A Comparison of Predicted Performance of Auxiliary Ventilation Ducting System

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ABSTRACT: The main objective of this study is to examine some modern forms of auxiliary ventilation fabric ducting and the efficiency of construction forms. Forcing auxiliary ventilation systems employing circular fabric ducting have been examined. Leakage of air from ducting is affected by ducting material and construction methodology (such as welded or sewn), quality of installation, number of joints, total length, pressure differences between the inside and outside and diameter. It has been found that the best ducting system with welded construction can have up to two times less leakage as compared with some ducting systems with sewn construction. Findings from this study include that examples of welded type ducting with less leakage than sewn is able to deliver more air that provides a greater degree of safety for employees in working areas. Welded type ducting requires less fan energy to deliver more air hence delivering increased air cooling power or dilution of contaminants. Using a ventilation ducting system with a lower leakage coefficient results in saving in capital and operating cost as in most situations a smaller fan can be used.

1 INTRODUCTION

Mine intake and return airways are used to ensure the continual circulation of fresh air. Auxiliary ventilation is required for dead end workings such as development headings, draw points and some stopes. The most common form of auxiliary ventilation is a fan and ducting system that is re-locatable as the mine develops. The most dynamic form of ducting is some form of fabric or canvas due to its lightweight and ease of installation. However the porous nature of these ducting materials results in leakage.

Leakage of air from ducting is affected by the following factors:

- Ducting material and construction methodology (i.e. welded or sewn)
- Quality of installation
- Number of joints
- Total length of ducting
- Pressure differences between the inside and outside of the ducting
- Diameter of the ducting

Using a ventilation ducting system with a lower leakage coefficient will result in a direct saving on fan operating cost compared with a flexible ventilation ducting system with a standard or higher leakage coefficient. Similarly, using a ventilation ducting system of a lower leakage coefficient with the same kW rated fan will supply more airflow to the mine face as the system has less leakage. Other savings or advantages associated with the use of such a system include

- Potential capital saving on auxiliary fan as smaller fan can be used.
- Potential saving both on capital and operating costs of ventilation fan.
- Potential savings on ventilation airways, raises, shafts and similar.
- Ease in providing a working place that complies with mine health and safety standards.

Using a ventilation ducting system with a lower leakage coefficient represents a sound solution to new challenges faced by the industry for increasing demand of increased quality and quantity of air to be delivered to working faces due to higher production schedules and stricter mine health and safety regulations within the Australian mining industry.

A brief review of prediction techniques for determination of losses due to leakage and friction has been undertaken. The main objective of this paper is to examine some modern forms of auxiliary ventilation fabric ducting and the efficiency of construction forms. Forcing auxiliary ventilation systems employing circular fabric ducting have been examined.

2 THEORY OF LEAKY DUCT

Early investigations of auxiliary ventilation ducting leakage performance assumed that the problem was purely practical and could be eliminated through proper installation and maintenance. Greater emphasis was placed on theoretical studies as it became apparent that some degree of leakage is inevitable even under the best conditions. These studies primarily focused on mathematical analysis of ducts with uniformly distributed leakage resulting in complex integrals that required numerical solutions. More recent work assumes the existence of discrete leakage paths and analyses the leaky duct as a ventilation network.

2.1 *Magnitude of Leakage*

Many mining operations classify the quality of auxiliary ventilation ducting in terms of the percentage or volumetric leakage that occurs over a 100 m interval. This principle is scientifically unsound as variations in the air pressure along the length of the duct are not considered. A scientific method for expressing the magnitude of leakage from a ventilation column employs a leakage coefficient, a concept developed by the British National Coal Board. The leakage coefficient, L_C, is defined as the volume of air in m^3/s that leaks from a 1,000 m length duct subjected to a uniform pressure of 100 Pa.

Calculation of the leakage coefficient of a duct from first principles is a highly complicated mathematical exercise as in practice ducts are never under uniform pressure. The National Coal Board leakage nomogram was developed to determine the leakage coefficient as referenced in metric units by Le Roux (1979). Robertson and Wharton (1980) developed a good approximation for the leakage coefficient.

$$L_C = \frac{3(Q_1 - Q_2)(P_1 - P_2)}{2L\left(P_1^{1.5} - P_2^{1.5}\right)} \times 100 \times 1000^{0.5} \tag{1}$$

where L_C = leakage coefficient; $Q_{1;2}$ = airflow quantities at the upstream or downstream points; $P_{1;2}$ = pressure at the upstream or downstream points; and L = distance between upstream and downstream points.

The pressure is always greatest adjacent to the fan and so a duct section near the fan will leak significantly more than a duct section further away. When the duct is extended the fan duty pressure will increase and leakage will increase from all sections of the duct. If two different sized columns are constructed and installed to equal standards it can be expected that the larger diameter duct will have a greater L_C on account of the increased area of the material seams and joints.

Other parameters commonly used to evaluate the performance of auxiliary ventilation columns are the volume and pressure increase ratios. The volume increase ratio is the volume rate handled by the fan over the actual volume reaching the working face. The pressure increase ratio is defined as the pressure required to deliver a specified quantity through the duct under leaky conditions over the pressure required to deliver the same volume under leakless conditions. Roberts (1960) stated that the volume ratio and the pressure increase ratio are both approximately equal and given by:

$$\frac{Q}{Q_o} = \frac{P}{P_o} = 1 + 0.7 L_C \sqrt{R} \times l^{0.67} \tag{2}$$

where Q = quantity handled by the fan; Q_0 = quantity actually delivered to the face; P = fan static pressure in the duct; P_0 = fan pressure required to deliver Q_0 to face under leaking conditions; R = duct resistance; and l = length of duct.

By re-arranging equation 2, L_C now can be calculated by knowing resistance constant, duct length, and air quantities at upstream and downstream measuring points.

2.2 *Mathematical Solutions*

Mathematical solutions have been proposed for duct leakages which take into consideration the pressure gradient along the duct. Using the assumption that leakage is uniformly distributed along the length of a duct Holdsworth, Prichard & Walton (1951) proposed that the variation in Q can be represented by various differential equations.

Holdsworth, Pritchard & Walton (1951) demonstrated the close correlation between experimentally derived leakage constants and theoretically predicted values for both forcing and exhausting ventilation. Similarly Metcalf (1958) obtained a volume and pressure increase ratio by dividing the length of duct into short intervals, each having an individual leakage resistance and the total length of duct having a combined leakage resistance.

A relationship between P_0 and P was established by considering the leakage quantities through the joints between individual duct lengths. The quantity of air can be determined by integrating the equation for leakage. A change in quantity due to leakage results in an immediate change in pressure. The pressure after "n" duct intervals can be determined by integrating this expression. Change in pressure will result in change in the quantity of leakage so a more accurate approximation for leakage is obtained.

2.3 *Summation of Discrete Leakage Paths*

Dzidziguri and Cholikidze (1977) proposed a method for the summation of discrete leakage paths for calculating the total air losses in long air ducts. Assuming that air leakage in the first 1 m of a duct is ΔQ m^3/s, and the initial quantity of air beyond the fan is Q_0 m^3/s, then a leakage coefficient can be described as $\delta = (\Delta Q/Q_0) \times 100$, (%). An equation can be derived for summing air leakages over an entire duct length. Sufficient accuracy can be obtained by considering only the first five to six terms. For low values of δ (0.4 -1.0%) three terms are sufficient with the error incurred being less than 2.0% (Dzidziguri and Cholikidze, 1977).

2.4 *Ventilation Network Analysis*

Vutukuri (1983) proposed that analyzing flow in a leaky duct is possible by assuming a number of discrete leakage paths and treating the leaky duct as a ventilation network. In Figure 1 air enters the duct and leaves either through leaky joints or via the exit of the ducting.

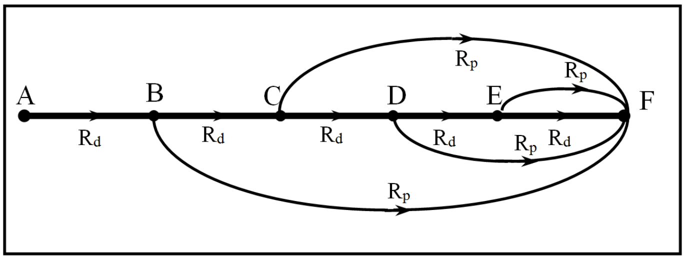

Figure 1. Vutukuri’s network analysis for leaky duct.

A number of assumptions have been made in the following ventilation network analysis equations proposed by Vutukuri (1983).

- Leakage paths have some resistance and the resistance coefficient of leakage paths (*Rp*) is the same (all joints and other leaks are made and maintained in the same fashion).
- The resistance coefficients of all duct sections are the same (*Rd*).
- The pressure outside the duct is assumed to be the same along the airway.

With a fan is installed at “*A*”, the intersection of the fan operating curve and the duct resistance curve gives the operating point data for the fan (Q_{AB}) and

$$Q_{AB} = Q_{BF} + Q_{BC} \tag{3}$$

and because these are in parallel

$$R_{BF}\,Q_{BF}^{\;2} = R_{BC}\,Q_{BC}^{\;2} \tag{4}$$

Using Equations 3 and 4 the leakage from B to F can be found.

$$Q_{BF} = \frac{Q_{AB} \times \sqrt{\dfrac{R_{BF}}{R_p}}}{\left(1 + \sqrt{\dfrac{R_{BF}}{R_p}}\right)} \tag{5}$$

This can be repeated in a similar fashion to find discrete values for all leakage paths. Using a computer program to calculate the leakage Vutukuri found that the results were within 2.0% of those obtained by the method developed by Holdsworth, Pritchard and Walton (1951).

2.5 *Duct Leakage Measurements and Prediction*

Gillies and Wu (1999) suggested a method of macroscopic investigation of air leakage and friction resistance of auxiliary ventilation ducting systems. Conceptual models that describe the leakage characteristics of auxiliary ventilation ducting systems were developed based on this information. Experimental methodology proposed relying on computer data acquisition has allowed the accuracy of measured values to be treated with a high degree of confidence.

Test work results confirm that ventilation ducting leakage is dependent on the ducting material, length and diameter and the pressure difference between the inside and outside of the ducting. The literature review performed identified a number of equations available for calculating the leakage and impedance of ducting. The equations for calculating leakage are complex and require a number of measurements, therefore an approximate solution was proposed and developed. The approximate equation is based on use of a leakage coefficient that was found to be in the form of

$$L_C = \left(a\;\; P_f\right) D^2 + \left(b\;\; P_f\right) D + c \tag{6}$$

Constants *a* and *b* are dependants on the ducting material and the quality of installation. Once these constants have been calculated for a specific type of ducting or provided by the manufacturer an approximate solution for the leakage coefficient can be found if the fan pressure and duct diameter are known.

An approximate solution for calculating the air delivered to the face via fan and ducting system was found by converting Robert's volume increase ratio empirical equation into metric form using British National Coal Board's Leakage Nomogram.

$$Q_o = \frac{Q_i}{1 + 7 \times 10^{-6} \times L_C \sqrt{R} \times l^{1.5}} \tag{7}$$

A comparison was undertaken between the equation developed in this study to find the air quantity delivered to the working face, Vutukuri's leakage prediction network analysis program and the British National Coal Board's leakage Nomogram. Vutukuri's network analysis approach is based on assigning a resistance coefficient to the leakage path analogous to the resistance of the duct and dependent on the joint construction and quality of installation. The results of this exercise are set down in Figure 2.

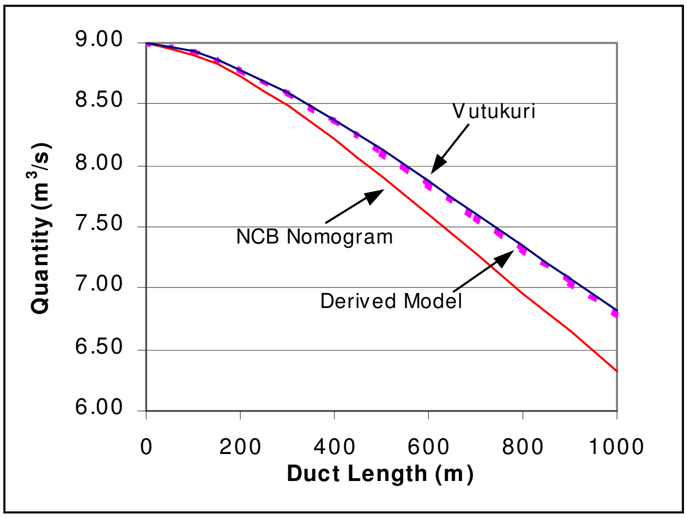

Figure 2. Comparison of prediction techniques.

The three comparison was made for the situations of 9m^3/s of air enters the ducting, the difference in pressure between the inside and outside of the ducting is 100 Pa, duct diameter is 915 mm, resistance of leakage paths per 100 m is assumed to be 10,000 Ns^2/m^8 and the leakage coefficient was calculated using Equations 6 and 7. This leakage coefficient was used in both the derived model and the British National Coal Board's leakage Nomogram to calculate the air exiting the ducting. The differences between the derived model over 1 km of ducting and the other two estimates are 0.4% for Vutukuri and 5.0% for British National Coal Board's leakage Nomogram.

3 MEASUREMENT OF DUCT LEAKAGE

Experimental methodology adopted for field ventilation duct leakage tests has been documented by Gillies and Wu (1999). Due to the high degree of req803uired accuracy and large amount of data electronic precision pressure transducers were used with a portable computer for data recording. Pitot-static tube traverses were conducted at strategic intervals along the length of the ventilation duct in order to measure the total and static pressures. From this information the velocity pressure and volumetric airflow rate through the duct at any specific location could be determined.

All tests were undertaken in the open air within the grounds of the Uunversity of Queensland Experimental Mine (UQEM). Metal clips and ropes were used to hang and support the ducting from catenary wire. The catenary wire was supported by a system of rigid metal supports set 8 to 10 m apart. Figure 3 shows a graphical representation of the location of the joints and metal pillars along the entire 80 m test length. A variable speed forward curve bladed centrifugal fan forced air along the ducting.

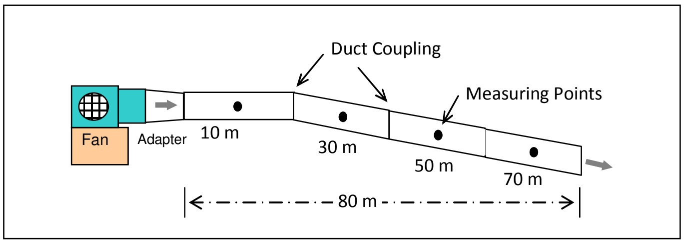

Figure 3. Location of joints and measuring points along the ducting 80 m traverses.

A Pitot-static tube connected to the pressure transducers was used to measure total and static pressures while manually recording data. Two digital pressure transducers were used. This apparatus is shown in use in Figure 4. This package has the ability to provide direct pressure results in any engineering units. The degree of accuracy that the sampling resolution of the transducers produced increases with higher velocities. The predicted error for velocities above 8 m/s is less than 0.25 %.

Figure 4. Pressure and temperature measuring and data recording equipment.

An equal area traverse method was used to measure the quantity of airflow at a given point. Circular ducts were divided into a number of concentric areas and readings taken at the center of each area along horizontal and vertical diameter arms. Five concentric areas were used for each cross section traverses. The center point of the duct was taken as a twenty first measurement point.

It was decided to take the traverses on both upstream and downstream sides of the joints. It must be noted that traverse points were not placed close to joints in order to avoid disturbance of airflow and as a consequence were located normally 5 m upstream and downstream of these locations. No measurements were possible immediately after the second joint as this section of the ducting was strung across a gully in rough ground. The points along the 80 m length of ducting where traverses were undertaken are illustrated in Figure 5.

Figure 5. Measuring apparatus, suspension and join during duct leakage measurements.

The quantity flowing through auxiliary ducting will depend upon the fan operating curve and the resistance of the system. The fan was set to operate at various speeds to obtain three different flow rates through the tested ventilation ducting system.

Once the auxiliary ducting had been hung points for incisions were located. An incision was made large enough for the positioning of the Pitot-static tube but small enough to limit leakage. The measurement procedure then proceeded as follows.

1. Transparent tubing pieces used to connect the transducers to the total and static Pitot-static tube ports were checked for cuts, dirt and water.
2. Dry bulb temperatures were taken at the inlet of the fan using a whirling hygrometer.
3. Atmospheric pressure was taken at the inlet of the fan using a pressure transducer.
4. The fan was turned on and the speed adjusted until the required velocity could be observing as a centre reading at the first ducting traverses point.
5. Two transducers were connected to the computer and the interface program activated.
6. The Pitot-static tube was inserted.
7. The head of the Pitot-static tube was positioned in the ducting by aligning the edge of the ducting with the corresponding mark on the Pitot-static tube stem. Once aligned the computer was prompted to take readings via an operator switch.
8. A total of 22 measurements were taken in the horizontal traverses. This exercise occurred three times to ensure repeatability of results.
9. After completing the measurements ducting was sealed using cloth tape.
10. Steps 5-9 were repeated at all measurement points along the ducting.

All static pressures measured at each measuring station were averaged and the difference between this pressure value and the atmospheric pressure measured at each station assumed to represent the static pressure for this cross section. The following equation is given by Browning (1983) for the calculation of resistance constant of ventilation ducting.

$$R = \frac{P_1 - P_2}{L} \times \left(\frac{5}{2Q_1 + 3Q_2} \right)^2 \times 100 \qquad (8)$$

where R = resistance constant; $P_{1;2}$ = pressures at the upstream or downstream points; $Q_{1;2}$ = airflow quantities at the P_1 or P_2 points; and L = distance between upstream and downstream points.

This resistance constant was then converted to Atkinson's friction factor, K, using the average air densities measured at the beginning of each measurement series. The ventilation duct was divided into a number of intervals each of which contained a different arrangement of straight section, joints and bends. This allowed the friction resistive properties of the material to be determined and equivalent friction factors for various anomalies to be determined. Standard data processing techniques were implemented with obvious errors being eliminated and the remaining values averaged.

4 CHARACTERISTICS OF VENTILATION DUCTING SYSTEMS

Over the years, various types of ventilation ducting systems have been tested for their performance characteristics in term of their friction factors and leakage coefficients. The following table shows the performance characteristics of various selected ducting construction types (two welded and two sewn) of ventilation ducting systems that have been tested.

Table 1. Performance characteristics of various construction types of ventilation ducting systems tested.

Type (size)	K	L_C	Comments
Duct A (610 mm)	0.00259	0.248	Welded duct; high performance ducting.
Duct B (610 mm)	0.00337	0.320	Welded duct; standard performance ducting.
Duct C (610 mm)	0.00373	0.571	A durable material from a single length of material joined by a single line of stitching at the top attachment flange.
Duct D (610 mm)	0.00254	0.570	A lightweight material with length of material joined by a single line of stitching at the top attachment flange.

These ducting systems were tested with various duct diameter sizes which affect the leakage characteristics of the systems. The larger diameter ducting has greater leakage. Le Roux (1990) proposed that this is to be expected on account of the greater surface area of the seams and joints. Therefore it is important to convert all the leakage coefficients listed in the table above into ducting diameters of interest using the leakage prediction equations derived by Gillies and Wu (1999), for example 1,067 mm, and 1,400 mm. The following table shows the converted leakage coefficients for the six ventilation ducting systems.

Table 2. Predicted leakage coefficients for various construction types of ventilation ducting systems tested.

Ducting Type (duct size)	Friction Factor K, Ns^2/m^4	Leakage Coefficient L_C, $m^3/s/100m$ for various ducting diameter sizes		
		Original	1,067 mm	1,400 mm
Duct A (610 mm)	0.00259	0.248	0.342	0.401
Duct B (610 mm)	0.00337	0.320	0.446	0.522
Duct C (610 mm)	0.00373	0.571	0.747	0.875
Duct D (610 mm)	0.00254	0.570	0.745	0.873

It should be noted that all predicted operational performances of the forcing fan and ventilation ducting systems stated in this study are derived based on the standard ventilation duct leakage test results which were carried out under a simulated mine ventilation ducting operational condition that takes into account minimum bends and kinks in the brand new ducting and with no obvious wear and tear or cut holes. Therefore when assessing the performance of a fan and ducting system installed under harsh operational condition at mines, extra bends, kinks, wear and tears or cut holes could seriously affect the performance of the fan and ducting system.

5 PREDICTED PERFORMANCE OF THE VENTILATION DUCTING SYSTEMS

Mathematical modelling has been undertaken to predict the performance of welded and sewn ventilation ducting systems by providing some indications of differences in ventilation flows to a mining face. These models were for 1,067 mm and 1,400 mm ventilation ducting over 300, 500 and 700 m length lengths.

Performance information sought are resulting fan pressure, leakage loss and the air flows at the outlets of the ducting. Ventilation airflow simulation modelling using "Ventsim" program and Excel spreadsheets have been used to establish the predicted performances of the forcing fan and ducting systems as described above.

5.1 *Evaluation of Ducting Performance of Various Diameters over lengths*

The following tables show the predicted performance of the various ventilation ducting systems with given ducting diameters. The modelling results show predicted air quantities at inlet and outlet of the ducting systems and fan static pressures.

Table 3. Predicted performance for various construction types of ventilation ducting systems tested.

Duct Type Diameter (mm)	**Ducting Length (m)**	**Air Q Inlet**	**Fan Pressure**	**Air Q Outlet**	**Leakage Loss**
		m^3/s	**Pa**	**m^3/s**	**%**
Duct A (Welded) 1067	300	22.6	1,738	22.4	1.2%
	500	22.9	2,967	22.4	2.6%
	700	23.3	4,285	22.4	4.2%
Duct A (Welded) 1400	300	38.8	1,002	38.5	0.7%
	500	39.1	1,694	38.5	1.5%
	700	39.5	2,417	38.5	2.5%
Duct B (Welded) 1067	300	22.8	2,281	22.4	1.8%
	500	23.2	3,940	22.4	3.8%
	700	23.8	5,774	22.4	6.1%
Duct B (Welded) 1400	300	38.9	1,311	38.5	1.1%
	500	39.4	2,231	38.5	2.3%
	700	40.0	3,211	38.5	3.7%

Duct Type Diameter (mm)	**Ducting Length (m)**	**Air Q Inlet**	**Fan Pressure**	**Air Q Outlet**	**Leakage Loss**
		m^3/s	**Pa**	**m^3/s**	**%**
Duct C (Sewn) 1067	300	23.0	2,566	22.4	2.8%
	500	23.8	4,523	22.4	5.9%
	700	24.7	6,800	22.4	9.4%
Duct C (Sewn) 1400	300	39.2	1,468	38.5	1.9%
	500	40.1	2,540	38.5	3.9%
	700	41.1	3,731	38.5	6.4%
Duct D (Sewn) 1067	300	22.9	1,740	22.4	2.6%
	500	23.6	3,053	22.4	5.4%
	700	24.5	4,561	22.4	8.6%
Duct D (Sewn) 1400	300	39.0	993	38.5	1.4%
	500	39.7	1,703	38.5	3.0%
	700	40.5	2,473	38.5	4.9%

From the above tables it can be seen that for the two duct diameters of 1,067 mm and 1,400 mm over the duct incremental lengths of 300 m, 500 m and to 700 m, the best ducting system with welded construction has more than two times less leakage as compared with the worst of previously tested sewn construction ducting.

For example, to have a minimum face air quantity of 38.5 m^3/s over a 700 m ducting length using a 1,400 mm diameter ducting, Duct A with welded construction method would require 39.5 m^3/s of air at the fan inlet with an expected fan operating pressure of 2,417 Pa. For the same conditions it would require 40.0 m^3/s of air at the fan inlet with an expected fan operating pressure of 3,211 Pa if Duct B is used. However, if a sewn type ducting system such as Duct C is used for the same application, it would require 41.1 m^3/s of air at the fan inlet with an expected fan operating pressure of 3,731 Pa.

Calculation of the power cost required to operating the 1,400 mm diameter ducting systems delivering 38.5 m^3/s of air to the face over 700 m length is shown in the following Table 4. If the power cost is $0.1/kWh with power efficiency of 70%, the power cost saving for using the welded Duct A over Duct C with sewn construction ducting is about $72,274 per year.

Table 4. Predicted annual power costs for Duct A and Duct C ventilation ducting systems.

Duct Type	Air Q Inlet	Fan Pressure	Power Cost	Power Efficiency	Annual Power Cost
	m^3/s	Pa	$/kWh	%	$
Duct A (Welded)	39.5	2,417	0.1	70.0	$119,230
Duct C (Sewn)	41.1	3,731			$191,504

5.2 *Case Study for Ducting Performance*

A case study of ventilation ducting usage has also undertaken to predict operational performances of the forcing fan and ventilation ducting system under consideration. The case study consists of an axillary fan such as a *CLEMCORP CC1400 Mk4* vane axial fan (1,400 mm diameter with twin 110 kW motors) connected with a 1,400 mm diameter Y-piece ducting into two separate 1,067 mm diameter ducting sections over a distance of 700 m.

An Excel spreadsheet and Ventsim modeling have been used to establish the predicted performance of the forcing fan and ducting system as described above. A friction factor, K, of 0.00259 Ns^2/m^4 and a converted leakage coefficient, L_C of 0.343 $m^3/s/100m$ @ standardized 1 kPa fan pressure based on the results of recent tests were used for the modeling of the Duct A welded construction ducting system. A friction factor, K, of 0.00373 Ns^2/m^4 and an assumed leakage coefficient, L_C of 0.747 $m^3/s/100m$ @ standardized 1 kPa fan pressure were used for the modeling of the Duct C sewn construction ducting system.

The modeling results as shown in the following figure and table include predicted air quantities at inlet and outlet of the ducting, expected fan static pressures and projected annual power costs based on power costs $0.1/kWh and power efficiency of 70%.

Annual power cost saving for using the welded construction Duct A over the sewn construction Duct C is about $24,000 per year. From the modelling results, it is evident that the older style sewn ducting system will deliver less air (3.4 m^3/s or 8%) to working faces and require more fan power or operating cost to run when connected to the same axillary fan.

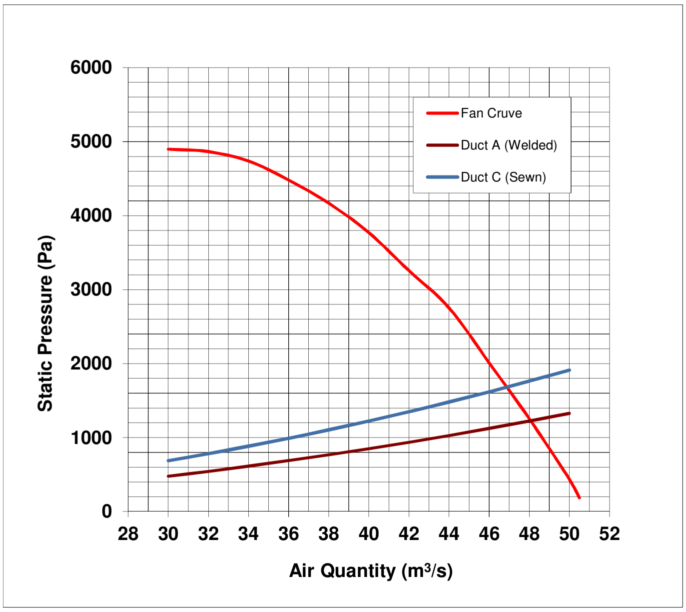

Figure 5. Expected fan operating points of Duct A and Duct C under the Case Study condition.

Table 5. Predicted annual power costs for Duct A and Duct C under the Case Study condition.

Ducting Type	Air Q Inlet	Fan P	Air Q Outlet	Power Cost	Power Efficiency	Annual Power Cost
	m^3/s	Pa	m^3/s	$/kWh	%	$
Duct A (welded)	48.1	1,232	46.1	0.1	70.0	$74,187
Duct C (sewn)	46.8	1,676	42.7			$98,132

Less air at the working faces would mean a longer after blast re-entry time in required to allow blasting fumes to be diluted. Otherwise harmful contaminants levels will be higher at working faces.

6 CONCLUSIONS

The main objective of this study was to predict and evaluate the performance of a ventilation ducting systems using different construction methodologies, namely welded and sewn ducting. The friction factors and leakage coefficients of these various types of ducting systems referred to in this study were either from the ventilation ducting and joint leakage test results undertaken by the authors using testing facilities at the UQEM in the past or from public available sources.

Mathematical modelling has been undertaken to predict the performance of two welded and two sewn ducting ventilation ducting systems by providing some indications of differences in ventilation flows to the mining face. Performance information sought are resulting fan pressure, leakage loss and the air flows at the outlets of the ducting. Excel spreadsheet usage and Ventsim modelling has been used to establish the predicted performances of the forcing fan and ducting systems considered. It was found that the best ducting system with welded construction has almost two times less leakage as compared with the average of previously tested sewn construction ducting.

Findings from this study include that welded type ducting with less leakage is able to deliver more air that provides a greater degree of safety for employees in working areas especially in typical hot and humid Australian underground mining environments as compared to sewn type ducting which does not optimize ventilation air delivery to working faces.

Welded type ducting requires less fan energy to deliver more air hence increased air cooling power of the ventilation air system to working areas. Therefore, using welded construction type ducting will reduce potential heat stress risks when compared with the use of sewn construction types of ducting with poor leakage characteristics.

Using a ventilation ducting system with a lower leakage coefficient will result in a direct saving on fan operating cost compared with a flexible ventilation ducting system with a standard or higher leakage coefficient. Using a ventilation ducting system of a lower leakage coefficient with the same kW rated fan will supply more airflow to the mine face as the system has less leakage. Other savings or advantages associated with the use of such a system include

- Potential saving both on capital and operating cost of auxiliary ventilation fan as smaller fan can be used.
- Provision of a safer working environment that complies with mine health and safety regulations especially for higher production.

Using a ventilation ducting system with a lower leakage coefficient represents a sound solution to new challenges faced by the industry for increasing demands for better quantities and qualities of air delivered to working faces due to higher production schedules and stricter mine health and safety regulations within the Australian mining industry.

It should be noted that all predicted operational performances of the forcing fan and ventilation ducting systems stated in this study were derived based on the standard ventilation duct leakage test results which were carried out under a simulated mine ventilation ducting operational condition that takes into account minimum bends and kinks in the brand new ducting and with no obvious wear and tear or cut holes. Harsh operational mine condition where, extra bends, kinks, wear and tear or cut holes may occur are all too common. When assessing the performance of a fan and ducting system it is important to recognize the serious effects these can have on the performance of a fan and ducting system.

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