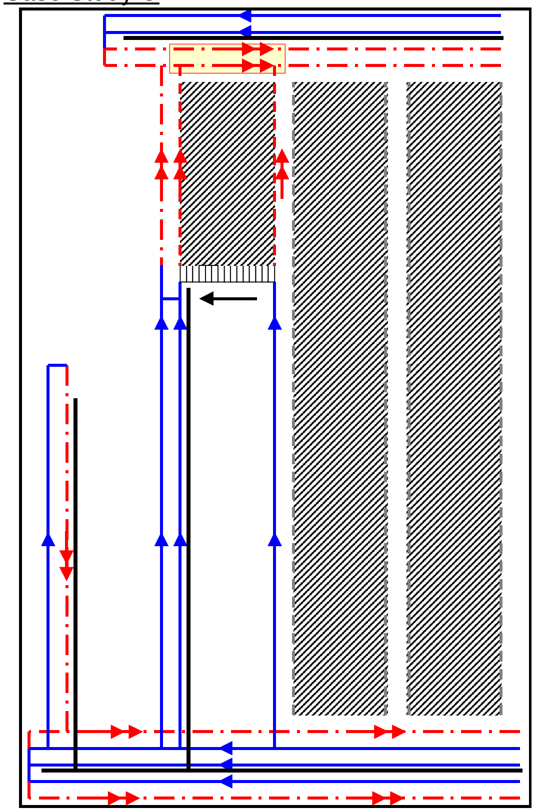

Figure 8. Case Study G

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

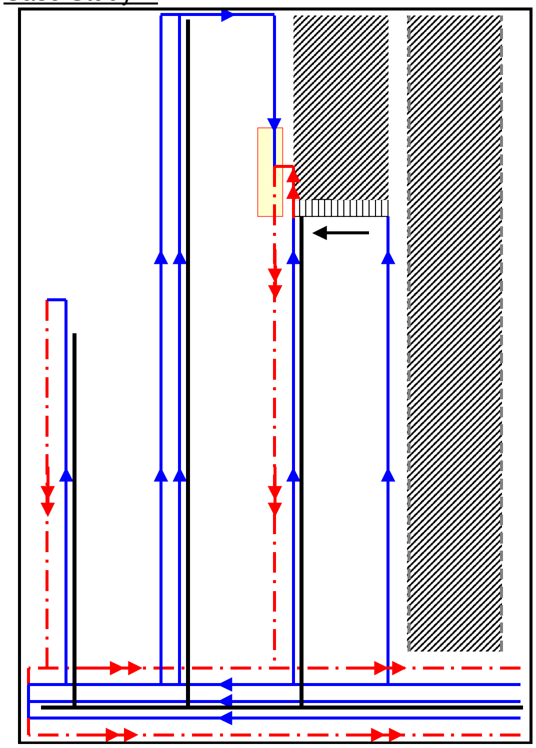

Figure 9. Case Study H

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. 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.

GENERIC DISTRICT VENTILATION MODEL

An example of a generic district model can be seen below in Figure 10. This model allows the framework of an economic model to be established with the option to relocate infrastructure or not use items such as back return headings/shaft installations and Submain headings.

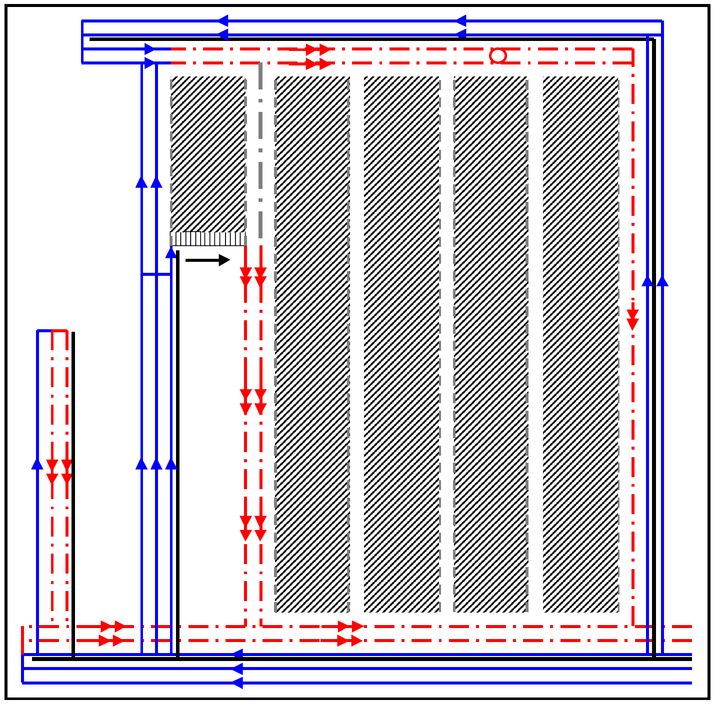

Figure 10. Generic District Ventilation Model

This model has been established with a five heading Mains, three heading Maingates, the remaining two headings in the Tailgate, Submains at the back of the longwall panels (not in bleeder operation mode) and a back return shaft installation. In developing a generic economic model for a base ventilation network it is then possible to test the case studies as established previously but also to test with some confidence models that are outside current practice and thinking. Some examples of this are more extensive use of back return systems similar to North American practice and establishing Mains development well in advance of longwall development activities sufficiently enough to sink a shaft and either extract panels towards or away from this shaft installation.

<u>Established Economic Factors</u>

Maingate Development The development of maingate entries using two headings has been the standard method of development used industry wide 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. It can be considered in three heading Maingate development that there may be some apparent operational benefit to having the additional heading. This may be to store equipment in roadways as opposed to cut throughs in the two heading case. This can be quantified but probably ranks as a small benefit.

The 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. This productivity can be investigated using Australian colliery experiences and given some factual evidence to further develop these cases. In any case a cost per metre advance can be established to the necessary level of detail. A factor to consider for "place changing" operations is the larger number of cut throughs which has two implications. The first is during the development phase where leakage through stoppings becomes a critical aspect of the development panel ventilation. More stoppings means more leakage. This second is the additional capital cost of extra mining cut throughs and the additional stoppings placed within.

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. This also highlights a difficult aspect of mine operation to quantify, which is the quality of these installed seals and to what quality is it necessary to install and maintain a seal for exactly what purpose. For this issue it is proposed to use risk based analysis.

Sealing Practice With a recent statutory emphasis on ventilation control devices in Queensland coal mines and a similar following in NSW it is important to consider the costs and benefits of these devices over their service life. Pressure balancing of ventilation control devices and sealed goafs is also an important issue. This consideration also necessitates the use of risk type analysis when considering spontaneous combustion possibilities. With the appropriate design of a ventilation network the distribution of differential pressure over ventilation structures and zones can be managed using engineering as a fundamental design tool. Eliminating or minimising this risk can be considered a superior approach to spontaneous combustion management.

Contract vs. Pit Labour The costs of labour can be readily established especially when using contract options and having a good understanding of the total costs attributed to specific tasks.

Shaft/Raisebore Installations 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. In 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 longwall productivity focus. In this case the time value of the development ahead of the longwall extraction schedule can be considered.

To provide ventilated access to the current goaf seals some collieries are boring raises behind the longwall panels that are 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. Again these additional uses might share some of the cost of the installation. An exercise in ventilation costs verses the capital cost of installation can be undertaken for these style of installations.

Operational Delays The greatest potential for minimising operational costs due to ventilation can be seen as preventing ventilation scenarios that prohibit the continued operation of the mining equipment. This situation can arise due to inadequate ventilation management of gas, dust (respirable and total), heat and other issues like spontaneous combustion. In this situation two schools of thought exist where the delay cost is the loss of revenue from the loss of production and where the delay cost is only a function of the time value of lost revenue. A solution probably lies in between these two concepts with appropriate consideration of fixed and variable costs.

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 goafs due to excessive gas accumulations. Due to this limited application this ventilation method will only be considered at a more general level.

CONCLUSION

From the case studies discussed it can be seen that there are many different issues that affect either directly or indirectly various economic considerations. It can also be observed that there are also some extreme variations of ventilation approaches utilised to facilitate management of severe ventilation issues each with the consideration of cost verses risk reduction and benefit. 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 goafs 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.

A first step is the development of a generic ventilation network overlayed by an economic model based on each of the fundamental cost areas. With this in hand existing and new ventilation models can be tested against a set of developed standards or industry averages.

ACKNOWLEDGMENT

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