District Environmental Planning

Ocak Havalandırma Planlaması

Ian LONGSON *
Darron William DIXON **

ABSTRACT

The paper describes current work to develop an improved ventilation strategy to handle increased methane emission from some highly productive faces. District geometrical configuration and air quantity determine the amount of methane which can be handled. Ventilation cost simulation exercises were carried out on a common network for differing ventilation layouts and fan capacity. The suitability of the various layouts in relation to total production rates was recognized and related to the practicalities of their introduction to real systems, the intended aim being to arrive at a means of showing ventilation cost versus production for a particular district layout

ÖZET

Bu makale, yüksek üretim kapasiteli bazı ayaklardan gelen aşın metan emisyonunun kontrol altına alınabilmesi için, geliştirilmiş bir havalandırma stratejisinin iyileştirilmesine yönelik bir araştırmayı vermektedir. Ocağın geometrik şekli ve hava miktarı kontrol altına alınabilecek metan miktarım belirlemektedir. Havalandırma maliyeti modelleme testleri sabit bir şebeke üzerinde havalandırma şemasının ve fan kapasitesinin değiştirilmesiyle yapılmıştır. Toplam üretim oranlarına bağlı olarak değişik şemaların uygunluğu, tanımlanmış ve bunların gerçek sistemlere uygulanabilme durumları verilmiştir, hedeflenen amaç, belirli bir üretim yeri şeması için, üretim miktarlarına kaışın havalandırma maliyetlerini verebilmek olmaktadır.

(*) Senior Lecturer, Department of Mining Engineering, University of Nottingham
(**) Research Student, Department of Mining Engineering, University of Nottingham

1. INTRODUCTION

In many UK coal mines there is a trend to reduce the number of working faces and obtain the same or increased production for less capital expenditure and operating cost. Improved strata control techniques, standards of machine utilization and equipment reliability allow higher levels of production to be attained provided environmental conditions are favourable. However, in many cases, environmental factors have the potential to restrict production and of these methane is the principal constraint. Methane creates a risk of explosion within a concentration range of 5%-15% in air and can, in the UK, halt production if general body concentrations reach 1.25% as by law the power supply to the face must be switched off. The methane release into the ventilating airstream can be reduced by employing methane drainage techniques and these are widely used. A particular district ventilation layout can handle varying rates of methane emission depending on its geometrical layout, face section and district air quantity. As the rate of face production is increased so must air quantity in order to maintain legally acceptable methane concentrations. At some critical tonnage a particular layout may cease to provide the most economic ventilation solution and alternative layouts merit investigation. This tonnage can be variable from mine to mine and even within the same mine. The paper serves to demonstrate the differing ventilation costs for various layouts using a common ventilation supply network and discusses some of the implications of these layouts when considering their introduction to real systems.

2. THE NETWORK USED IN THE TESTS

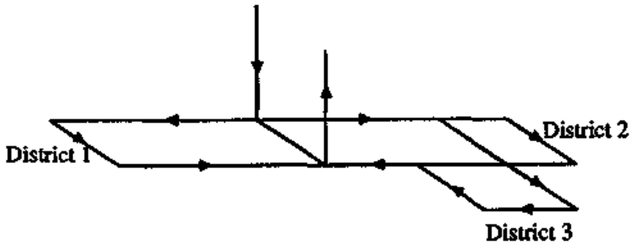


Figure 1 The Basic Network

A simple network was chosen (Figure 1) supplying three working districts. In each simulation the supply network (i.e. the shafts and main airways) were kept constant while the district configurations were changed. The total length of roadway (i.e. face, intake and return airways) for each layout was also kept constant for all the district configurations. The resistances of the airways were calculated using the established ventilation resistance equation;

$$R = \frac{k\,O\,L}{A^3} \qquad [1]$$

R = resistance Ns^2/m^8,
k = friction factor kg/m^3,
O = perimeter of roadway m,
L = length of roadway m,
A = cross-sectional area of roadway m^2.

The inevitability of changes in face cross-sectional area, perimeter and surface roughness led to a value of $k = 0.04$ kg/m^3 being chosen which is taken to represent good to normal face conditions (1). Using this value in Equation 1 gave a corresponding face resistance of 0.72 Nfym^8 for a face of 250m length by 2m height by 2.5m wide. The maximum permissible face air velocity was taken as being 4.5 m/s which gave a maximum face flowrate of 22 m^3/s.

3. SIMULATION METHOD

The cost simulation exercises were carried out using a demonstration version of the VNETPC 3.0 ventilation simulation program. In each case the surface fan was attached to the upcast shaft. In these tests, five different district configurations were investigated, which were U, W, Y, Double Z and E. The first exercise for every layout used the standard fan characteristics which were subsequently uprated by varying amounts to deliver the required flowrate. The fan was uprated by using the Fan Laws, i.e. a 10% increase in flowrate resulted in a 33% increase in ventilation costs (power <* quantity^3). The fan gave an approximate range of airflow from 72 to 125 m^3/s. No account was taken of waste leakage, the whole of the total district airflow being considered to be delivered to the face.

Operating cost data was produced from the simulation and this was used to enable operating cost graphs to be drawn for each of the different layouts. The final graphs show the weekly production with its corresponding ventilation cost for a given return methane concentration. These graphs were arrived at by;

1. using return methane levels for a constant weekly production (2). These methane emission quantities used relate to the gas being released directly into the ventilating airstream (Figure 2).

2. calculating all the necessary airflow quantities to deal with a specific return methane level at the UK statutory methane limits of 1.25 and 2.0% (Figure 3).

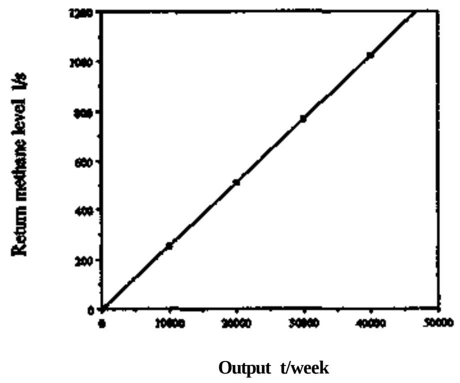
3. from 1 and 2 arriving at an airflow versus tonnage graph at the 1.25 and 2.0% methane limits (Figure 4).

4. once all of the simulation exercises had been completed for a particular layout, a graph showing annual ventilation cost versus airflow was produced (Figure 5).

5. from 3 and 4 a final graph showing the weekly ventilation costs for a weekly output at 1.25 and 2.0% methane limits was found (Figure 6,7).

4. RESULTS OF THE TESTS

Analysing the ventilation cost/air quantity graph (Figure 5) the smooth curves allow a definite cost to be found for a given quantity using any of the five layouts, when considered in this particular network and using the network fan. As a comparison the predicted ventilation cost/air quantity curves are shown alongside the simulated values for each layout (Figure 8-12). These predicted values were obtained by using the initial set of results when the standard fan (i.e. no modification) was used in the network. For each layout the three initial district ventilation costs and quantities were increased using the Fan Laws to obtain the theoretical increases in ventilation quantity and cost In the case of the V, W and Double Z system the predicted and simulated values were found to be almost identical. However, the Y and E layouts demonstrate different predicted cost curves for each of the three districts. In both cases district 1 proves to be the cheapest to ventilate, while district 3 is more expensive than district 2. In these two layouts it was necessary to regulate the airflow to the face, as the maximum face quantity was set as 22 m^3/s. The standard fan does not deliver an adequate total flow and this results in insufficient flow-rates on districts 2 and 3 in the Y system and district 3 in the E system. When the district quantity is below this value the simulation introduces some uncontrolled recirculation to provide the required airflow which is unacceptable practically. Where uncontrolled recirculation is occurring the predicted costs are greater than without recirculation and for prediction and practical purposes these layouts should only be used when the fan is able to supply in excess of the regulated amount



Rgure 2 Return methane level/Output

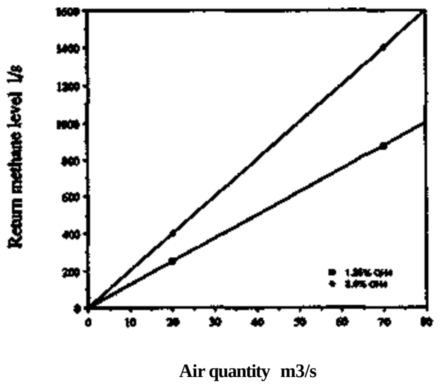


Figure 3 Return methane level/Air quantity

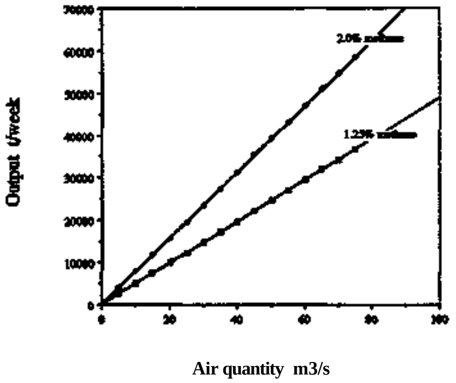


Figure 4 *Oatpat/Aix* quantity at 1.25 and 2.0% methane

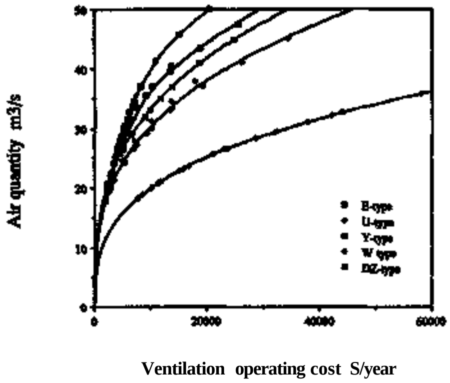


Figure 5 Air quantity/Ventilation operating cost

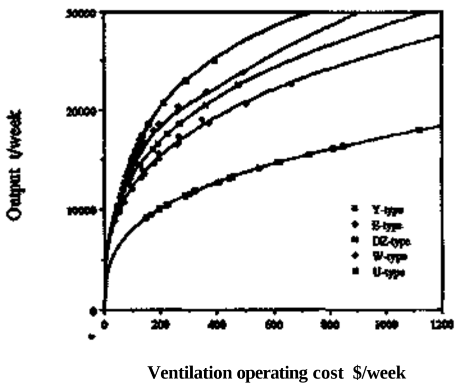


Figure 6 Output/Ventilation operating costs at 135% methane

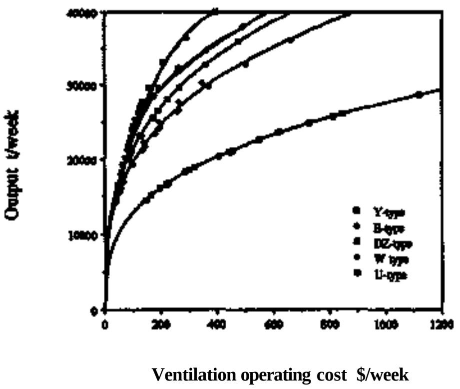


Figure 7 Output/Ventilation operating costs at 2.0% methane

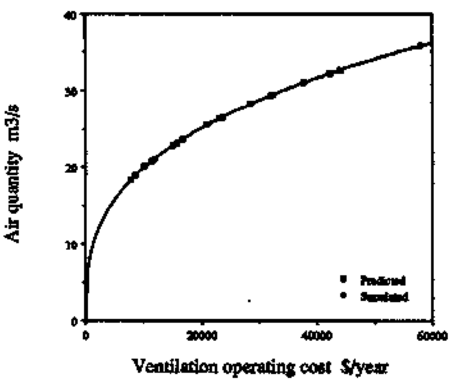


Figure 8 Predicted/Simulated Ventilation operating costs for U-type ventilation

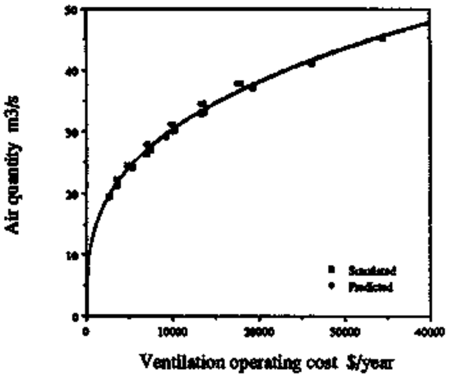


Figure 9 Predicted/Simulated Ventilation operating costs for W-type ventilation

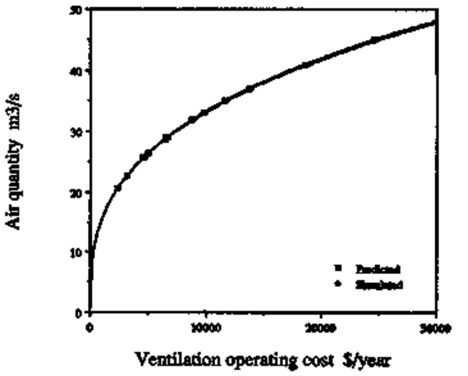


Figure 10 Predicted/Simulated Ventilation operating costs for Double Z-type ventilation

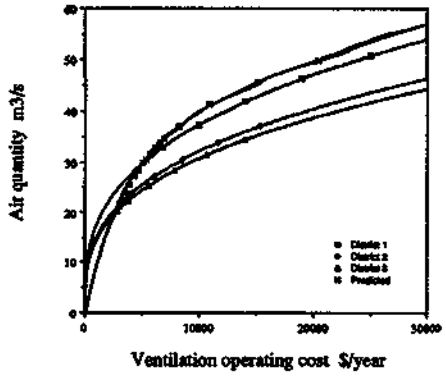
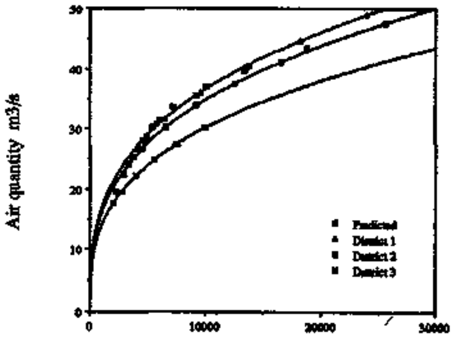


Figure 11 Predicted/Simulated Ventilation operating costs for Y-type ventilation



Ventilation operating cost $/year

Figure 12 Predicted/Simulated Ventilation operating costs for E-type ventilation

5. DISCUSSION OF THE LAYOUTS

5.1. U-Type

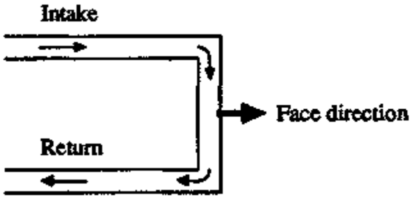


Figure 13 U-type Ventilation

U-type ventilation is the most expensive of all the considered layouts where ventilation costs are concerned. For the particular methane emission/output rates used the costs increase steadily but with a maximum face quantity of 22 m^3/s the system is limited to a maximum weekly tonnage of 11,000 or 17,600 at methane concentrations of 1.25 and 2.0% respectively. At these relatively low rates of production the ventilation costs are significantly more expensive than for alternative types. This is the simplest ventilation layout and is currently the most popular in use. It requires the least development of any of the layouts considered, even when used in its retreat form where the gates are pre-driven. Current faces using this type of ventilation are capable of very high production, however, some problems do occur due to methane concentrations in gassy seams. Even with efficient methane drainage, production is invariably limited by return methane concentrations. In less gassy mines the U-type ventilation system can be regarded as highly satisfactory, since they are capable of producing production in excess of 2 million t/year per face, without the need for a costly and more complicated layout. Where methane emission is severe, production must be necessarily limited or another ventilation layout chosen. U-type retreat layouts often have low methane drainage capture efficiencies due to closing of the drainage holes behind the faces.

5.2. W-Type

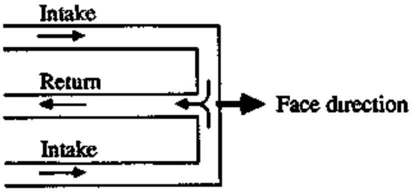


Figure 14 W-type Ventilation

W-type ventilation offers a considerable cost saving over the U system and can either be advancing or retreating though it is generally used in advancing form. The system is comprised of two intakes (providing air to each half of the face) and a central return on the same side of the face as the intakes. Practically, the system is limited (as far as the example network is concerned) to a total district airflow of approximately 44 m^3/s i.e. 22 m^3/s passing along each half of the face. This quantity, which is not very large, would allow a weekly production of 22,000 and 35,200 tons at 1.25 and 2.0% methane concentrations. At this maximum face quantity the layout offers a good alternative to U-type ventilation since for any given methane emission the possible weekly production is effectively doubled. The return airway is unlikely to be used for mineral conveying and should be of a sufficient standard to handle large quantities of air. Electrical power would not be needed in the return so long as the roadway was free from maintenance. The shortening of the distance between the intake and return airways may encourage higher amounts of waste leakage (3). Such leakage would not only subtract from the available face airflow but may also introduce additional quantities of methane onto the return airway. This could be reduced to some extent by using appropriate roadway packs. Methane drainage can be practised in either the intake or return airway though an electricity free return would necessitate the use of hydraulic drilling of the drainage holes. The use of a W-type layout need not incur greatly increased development costs over those entailed by the U-type system, though an advancing W-face would need an additional roadheading machine to drive the central return airway.

5.3. Double Z-Type

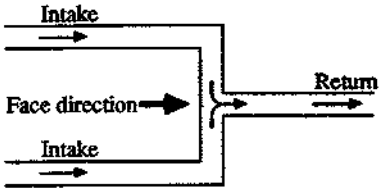


Figure 15 Double Z-type Ventilation

The Double Z system is essentially similar to the W-system, both in geometrical configuration and design constraints, the main difference being that the central return is on the opposite side of the face to the twin intakes. The system offers a considerable ventilation operating cost saving over U-type ventilation and a small saving over the W-type. At a maximum district quantity of 44 m^3/s the possible weekly production would be 22,000 tons (1.25% methane) and 35,200 tons (2.0% methane). From a geometrical point of view the Double-Z and W systems are identical and in simulation should yield the same results. The slight difference in ventilation costs revealed by the simulation are accounted for by the small difference in district roadway length. The leakage potential is less than with the W-system.

5.4. Y-Type

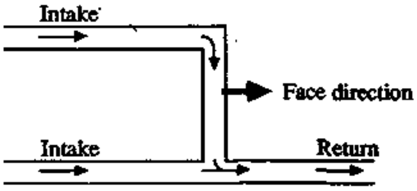


Figure 16 Y-type Ventilation

This layout offers the cheapest alternative to the U-system. It comprises two intakes and a single return which runs on from one of the intakes. For the purpose of the comparison the face airflow has been regulated to 22 m^3/s but if this system is to be used underground the maximum face quantity will differ and may not need to be regulated. Once the face has been supplied the remaining district airflow is passed along the second intake and mixes with the face air at the face end. Assuming the quantity being passed along the face is sufficient to deal with face methane emission the limit on production is placed on the quantity of air which is passed along the second return. The return airway should be of sufficiently high cross-sectional area to cope with a high district airflow. The Y-system can either be advancing or retreat and does not require extensive development over that necessary for a retreating U-face.

5.5. E-Type

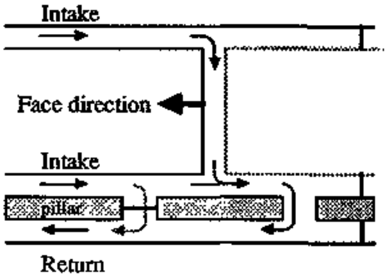


Figure 17 E-type Ventilation

The E-type configuration offers good potential for sustained high production. The layout is a three roadway configuration of a back-return system with no contact or bleeder roadway behind the face, with the exception of the immediate back return circuit. The face intake has been regulated to receive 22 m^3/s with the remainder of the district airflow passing along the second intake. Some of the face airflow is lost to the waste with the effect of sending the face air behind the face as it mixes with the second intake air to contain the waste methane fringe. A certain amount cffeakage occurs from the second intake to die return, depending on how effective the temporary stoppings are. It is envisaged that such a system could be used in me UK as it has been proven to work in Australia (4). Before production begins the three roadways will have to be pre-driven along with the necessary cut-throughs. The pillar between me leakage intake and return should not be too wide, otherwise the task of drilling the methane drainage holes could become too time consuming and it is therefore considered that a pillar width of 20 m to 40 m is preferable. Some of the holes could be drilled prior to production to see whether any gas can be predrained. Once the face moves forward, drainage holes are more likely to stay open and drain gas for longer periods of time because of the supporting and cushioning effect of the pillar.

Practically, the cut-throughs will be difficult to drive and it would be difficult to decide on the distance between them. If the interval is too large, the resistance to airflow in the back-return may reduce the airflow drastically. If the interval is too small, the loss of air between the leakage intake and the return may be excessive. It is, therefore, something that must be determined by experience. The time taken for development is likely to be dependent on how fast the cut-throughs can be driven. If the length of die gate roads is to be 1500 m, and the cut-throughs are placed at 75 m intervals, 20 cut-throughs would be needed. For 40 m width pillars this would mean driving another 800 m of roadway with the difficulty of moving the drivage machine after each cut-through.

6. CONCLUSION

The ventilation cost simulation exercises have demonstrated the comparative ventilation operating costs of the various layouts which can then be used to determine the most suitable layout. Ventilation cost is, of course, not the only expense to be considered and therefore the cost curves should not be the ones to make the decision on which layout to use. Development and maintenance expenditure should be considered as they will influence the final expense of using a particular ventilation layout Attention must also be paid to the practicalities of implementing a ventilation layout underground particularly with respect to safe operation under normal conditions and its ability to handle foreseeable abnormalities.

The demand for ever increasing production rates can only be met by paying greater attention to environmental planning. Other pollutants such as dust and radon also have the ability to impose limits on production and these must be considered in addition to methane emission. Environmental planning should, however, work very closely with the development of the mining system, embracing extraction method, strata control, machine utilization and others.

REFERENCES

1. McPHERSON, HJ., BRUNNER, DJ., An Investigation into the Ventilation Characteristics of a Longwall District in a Coal Mine, U.S., Department of Energy, September, 1983, 52 p.

2. CREEDY,D.P., and KERSHAW, S., Investigation of Firedamp Emission at Harworth Colliery, Report ER(88)5, British Coal HQTD.

3. BROWNING, E.J., Environmental Aspects of Harworth Deep Soft Workings, British Coal HQTD, November 1988.

4. fflGHTON, W., BROWNING, E.J., Environmental Control and Design for the Future, Journal of the Institution of Mining Engineers, July 1988, pp. 7-12.