Mine Ventilation Implications of Segregated Intake and Neutral Air Beltways

A.D.S.Gillies, B.E.(Hons), Ph.D

Department of Mining, Minerals and Materials Engineering

The University of Queensland

Summary

Although it is believed that exemption to the ruling has been common, coal underground beltways in mine areas developed since 1978 in Queensland are required to have belt heading air segregated from other intake headings to improve the likelihood of maintenance of an uncontaminated escape airway in the event of a mine fire. Furthermore, the 1996 Moura No 2 Warden's Inquiry Recommendations set down that underground mines should have one intake airway that is completely segregated from other parallel intake airways so as to provide two separate intake airways means of egress from the mine. The results of a study to examine the implications and costs of these provisions are set down and discussed.

A number of Queensland mines are facing conditions of having to mine through extensive seam pockets of high concentration unpleasant and toxic gases such as H_2S. These gases are liberated both from the face and from coal travelling on and being tipped from belts. Panel mining necessitates routing face return air down belt headings homotropally and under these conditions Mains Headings belt air will be contaminated and cannot be reused within the mine. The Mains belt heading must be fully segregated and one option is for it to in effect become a neutral airway with a low airflow being coursed either homotropally or antitropally and dumped to returns. This restricts the number of possible mine intakes and so has implications on the provision and cost of mine ventilation. Examples from a study on this situation are discussed.

Background to the Study

Queensland Coal Mine Regulations as they pertain to mine ventilation have always been considered to be onerous. Queensland General Rules for Underground Coal Mines state that for mines developed since 1978 all belt conveyor roadways shall be segregated from other intake airways and from return airways. While it can be generally observed that most mine crosscuts connecting belt roadways with other airways carry segregation stoppings some exemption has been given from a strict interpretation of the rule of the years for the following reasons.

1. It is awkward to have to carry a Panel belt through a segregation stopping before joining a Main belt.
2. Men and materials need to pass from time to time in most mine layouts from a roadway on one side of a beltway to a roadway on the other. To allow this and maintain segregation

requires the expense of installation of a pair of doors, a pair of sealing flaps or use of an overcast.

3. Likewise, intake air needs to be brought from one side of a beltway to the other and segregation implies necessity for construction of an overcast.
4. In an emergency, escape from the mine may be slowed or impeded by personnel having to travel around long lines of segregation stoppings.

Following publication of the Moura No 2 Mine Disaster Inquiry report some points of interpretation have been clarified by the Inspectorate and it is understood that some tightening up has occurred in granting of exemptions. The Inquiry report placed emphasis on the matter with the recommendation that there be a requirement for all underground mines to have one intake airway that is completely segregated from other parallel intake airways so as to provide two separate means of egress from a mine via an intake airway.

The study has undertaken a technical and cost comparison of ventilation of a typical (although artificial) model of a modern longwall mine layout examining the generally accepted pre Moura situation (Casestudy 1) with what appears to be the evolving post Moura approach (Casestudy 2).

Casestudy 3 examines the ventilation technical and cost implications of handling release of noxious emissions such as H_2S seam gas. A number of Queensland mines are facing conditions of having to mine through extensive seam pockets of high concentration unpleasant and toxic gases such as H_2S. These gases are liberated both from the face and from coal passing through breakers and travelling on and being tipped from belts. Within these mining conditions, longwall panel mining necessitates routing face return air down belt headings homotropally. As coal passes into Mains beltway heading air will be contaminated and so cannot be reused within the mine. As a consequence the beltway cannot serve as an intake. The Mains belt heading must be fully segregated and one option is for it to become, in effect, a neutral airway with a low airflow being coursed either homotropally or antitropally and dumped to returns. This restriction in the number of possible mine intakes has implications on the provision and cost of mine ventilation.

The concept of use of the term "Neutral belt airway" has been adopted from United States of America coal mine practice. In that country there has been a generally accepted practice for over two decades that to reduce possibility of emissions from belt fires passing to the working face belt air is dumped to returns. Belt air is nonactive air and cannot be considered as intake air. This concept has been adopted for handling beltway air under H_2S mining conditions and is the general approach being used by a number of Queensland mines currently facing this problem.

The Casestudy Models

Ventilation models have been established for the three casestudies and computer simulations undertaken. The ventilation network program VENTSIM has been use to model behaviour. The model longwall mine tested incorporates the following features and a general schematic can be seen in figure 1.

1. Mine Mains development has a five heading configuration with the outer A and E headings as returns, B and D headings as intakes and the centre C heading as belt road.
2. The mine is well established with old worked out longwall panel goafs to the north and extraction currently occurring in a second longwall panel to the south. Four development faces are ventilated with two being longwall panel gateroad headings and two Mains development.
3. In seam roadway and decline dimensions have been standardised at 5.2 m wide and 3.3 m high.
4. The upcast raise bored ventilation shaft to the south of the portal declines (Shaft A) and a second shaft near the bend in the Mains (Shaft B) have frictional impedances of 0.006 kg/m^3.
5. Design face air quantities are 25 m^3/s for development and 45 to 50m^3/s for longwall extraction.
6. Belt headings are separated from intake headings by segregation stoppings with impedance of 135 Ns^2/m^8. Where flaps are used when gateroad belts join the main belt, an impedance 2 Ns^2/m^8 has been assigned.
7. Other impedance values used (in Ns^2/m^8) have been predicted conservatively as 195 for main stoppings and 8.5 for belt mouse-traps and 0.01 for overcasts respectively.
8. The surface upcast shaft fans are of a type commonly used within the industry. They have adjustable blades allowing a number of characteristic curves to be simulated for a range of 50 to 150 m^3/s airflow quantity throughput. Within all simulations a pair of fans in parallel is situated on shaft A and a single identical fan draws air through shaft B.
9. Methane (which generally dictates face air quantities) and hydrogen sulphide are the only seam gases of concern from a ventilation point of view.
10. Electrical power cost used is $0.032/kW-hr.

Casestudy simulations have been undertaken using ventilation modelling on a basis that includes the following interpretations.

Casestudy 1

Layout of belt roadways in a way commonly found prior to the mid 1990s. This approach allowed intake air to mix with belt roadway air where gateroad belts met Main belts, where travel roads passed under (over) belts or where there was a need to equalise airflow between parallel intake headings. Crosscuts intersecting belt roads, and not used for the above purposes normally carried a segregation stopping. This stopping was often of lighter construction than those used for separating intake and return air. A view of part of this mine layout at the intersection of Mains and Panel gateroad headings is shown on figure 2.

Casestudy 2

Segregation of intake belt air from intake air occurs throughout the mine until the last open crosscut outbye the working face where mixing of belt air with intake air may occur prior to passing this mixed air across the face. An overcast must be used to carry intake air across a segregated belt heading. Men and Materials roadways entering or leaving a belt heading must incorporate isolation doors or flaps or must do so where an overcast is in place. Panel belts joining Mains belts must pass through isolation flaps or a segregating mouse trap. A view of part of this mine layout at the intersection of Mains and Panel gateroad headings is shown on figure 3.

Casestudy 3
Belts that carry broken coal which liberates high levels of contaminant H_2S are segregated neutral airways. Panel belts carry coal from the face in a non-entry heading with homotropal airflow direction. This heading air dumps to return while the belt passes through flaps to tip onto the Mains belt. The Mains belt roadway is similarly non-entry neutral air moving both homotropally and antitropally with the belt and with flow regulated by flaps which as convenient dump air to returns. A view of part of this mine layout at the intersection of Mains and Panel gateroad headings is shown on figure 4.

To allow a fair technical and economic comparison between the alternative casestudies presented, the mine layout has in all other aspects been kept identical. This has meant the placement of a number of overcasts in casestudy models 2 and 3 to allow airflow equalisation between Main Heading A and E (Returns) and B and D (Intakes) where this equalisation would have more readily occurred with the less segregation inherent in the casestudy model 1 layout.

Results

To highlight differences between each alternative, model simulations have been undertaken to determine the minimum fan blade setting and power requirements to meet design face air requirement specified for ventilating one longwall panel and four development headings. For analysis purposes models are compared as to fan blade settings (high number refers to higher air duty), total mine airflow necessary to meet design face requirements, mine air usage efficiency (ratio of air delivered to faces to total mine flow), total mine impedance imposed by the mine network, total fan motors electrical power, efficiency of fan operation (air power to consumed electrical power) and annual power cost.

The figures set down only selected or key quantity values and direction arrows. Results of simulation studies on the three casestudies are as follows.

1. Casestudy 1 (Partially Segregated Beltway)

Fans and fan blade setting required	Shaft A : 2 fans @ blade angle 6 Shaft B : 1 fan @ blade angle 6
Total mine airflow (m^3/s)	252
Mine air usage efficiency (%)	58.6
Total mine impedance (Ns^2/M^8)	0.01870
Total motor electrical power (kW)	367
Fan efficiency (%)	82
Annual power cost	$103,027

2. Casestudy 2 (Fully Segregated beltway)

Fans and fan blade setting required	Shaft A : 2 fans @ blade angle 7 Shaft B : 1 fan @ blade angle 6
Total mine airflow (m^3/s)	273

Mine air usage efficiency (%)	54.2
Total mine impedance (Ns^2/M^8)	0.01942
Total motor electrical power (kW)	451
Fan efficiency (%)	87
Annual power cost	$126,552

3. Casestudy 3 (Neutral Air Beltway - Full segregation and Isolation of beltway)

Fans and fan blade setting required	Shaft A : 2 fans @ blade angle 10 Shaft B : 1 fan @ blade angle 7
Total mine airflow (m^3/s)	307
Mine air usage efficiency (%)	47.7
Total mine impedance (Ns^2/M^8)	0.02922
Total motor electrical power (kW)	983
Fan efficiency (%)	86
Annual power cost	$275,636

Analysis of Results

Simulation results emphasise that there is a higher load placed on the ventilation system as increased segregation and isolation of the Mains beltway occurs. While fan nominated blade angle 6 is sufficient to meet design airflow for all three fans for Casestudy 1, two fans need to operate at relative blade angle position 7 in Casestudy 2. In Casestudy 3 two fans operating at blade angle 10 and one at 7 are required to handle the increased duty requirements. Total mine air requirements increase with leakage of air through stoppings and loss through flaps and other restricted passageways with higher fan pressures at increased blade angles. This leads to a need for 8 per cent more mine air with segregation in Casestudy 2 and 22 per cent with segregation and isolation in Casestudy 3. These losses lead to a comparable loss in Mine air usage efficiency with segregation and isolation of the beltway. Mine air usage efficiency ratios are a relative measure highlighting losses in the mine system. It is a figure which can be expected to rise with age of a mine due to extent of workings and deterioration of stoppings. In this study it highlights an inefficiency imposed on the mine system due to incorporation of additional safety requirements or the presence of unpleasant or toxic gases within the mine atmosphere.

The rising mine impedance values from casestudies 1 to 2 and 3 indicate the extra resistance placed on the essentially parallel airflow pathways that make up the mine networks under study. Similarly the increasing fan motors electrical power requirements and annual power cost for the three models emphasise the additional impositions of segregation and isolation placed on the ventilation system. Casestudy 2 has additional power draw and cost requirements over model 1 of 22 per cent while Casestudy 3 imposes an increase of 167 per cent load. These values underline higher operating cost of meeting ventilation needs. The larger electrical motors and structural components needed to operate the fans will mean that the capital cost of establishing ventilation systems that meet requirements set down in casestudies 3 are significantly increased over casestudy 1. In this case, as an example, Shaft A fan motor ratings of 400 kW would be required whereas 250 kW units would be sufficient for casestudy 1 mine layout. The capital cost of additional overcasts, segregation stoppings and other devices needed in casestudies 2 and 3 will in addition be of a high order.

The full beltway segregation approach of casestudy 2 is seen as giving an advantage to miners working inbye a belt fire to leave the mine using uncontaminated intake airways (for example headings B and D in the mine layouts). The general Queensland practice of placing the belt heading flanked by intake headings means that belt fire fumes can quickly travel to and contaminate working face air. The alternative of placing the belt heading adjacent to a return air heading allows, if there is quick action in the event of a belt fire starting, the dumping of belt air directly into the return. This allows fire fumes to be directly short circuited out of the mine and gives miners at working faces valuable additional time to leave the face area and travel out of the mine. Under general Queensland practice incorporation of devices to allow contaminated belt air to be dumped to return, such as placing at intervals tubing linking headings or isolation doors, would be expensive.

Conclusions

A study has been undertaken using technical and cost evaluation of ventilation of a typical (although artificial) model of a modern longwall mine layout by comparing a partially segregated beltway approach with a fully segregated beltway system and a segregated and isolated beltway system appropriate for handling mining in seams containing unpleasant or toxic gases. The casestudies examined have highlighted the requirements for increased ventilation air with both segregation and segregation and isolation of beltway heading air. The additional fan duty required to deliver more air against higher mine impedance considerably increases fan annual operating costs and capital cost of fan installation. The discussion allows the implications of installation of fully segregated or neutral belt airways to be carefully considered.

References

Queensland Government. Wardens Inquiry report on an accident at Moura No 2 Underground Mine on Sunday 7 August 1994, F. W. Windridge, Warden,January 1996 74p.

Queensland Government. Coal mining Act, General rules for underground coal mines.

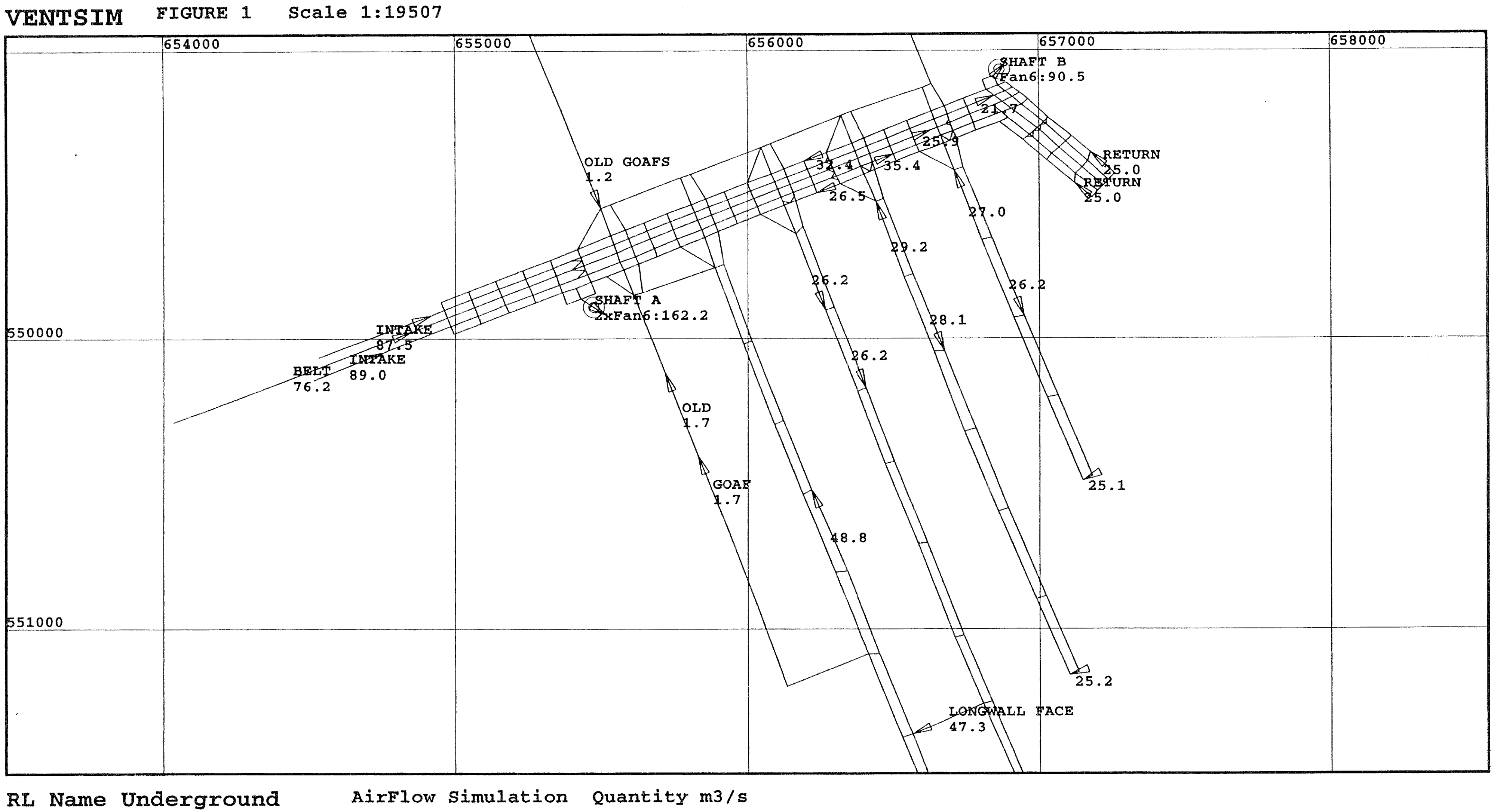

Figure 1 Study mine schematic showing longwall panel, four ventilated development headings, Main returns, intakes and beltway and two fan mounted upcasting shafts

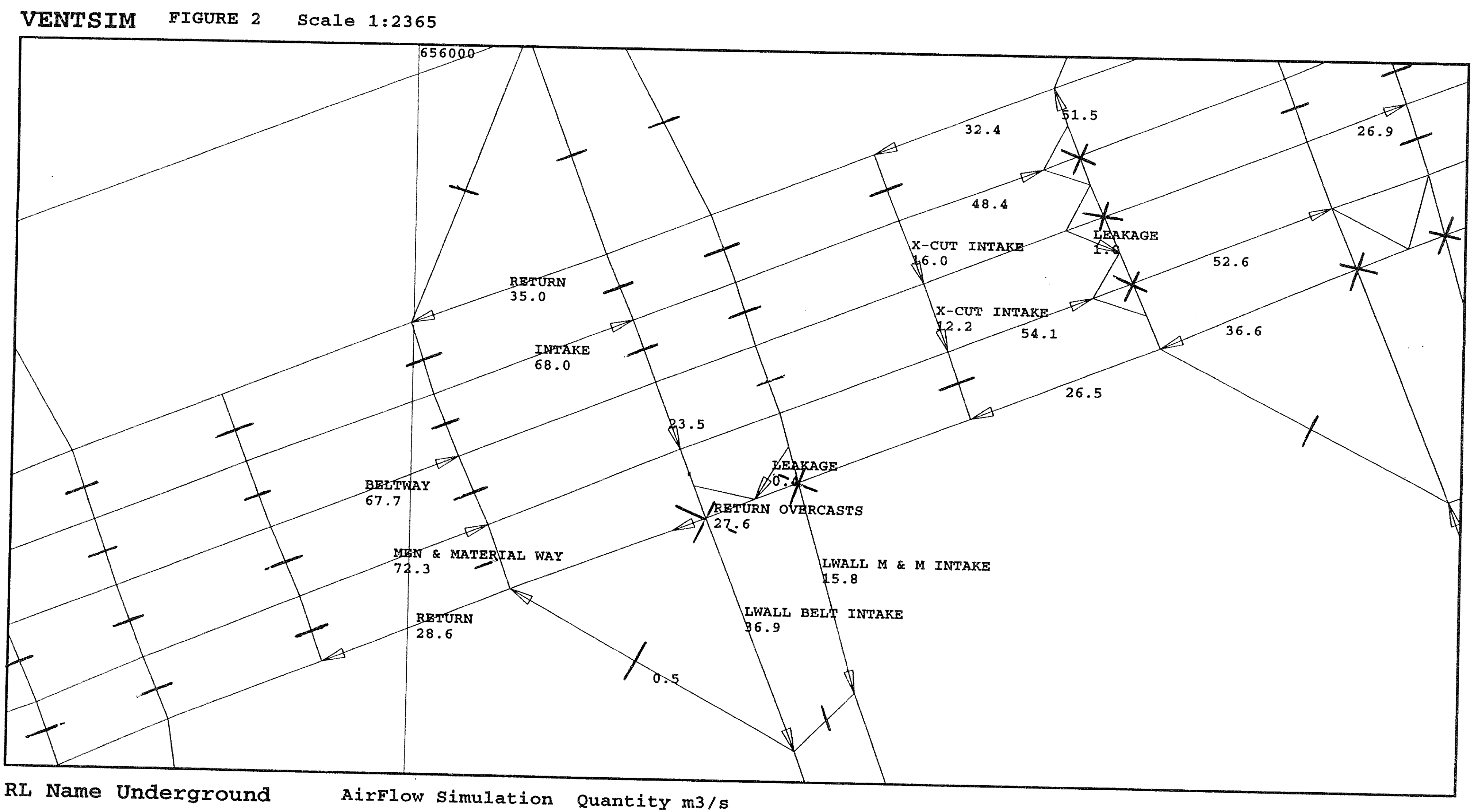

Figure 2 Mine heading layout at intersection of Mains and longwall main gateroad showing ventilation pattern with partially segregated beltway

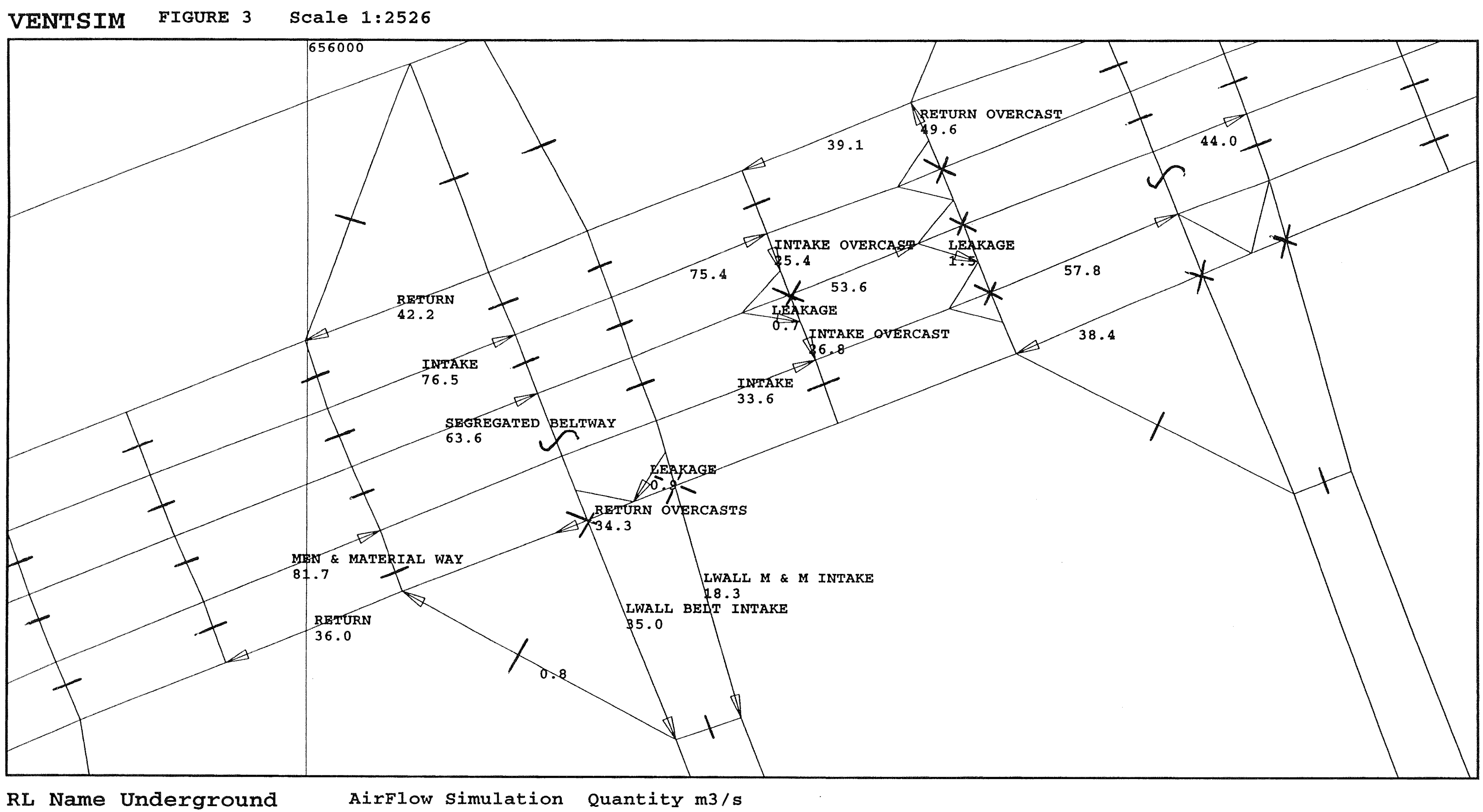

Figure 3 Mine heading layout at intersection of Mains and longwall main gateroad showing ventilation pattern with segregated beltway ventilation as simulated in casestudy 2

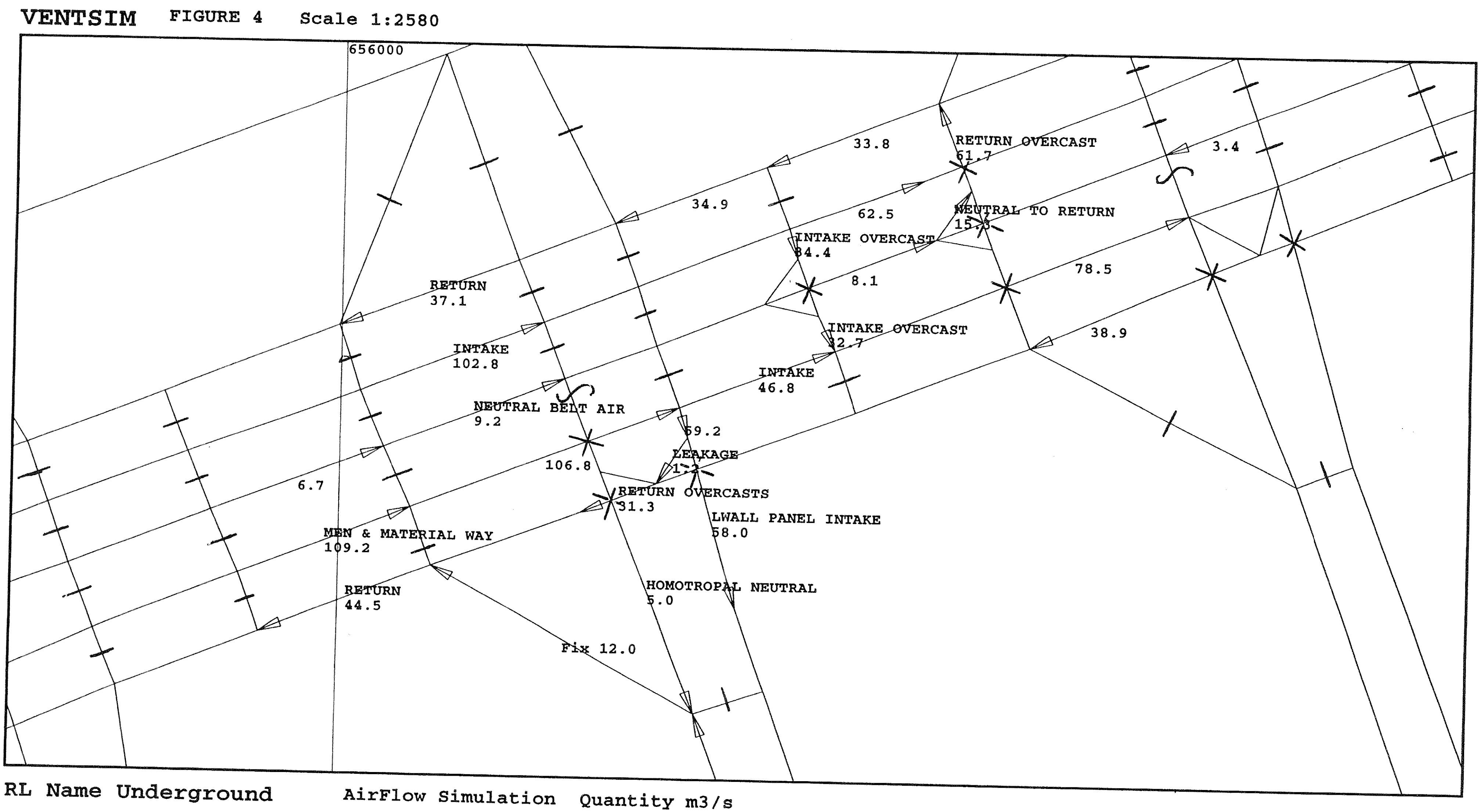

Figure 4 Mine heading layout at intersection of Mains and longwall main gateroad showing ventilation pattern with neutral beltway ventilation as