AN ANALYSIS OF THE DATA OBTAINED FROM VENTILATION STUDIES OF LONGWALL PANELS

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With the trend in the coal mining industry pushing towards improved productivity and greater production, the number and size of longwall panels is increasing rapidly. The development and mining of large longwall panels causes unique problems in the provision of adequate ventilation at the working faces. Because of the transient nature of the longwall panel, and the difficult field conditions for ventilation measurements, detailed pressure and volume surveys around the longwall circuit are often not conducted. This paper examines data collected from ventilation studies of longwall panels at nine mines. The variation in airway resistance, ventilating pressure and airflow is examined and compared with specific factors such as airway dimensions, ground conditions and support type used. The highest resistance airway in longwall mines is typically the longwall tailgate, which often represents the only unregulated split in the ventilation network.

INTRODUCTION

To date there have been few studies devoted to the determination of typical resistance values and frictional factors for longwall panels. Traditionally, mine ventilation planning has been conducted by selecting suitable friction factors, and then determining expected resistance values for future mine airways based on proposed airway geometry. The main drawback with this approach is that published friction factors are typically derived from work conducted by the U.S. Bureau of Mines in the 1920’s and 1930’s (McElroy, 1935). These friction factors were mainly developed from measurements taken in metal mines, and their application to coal mines is questionable due to the variation in typical airway geometry, roughness and ground support between hard rock and soft rock mines. More recent work was conducted by Kharkar et al. (1974) on the determination of typical friction factors for U.S. coal mines, and this work was published by Hartman in the second edition of his ventilation textbook (1982). A more recent study was conducted by Wala, in association of the U.S. Bureau of Mines (1991), which determined typical coefficients for airway resistance and Atkinson friction factors for Kentucky coal mines. McPherson (1993) provides a more detailed list of friction factors in his textbook, which have been compiled from a combination of reported tests, and the results from numerous unpublished ventilation surveys. Friction factors are listed for both hard and soft rock mines, and typical values are provided for a longwall faceline with steel conveyor and powered supports. However, none of these references provide detailed empirical data for ventilation engineers who wish to establish resistance values for entire longwall panels. While the determination of resistance for the headgate entries may be simple, evaluating the resistance of the longwall and tailgate sections can be considerably more complex. It is necessary to not only consider the frictional losses of the air moving around the panel, but also the shock losses encountered by the air as it enters...
and exits the longwall faceline. In addition, the tailgate entry of the panel is frequently unlike any other airway in the mine. The high stresses can result in an airway that is in poor condition, requiring timber cribbing, or other roof support, for the entire length of the entry.

The number of mechanized longwall panels in the U.S. has increased considerably over the last decade, and the demand for reliable empirical data has grown accordingly. To the authors’ knowledge, there have been no publications that provide an analysis of the data collected from ventilation studies of longwall panels. This work presents typical measured data for use by engineers for modeling proposed longwall panels.

GENERAL THEORY

The determination of frictional pressure drop in mine airways may be obtained from the following relationship:

\[ p = fL \frac{\text{Per}}{A} \rho \frac{u^2}{2} \]  \text{(Pa)}

\[ f = \text{Chezy Darcy coefficient of friction} \]
\[ \rho = \text{Air density (kg/m}^3\text{)} \]
\[ \text{Per} = \text{Airway perimeter (m)} \]
\[ u = \text{Air velocity (m/s)} \]
\[ A = \text{Area (m}^2\text{)} \]
\[ L = \text{Length (m)} \]

This is a form of the Chezy-Darcy (also known as Darcy-Weisbach) equation, and is applicable to circular and non-circular airways and ducts. The Chezy-Darcy coefficient of friction (dimensionless) varies with respect to Reynolds Number, the trend of which is plotted on the Moody diagram. The Chezy-Darcy equation was adapted by Atkinson to give the following, commonly used, Atkinson Equation:

\[ p = kL \frac{\text{Per}}{A} u^2 \]  \text{(Pa)}

The Atkinson friction factor (k) is a function of air density, and is computed as the product of the Chezy-Darcy coefficient of friction and the air density, divided by a factor of two. Since the Chezy-Darcy coefficient of friction is dimensionless, the Atkinson friction factor has the units of density (kg/m\(^3\)). The Atkinson equation may be expressed in terms of the Atkinson resistance (R) for the airway, where:

\[ R = \frac{p}{Q^2} = kL \frac{\text{Per}}{A^3} \]  \text{(Ns}^2/\text{m}^8\text{)}
The first section of this equation, relating frictional pressure drop and quantity to resistance, is known as the Square Law. This important relationship is used to establish resistance from measured pressure and quantity data. The second section of the equation is used to determine resistance from typical Atkinson friction factors, and known or proposed airway geometry. It should be noted that the frictional pressure drop term in the Square Law is directly proportional to air density, as is the Atkinson friction factor. Hence, the Atkinson friction factor that is applied must be adjusted for actual mine air density.

When using the Atkinson friction factor it is important to remember that the factor is not constant for a given airway, but varies with Reynold’s Number. However, in mine ventilation it normal to assume that the Atkinson friction factor is constant, regardless of the flow regime. This is because for fully turbulent flow (which is typically the case in mine ventilation) the friction factor is a function only of the relative roughness of the airway. Where the relative roughness of the airway is defined as the height of the airway asperities \( e \) divided by the hydraulic mean diameter \( d = 4A/Per \). The Von Kármán equation gives the relationship for Atkinson friction factor and relative roughness for fully turbulent flow:

\[
f = \frac{2k}{\rho} = \frac{1}{4 \left[ 2 \log_{10} \left( \frac{d}{e} \right) + 1.14 \right]^2}
\]

From this equation it is apparent that for airways with the same surface roughness (asperity height), but different hydraulic mean diameters, the Atkinson friction factor will vary. Hence, as the airway hydraulic mean diameter increases, and all other conditions remain the same, both the relative roughness and the Atkinson friction factor will decrease. However, this change in Atkinson friction factor is usually small, and is often not discernible from field measurements. If an example airway is taken which has an average asperity height of 50 mm, and dimensions of 2 m by 6 m, the Atkinson friction factor at standard density is 0.0068 kg/m^3. If a second airway is considered which has the same surface roughness, but has dimensions of 3 m by 6 m, the Atkinson friction factor drops to 0.0061 kg/m^3 at standard density. Hence, for this example a 50% increase in flow area results in only 10% change in the Atkinson friction factor. Due to the relatively small changes in airway dimensions measured during the study, and the considerable scatter in Atkinson friction factor values obtained from the data, the change in Atkinson friction factor due to variation in relative roughness was ignored.

**LONGWALL VENTILATION SURVEY TECHNIQUES**

For each mine the measured pressure and quantity data were used to develop ventilation networks, which were modeled and manipulated using a commercially available ventilation network simulation computer program (VnetPC for Windows). The longwall panel represents just one component of the system, however, it is often the only open split in the network, and it is therefore important to accurately model this component.
Resistances were evaluated from measured pressure and airflow data using the Square Law relationship. The air quantity surveys consisted of the measurement of mean air velocities and airway cross-sectional areas at predetermined locations throughout the longwall panels. A rotating vane anemometer attached to an extendible rod was used to traverse the airways for measurement of the mean air velocity. Traverses were repeated until two readings were obtained within ±5%. The airway cross-sectional areas were measured using steel tapes. The air quantities at each station were computed as the product of the air velocity and the airway cross-sectional area. The airflow quantities were checked in the field for adherence with Kirchhoff's First Law, namely that the sum of airflow entering a junction was equal to the sum of airflow leaving the junction (in practice this is within ±5%). The frictional pressure drops around the longwall panels were determined using the gauge-and-tube technique. The gauge-and-tube (or trailing hose) method allows direct measurement of frictional pressure differentials using a manometer connected into a length of tubing, the ends of which are connected to the total pressure tappings of pitot-static tubes. Static pressure drops were taken across regulators, doors and stoppings wherever possible. The pressure differential data were checked for adherence with Kirchhoff's Second Law, namely that the sum of the pressure drops around the longwall circuit equate to zero (in practice to within ±10%).

The majority of the longwall panels were surveyed when the longwall shearer was operating. To ensure maximum airflow stability it is preferable that the longwall is idle, however, most of the ventilation surveys were conducted during a time when the longwall was in operation. Pulling the pressure tubing across the longwall faceline is complicated by the movement of the shields, however, if the measurements are taken rapidly, and the tube is routed carefully along the shields, the measurements can be taken with no disruption to production. Mean air velocities are extremely difficult to measure across the actual faceline, and a more reliable value is often obtained by measuring the total airflows at the headgate and tailgate junctions.

GENERAL DESCRIPTION OF THE SURVEYED MINES

The data presented in this paper were collected from ventilation studies at nine longwall mining operations. Figure 1 shows four line diagrams representing the different types of longwall panels that were surveyed. The longwall configuration for each of the nine mines is represented by one of these general configurations.

Two of the mines employed a wrap-around or “U” type ventilation system shown on Sketch A. This design has the advantage of restricting airflow movement through the gob. This bleederless system is simple, and is generally used in those mines that are not particularly gassy, but which are susceptible to spontaneous combustion. Three of the mines that were surveyed utilized a “U” type ventilation system for the longwall with a back bleeder. This design is shown on Sketch B. The back bleeder allows some of the air to be vented around the gob behind the longwall to dissipate gas away from the faceline to either a dedicated raise or main return. The back bleeder acts to ventilate both the current gob area and the seals from previous panels. One mine used a “U” type ventilation system for the longwall while maintaining a bleeder solely around the current gob. This design is shown on
Sketch C. For this particular panel two entries were maintained on intake along the headgate. This was the first panel in a new longwall block, and consequently an intake split could be maintained along the tailgate, which was unaffected by previous panels. This intake split was maintained to allow diesel equipment to travel the tailgate up to the vicinity of the faceline, which facilitated the installation of tailgate support. As mining progresses to adjacent panels, this outside tailgate will be used to return the bleeder air from behind the panels to the main return. Three mines utilized a flow-through, or “Z” type ventilation configuration. This design is shown on Sketch D. For these mines the gas flow from the strata was considerable, and emphasis was placed on the control and isolation of all the return air. The return air from the longwall region is directed to a dedicated bleeder raise through both the gob and the bleeder entries. Using this method, significant amounts of air are drawn through the previously mined panels which ensures adequate gas dissipation.

Figure 1. Line diagrams showing general longwall configurations for the different mines
EXAMINATION OF SURVEY DATA

Figure 2 is a sketch showing one of the surveyed longwall panels. This illustration is not to scale. Certain measured airflow and frictional pressure drop data have been marked on the sketch. To simplify the figure measured frictional pressure drop data are shown for only the more important airways. During the survey many more measurements were taken throughout this region in order to correctly evaluate resistances for all the main airways and leakage paths.

Multiple airflow measurements were taken along the mains and through the longwall headgate in order to determine the leakage characteristics for this component of the ventilation system. This data is for a mine utilizing a “U” type ventilation system with a back bleeder, as shown in Figure 1 (B). The bleeder is used to ventilate the back seals of previously mined panels and exhausts through a dedicated raise. Table 1 shows the results from the balancing of the measured airflows throughout the longwall panel. This exercise uses Kirchhoff’s First Law to ensure that the sum of the intake and exhaust airflows balance within an acceptable error for the main junctions.

![Figure 2. Measured airflow and frictional pressure drop data for a longwall panel](image)
### Table 1. Balancing of measured airflows using Kirchhoff’s First Law

<table>
<thead>
<tr>
<th>Junction Location</th>
<th>Total Intaking (m$^3$/s)</th>
<th>Total Exhausting (m$^3$/s)</th>
<th>Error of Intake (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>281.2</td>
<td>284.5</td>
<td>1.2</td>
</tr>
<tr>
<td>B</td>
<td>238.4</td>
<td>234.9</td>
<td>1.5</td>
</tr>
<tr>
<td>C</td>
<td>59.4</td>
<td>59.3</td>
<td>0.2</td>
</tr>
<tr>
<td>D</td>
<td>45.5</td>
<td>48.9</td>
<td>7.5</td>
</tr>
<tr>
<td>Entire Area</td>
<td>223.9</td>
<td>230.4</td>
<td>2.9</td>
</tr>
</tbody>
</table>

The closure at junction A, indicated on Figure 2, is approximately 3.3 m$^3$/s, which represents an error of 1.2% of the total intake volume. This same exercise is conducted for each main junction to ensure that the measured airflow data is acceptable. For this mine, the only area where the measured data does not close to within ± 5%, is area D. This junction examines the balance of air intaking the longwall faceline, to that exhausting via the belt entry, tailgate and the back bleeder. An error of 7.5% exists at this location, but considering the difficult measurement conditions near the faceline, and the fluctuations caused by the operation of the longwall equipment, the error of 3.4 m$^3$/s was considered to be acceptable. A final check on the airflow intaking and exhausting the entire area should always be conducted, which provided a 2.9% error for this mine.

To ensure closure of the longwall frictional pressure loop, it is necessary to apply Kirchhoff’s Second Law to the data shown on Figure 2. By summating the frictional pressure drops along the headgate, across the longwall faceline, and down the tailgate, a total value of 231.2 Pa is obtained. To close the loop, the frictional pressure drop from junctions A to B must be totaled, while continuing around the loop in the same direction (clockwise). The total frictional pressure drop from points A to B is -244.4 Pa. Hence, the error on the loop is -13.2 Pa, or approximately 5.7%. This error is within the ± 10% criteria specified for the frictional pressure loops. In practice many smaller pressure loops would be closed using frictional pressure drops across stoppings and along other main airways (using additional data not shown on Figure 2).

### RESULTS FOR THE LONGWALL FACELINE

The majority of the air passing across the longwall faceline travels in the void formed by the fresh wall of coal, top of the support shields, and the primary rams on the shields. A small amount of air does pass through the area between the rams and the back of the shields at the gob, however, this area is generally much smaller than that adjacent to the wall. The leakage of air from or onto the longwall faceline is dependent on the resistance of the gob and the differential pressure maintained across the caved zone.

As the air enters the longwall faceline there is a shock loss encountered by the air as a result of the multiple changes in airflow direction and airway dimension. The intake air will typically travel along the center airway(s) of the headgate until it reaches the location of the last open cross-cut. At this point the intake air will turn abruptly into the cross cut, travel through the cross cut, and then turn into the
belt entry. The intake entry, inbye of the last open cross cut, will typically be regulated using a curtain hung across the airway. Some air may be routed around the back of the longwall panel to provide ventilation for personnel and to remove gas, however, most of the air will be forced into the belt entry at the faceline. For the majority of mines, as the intake air exits the last open cross cut, into the belt entry, the airflow will split. Some air will exhaust the headgate via the belt entry, while the remainder will be directed across the faceline. In order to enter the faceline the air has to move around various obstructions within the belt entry, and then turn at the first shield. To empirically compute the total shock loss of the air from the end of the intake airway at the headgate, to the first shield at the longwall faceline is extremely difficult, and at best is an estimate. In order to facilitate the estimation of this shock loss, survey data was examined to provide an average value and range for this resistance.

The shock loss of the air entering the longwall faceline may be considered as the first of three stages of resistance. The second stage is that of the actual faceline itself. To simplify the calculations the resistance was assumed to be linear across the breadth of the panel. In practice the resistance per length will actually vary according to the movement of the shearer and the associated positioning of the shields. However, without conducting considerably more detailed measurements to isolate various sections of the faceline, this change in resistance cannot be accurately determined.

The final section of the longwall is at the transition point into the tailgate. This “tail” section of the longwall is perhaps the hardest to empirically compute the resistance for. The constriction and shock loss varies considerably according to many factors, including; tailgate configuration and support, ground conditions, longwall mining technique and bleeder configuration. Because of these many factors, it is difficult to determine an average shock loss or equivalent length from measured data. For this study “best” and “worst” case resistances for the shock loss were determined from the field measurements, providing a range for use in future planning.

Faceline with no Shock Losses

Figure 3 shows a graph of resistance per length plotted against wall height for the measured longwall faces. This graph provides resistances for the actual faceline section, and does not include any shock losses. Because of the irregular cross section of the longwall it is considerably simpler to determine resistance directly from resistance per length, rather than using an equivalent Atkinson friction factor. The graph is plotted on a logarithmic scale on the y-axis, such that a complete range of wall height may be plotted from 1.0 m through 4.5 m. A definite trend is visible, formed by plotting resistance per length against wall height, and a trend has been fit to the data. Using the equation for this power curve \(y = 99.528 x^{-3.6731}\) the resistance per length can be obtained for any proposed wall height.
There is a considerable degree of scatter with the raw data, which is not that apparent due to the logarithmic scale, however, the data is well distributed throughout the length of the trendline. Perhaps one of the more interesting results from the longwall ventilation surveys is that it is possible to fit a trendline to the data. Even though it is reasonable to assume that the resistance should increase as the wall height decreases, the impact that the shield type, general longwall infrastructure and shearer movement have on resistance do not appear to be that significant.

Longwall Shock Losses

Figure 3 may be used to determine an approximate resistance per meter for a certain longwall height. This value may then be multiplied by the proposed longwall width to obtain a resistance value for the actual longwall faceline section. However, this will not incorporate the shock losses encountered by the air as it enters and leaves the faceline. The simplest method to incorporate these shock losses is by adding an equivalent length to the actual faceline length prior to multiplying by the resistance per meter.

Based on the longwall data collected from the ventilation surveys, resistances for the shock losses encountered by the air as it enters and exits the faceline were evaluated. Equivalent lengths were determined by dividing these resistances by the measured resistance per meter for the unobstructed longwall faceline. The results from this study are provided below:

- Entry shock loss: Range = 16.4 m - 60.1 m Average = 33.5 m
- Exit shock loss: Range = 25.7 m - 88.5 m Average = 61.5 m

Figure 3. Graph of resistance per length against measured wall height for the longwall faceline
There is a considerable variation in the shock loss encountered by the air at the longwall faceline. There is no discernible correlation between equivalent length and wall height, with the shock loss generally being dictated by the condition and constriction for each specific case. Unless information is available suggesting that the transition shock losses on the longwall faceline will be either lower or higher than “normal”, it is suggested that the average values are used for planning future longwall panels.

RESULTS FOR THE HEADGATE ENTRIES

Airflow and frictional pressure drop measurements were conducted along the length of each headgate intake entry. Based on the data collected from these measurements, resistance per length and Atkinson friction factors were determined for the eleven panels. Results showing resistance per meter plotted against entry height are given in Figure 4.

Examination of the graph shows that the resistance per length data for the headgate intake entries is rather scattered, and it is difficult to fit a precise trendline through the points. Under ideal conditions, where the entry does not change in shape or size throughout the entire length of the gateroad, there is no variation in surface roughness along the entry, and there is no disruption to airflow throughout the period of measurement, the resistance per length should be the same throughout the entry. During the survey this was not case, and the resistance per length and Atkinson friction factor was found to vary along the entry. For this study average values were determined for each mine. Some of the scatter probably results from the inaccuracies of measurement, however, the main reason is due to the variation in surface roughness at the different mines. For all the gateroad intake entries that were measured, the only support used was roof bolting. However, the mining method, general condition of the surrounding ground, quantity of fallen debris against the ribs, and the bolting, meshing and/or strapping techniques will certainly affect friction factor and resistance per length. In all cases the entries were driven using continuous miners, however, examination of the entries showed that variation in equipment type, size and operator technique had a substantial impact on surface roughness.
During the ventilation surveys the airway roughness at each mine was not measured. For this reason it is not possible to try to fit multiple curves to the data, and one power curve was best fit through the eleven points. This curve can be used to provide an approximate value for resistance per meter based upon entry height (for a standard 6.1 m wide roadway). However, perhaps the most accurate method is to allocate an Atkinson friction factor based on the expected condition for the entry.

A statistical analysis on the measured Atkinson friction factor for the headgate intake roadway at each mine produced the following results (each Atkinson friction factor is provided at standard density):

- Average Atkinson friction factor: 0.0056 kg/m³
- Standard deviation for the population (11 samples): 0.0018 kg/m³
- 95% Confidence range: 0.0045 to 0.0066 kg/m³
- Actual data range: 0.0036 to 0.0088 kg/m³

The results indicate that it is difficult to apply a mean value with any degree of confidence, which is apparent by the scatter of the resistance per length data on Figure 3. Hence, the recommended technique in modeling a proposed headgate entry is to make a decision as to the condition of the roadway and use a value within the actual data range shown above. The measured value of 0.0036 kg/m³ is very low and should only be used for exceptionally smooth entries maintained free of debris and obstructions. The average value of 0.0056 kg/m³ may still be considered low if compared to references determined from measurements in metal mines (McElroy, 1935). However, if this value is compared against an average value measured by Wala (1991) for straight, clean, unobstructed, roof-bolted entries driven using a continuous miner in Kentucky coal mines, exactly the same number is obtained. The peak value of 0.0088 kg/m³ should be used if the proposed entry is to be driven in poor ground, where additional debris, increased surface irregularities, and extra bolting/meshing/banding is likely.
RESULTS FOR THE TAILGATE ENTRIES

For those mines that used a wrap-around tailgate ventilation design, frictional pressure drops were measured throughout the length of the tailgate. For the nine mines surveyed, the majority used timber cribbing to support the roof in the tailgate. Generally two rows of 1.2 m wide cribs were used, placed on 2.4 m centers. In order to provide an estimate for the average resistance per length for this timber cribbing, a graph has been plotted of resistance per length against entry height. This graph is shown on Figure 5. Of the eleven longwall panels surveyed, only six used a single timber cribbed tailgate entry with a wrap-around ventilation system, therefore only six points are plotted. Those mines surveyed that were particularly gassy did not employ a wrap-around ventilation system, and generally used dedicated bleeder systems to maintain high differential pressures across the gob. Under these conditions the tailgate was kept as a low volume intake up to the faceline, and there was generally not enough airflow to provide measurable frictional pressure drops (or at least large enough values to enable accurate measurements).

![Figure 5. Graph of resistance per length against entry height for single tailgate entries supported by two rows of timber cribs (based on cribbing dimensions 1.2 m wide on 2.4 m centers, and 6.1 m original entry width)]](image)

Because of the low number of data points, the trendline fitted to the data in Figure 5 is at best a rough approximation. The data are distributed across the graph from a roof height of 1.7 m to 2.9 m. The data can be seen to follow a definite trend, however, tailgate resistance is very mine specific. Even if two mines drive the same size entry, and use the same method of tailgate support, the deterioration of the tailgate, and hence the resistance, may vary considerably. The weight of the overburden, competency of the overlying ground, and the age of the airway mainly dictates the condition of the tailgate. For these reasons it is often preferable to use an equivalent Atkinson friction factor for planning the resistance of the tailgate entry.

Applying an equivalent Atkinson friction factor to the tailgate allows the basic geometry of the airway to be used, without having to adjust the area and perimeter for the supports. This approach provides an approximate value, whereby the Atkinson friction factor is grossly inflated to account for
the obstruction of the supports, and the increased perimeter. It should be noted that certain parameters that may be derived from the equivalent Atkinson friction factor, such as the surface roughness, would be meaningless. The equivalent Atkinson friction factor is provided to allow rapid estimation of tailgate resistance based on a range of entry conditions.

A statistical analysis on the equivalent Atkinson friction factor for each mine produced the following results (each friction factor is provided at standard density):

- Average equivalent Atkinson friction factor: 0.1142 kg/m$^3$
- Standard deviation for the population (6 samples): 0.0355 kg/m$^3$
- 95% Confidence range: 0.0857 to 0.1426 kg/m$^3$
- Actual data range: 0.0726 to 0.1808 kg/m$^3$

As expected the statistical analysis indicates that there is a wide variation in the data. This is the result of the variation in the condition of the tailgate. It is recommended that if the ground condition is unknown, the average value of 0.1142 kg/m$^3$ is used for the equivalent Atkinson friction factor for a timber supported tailgate entry (1.2 m crib width). If the mine has very little overburden, and the roof is competent, a figure as low as 0.0726 kg/m$^3$ can be applied. Conversely, if the mine has a considerable depth of overburden, and the roof is in poor condition, a value as large as 0.1808 kg/m$^3$ is applicable. However, it should be noted that the latter value was measured in a mine that had an old tailgate that was in extremely poor condition. Based upon the data collected, there was no discernible correlation between Atkinson friction factor and whether or not the two rows of timber cribs were staggered along the entry.

In addition to timber cribbing, measurements were also taken along one tailgate that used pillar type supports. These supports were 0.6 m in diameter, with roof caps of 0.4 m by 0.8 m, and were installed in two rows on approximately 1.8 m spacing. The entry was in average to poor condition, and the following results were obtained for this configuration:

- Equivalent Atkinson friction factor: 0.0666 kg/m$^3$
- Entry height: 2.8 m
- Resistance per meter: $2.883 \times 10^{-4}$ Ns$^2$/m$^8$

Surprisingly the resistance per meter is high for the entry height, and plots right on the curve shown on Figure 5. This high resistance undoubtedly results from the poor condition of the entry, and shows that high resistances may still be experienced even with substantially smaller supports. This is apparent from the considerable range of equivalent Atkinson friction factor measured for the timber cribbed entries, as discussed previously.
SUMMARY

As the number of longwall panels increases globally, the demand for reliable empirical data to aide in ventilation planning and design has grown accordingly. Presented in this paper are the results from full ventilation surveys of eleven longwall panels at nine different mines.

The results for this study are split into three sections. These comprise of results from measurements across the actual faceline, and measurements along the headgate and tailgate entries. The results for the faceline measurements are provided on Figure 3. This graph plots resistance per meter (at standard air density) against measured wall height. The equation for the trendline fitted through the data is:

\[
\text{Resistance per Meter} = 99.528 \left[\text{Wall Height}\right]^{-3.6731} \quad \text{(Ns}^2\text{m}^9 \times 10^{-4})
\]

This equation may be used to determine an average resistance per meter for a longwall faceline based only on the proposed height of the wall. The impact that the shield type, general longwall infrastructure, and shearer movement have on the resistance could not be determined from the measurements, but did not seem to be significant when compared against the wall height. An Atkinson friction factor was not determined for this area of the mine because of the difficulty in measuring an accurate faceline area.

Equivalent length values were determined for the shock losses encountered by the air as it enters and exits the longwall faceline. These values should be added to the actual faceline length, and the total length multiplied by the resistance per meter. The average equivalent length for the entry shock loss was determined to be 33.5 m, with a range of 16.4-60.1 m. The average equivalent length for the exit shock loss at the tailgate was determined to be 61.5 m, with a measured range of 25.7-88.5 m. Engineering judgment should be used to estimate how constricted the longwall transition areas are, and a value within these ranges should be selected.

Resistance per meter data are also plotted for the headgate and tailgate entries (Figures 4 and 5). A 6.1 m entry width is assumed for both of the figures. These graphs may be used to estimate an average resistance per length. However, the scatter on both of the graphs makes it difficult to fit a precise trendline through the data points. Variations in mining technique, roof support, competency of the overlying ground, and the age of the airway resulted in large discrepancies in resistance per length. For this reason typical Atkinson friction factors were determined for both of these entries. These results are provided in Table 2.
Table 2. Results of Atkinson friction factor for headgate and tailgate entries

This table provides a range of Atkinson friction factors for each airway. The Atkinson friction factor should be selected based on known or estimated conditions for the entry.

By applying suitable values for the resistance per length, equivalent length and Atkinson friction factor, it is possible to rapidly obtain an estimate for the main airways around a longwall panel. This empirical data is valuable when establishing the ventilation requirements for proposed longwall panels, and may be directly input into ventilation simulation programs. However, it is important to remember that every mine is unique, and that the Atkinson friction factor, and resistance per length, will vary according to specific conditions. Hence, it remains important to update calculations and ventilation computer models with measured data as soon as feasibly possible.

REFERENCES


