COST SAVING STRATEGIES IN MINE VENTILATION

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ABSTRACT

Energy associated with ventilating an underground operation comprises a significant portion of a mine operation's base energy demand and is consequently responsible for a large percentage of the total operating costs. Ventilation systems may account to 25% to 40% of the total energy costs and 40% to 50% of the energy consumption of a mine operation. Appliances used to ventilate underground mines and the total fan power installed in a single mine operation can easily exceed 10,000 kW. Investigations of a number of mine ventilation systems have indicated to be, in general, fairly energy inefficient. The author has found that a large number of systems operate at efficiencies below 65%. This paper presents how engineering design principles can be applied to improve the performance and efficiency of ventilation systems, resulting in substantial reductions in power consumption, operating cost and greenhouse gas emissions. Case studies are presented to demonstrate that, by retrofitting current ventilation systems using proper engineering concepts of fluid physics and fluid flow, systems will operate at efficiencies well above common operating efficiencies, resulting in a drastic reduction in a mine's overall costs and base electrical and energy loads.

KEYWORDS

mine ventilation; mine fans; ventilation energy; ventilation efficiency; operating costs; ventilation economics; power costs; power consumption

INTRODUCTION

The increasing problems experienced with electricity supply in North America has encouraged an industry-wide re-evaluation of energy consumption and has resulted in a more urgent emphasis being placed on energy efficient designs and operation of all energy consuming systems. Electricity is a main mode of energy supply and the mining industry is affected by the increasing cost of this commodity.

Ventilation systems normally operate 24 hours per day, 365 days per year and account to 25% to 40% of the total energy costs and 40% to 50% of the electrical consumption of a mine operation. The ventilation engineer is under ever increasing pressure to reduce ventilation energy consumption and to be cost effective.

Experience has indicated that a large number of ventilation systems have efficiencies of 65% or lower. Ventilation network systems are extremely complex, they must be carefully managed and optimized, yet one must guarantee the health and safety of all workers. More and more engineers have been assessing the efficiency of their ventilation systems and the operating performance of fan installations, their efficiency, energy consumption and associated environment impact and operating costs.

In order to improve the energy efficiency of mine ventilation systems, a number of areas of development and application of energy efficient ventilation techniques have been addressed by many, and include:

- research on how ventilation modelling software can be used to optimise ventilation systems (Schraml, 2003; von Glehn et al, 2008);
- the economic sizing of main mine airways (De Souza, 2009; McPherson, 1993; Bonnington and Young, 2008);
- the application of on-demand based ventilation control as an energy and cost savings measure (Belle, 2008);
- intelligent active ventilation system control using live modelling and on-line monitoring;
- the application of heating-on-demand and cooling-on-demand (Marx et al, 2006);
- the application of main fan energy management, with reduced air flows during selected peak and off peak periods, resulting in substantial reduction in peak power demand (du Plessis and Marx, 2008; Gundersen et al, 2005);
- retrofit of main fan installations (De Souza, 2013);
- the use of variable pitch axial fans that can be adjusted down during periods of low activity;
- the use of variable speed drives to provide speed control, reduce mechanical stress on the fan and motor and reduce energy consumption;
- the upgrading or replacement of an impeller with a design impeller to suit the actual ventilation requirements, resulting in increased fan efficiencies;
- the use of composite materials (lighter than steel, with higher resistance to fatigue), limiting fan impeller and blade failure.

General solutions and tactics for improving ventilation systems, with minimum capital investment, are presented in this paper in four ventilation audits worked by the author. By increasing the efficiency of the ventilation systems, a reduction in energy could be achieved. With every kW offset, a mine not only reduces overall costs but lowers their overall base electrical and energy loads, helping to reduce the strain on its energy infrastructure.

CASE APPLICATIONS

Four case applications associated with engineering work conducted by the author are presented in the following sessions to demonstrate how, by conducting detailed ventilation efficiency audits, simple low-cost solutions can be devised to increase system efficiency, reduce power consumption and lower operating costs.

The low-cost solutions include improving the cone design of exhaust fans; changing a fan configuration from full-blade to half-blade; improving the installation of auxiliary ventilation systems; and controlling air leakage.

Case Application 1 - Main Exhaust Fan Cone Replacement

As part of an efficiency audit of a mine ventilation system, a main exhaust fan system was inspected and surveyed. The system consisted of two surface exhaust fans operating in parallel configuration. The fans were 2.1 m in diameter, with 0.8 m hub diameter. They had 261 kW motors installed operating at 1170 rpm. The fan assemblage was well designed, with acceptable resistance pressure losses. However, the fans were fitted with very inefficient cones. Figure 1 presents a simplified schematic of the fan installation.

The fans were exhausting 189 m^3/s total. The cones were 1.5m long and 2.4 m in outlet diameter. The cone losses were estimated at 0.161 kPa. The fan velocity pressure including losses, was estimated at 0.41 kPa and the fan total pressure was estimated at 1.9 kPa. The operating power per fan was calculated at 230 kW.

A simple retrofit, of just replacing the existing exhaust cones with more efficient cones was proposed. The proposed cones were 4.3 m long and 3.05 m in diameter. For the retrofit, and for the same flow, the cone losses were estimated at 0.149 kPa. The fan velocity pressure including losses, was estimated at 0.25 kPa and the fan total pressure was estimated at 1.74 kPa. The operating power per fan was determined at 211 kW.

The total operating power savings are thus 38 kW and the annual savings in operating cost is $37,330 based on a power cost of $0.112/kWh.

For an investment of $60,000 to construct and install the new cones, and with a discount rate of 10%, a Net Present Value analysis estimated a payback on year 2 and an Internal Rate of Return of 57.9%. This indicated a very attractive project, and it was successfully implemented by the mine.

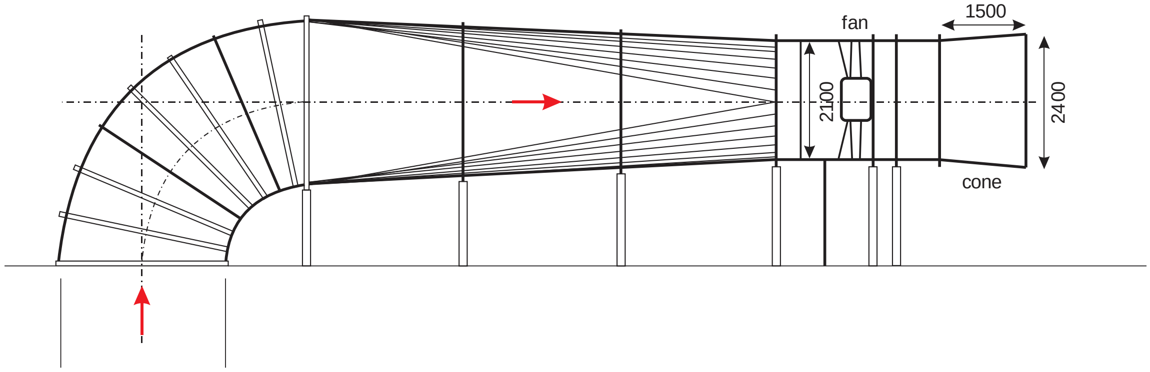

Figure 1 - Main Exhaust Fan Installation Schematic

Case Application 2 - Booster Fan Blade Configuration Change

A ventilation survey was conducted on a set of underground fresh air booster fans, installed on a bulkhead and operating in parallel in a large opening mine.

The fans were high pressure fans however, because of the low system resistance, they were operating very inefficiently.

The booster fans were 1.67 m in diameter, with 0.66 m hub diameter. They had 112 kW motors installed, operating at 1200 rpm. The blade setting was 20 degrees.

Survey results indicated a flow of 70.8 m^3/s per fan and a total pressure of 0.72 kPa. The fans operated at a relatively low efficiency of 46.5% and a brake power of 110 kW. The fans' annual operating cost was $150,000. The fan operating point is shown in Figure 2. As previously indicated, the fan is a higher pressure fan, not efficient for operation in systems of relatively low resistance.

In order to improve the fan operating efficiency without incurring any investment costs, a change in fan operation to a half-blade configuration was proposed to the mine. By operating the fans in half-blade and with a blade setting of 22 degrees (Figure 3), the fans would supply the same required flow but with an increased efficiency of 59.5%. The brake power would be reduced to 85.9 kW per fan and the overall annual operating cost would be reduced to $117,470, representing a decrease of 22% in operating costs.

This recommendation was successfully carried out by the mine. Following this accomplishment a number of operating fans were also modified to half-blade configuration, resulting in substantial savings in ventilation costs. When adding new fans to the mine, lower pressure fans were sized to operate efficiently and in conformity with the lower system resistance.

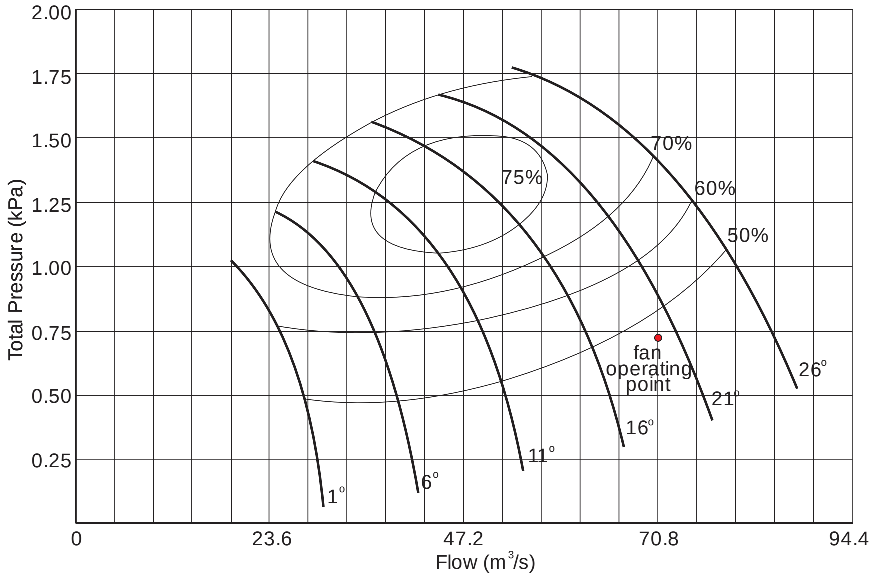

Figure 2 - Fan Operation In Full-Blade Configuration

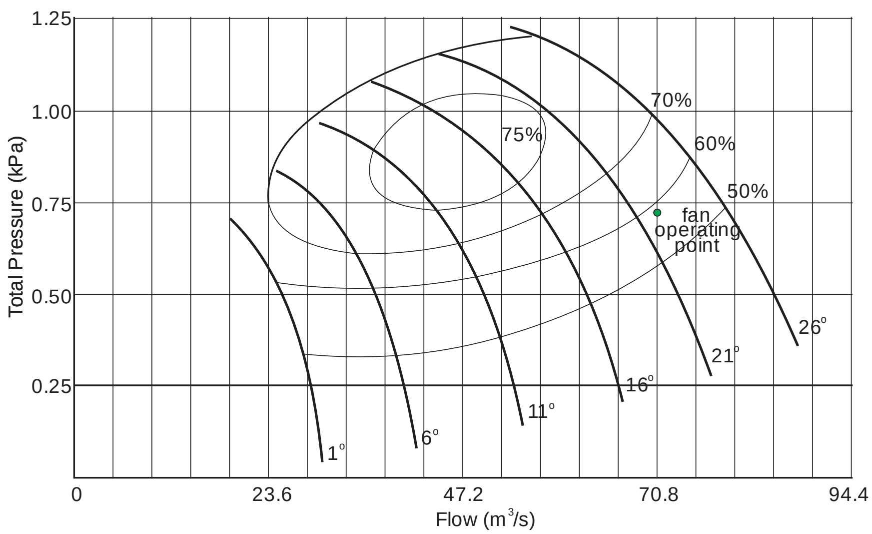

Figure 3 - Fan Operation In Half-Blade Configuration

Case Application 3 - Auxiliary Ventilation Installation Retrofit

In attempts to improve air quality conditions at production faces in an underground hard rock mine, a quality assessment of ventilation installations in all production stope access drawpoints of a mining block was performed.

Longhole stoping is used to mine the orebody and level mucking accesses are ventilated with auxiliary ventilation. Face ventilation requires a flow of 9.4 m^3/s per cross-cut, based on the production equipment utilized. Flow surveys at all active faces indicated flows ranging between 4.7 m^3/s and 7.6 m^3/s, with only 3 faces meeting the minimum flow requirements.

Typical auxiliary fans were 0.965 m in diameter with 0.686 m hubs, operating with 56 kW motors running at 1780 rpm. Canvas duct of same diameter were utilized.

Detailed inspections and surveys of all installations showed poor duct installation practices, with much higher than desired static pressure losses along each duct column. Fans were not properly hung and duct-to-fan connections were very leaky. Severely damaged duct sections were noted in most installations.

The fan operating point for one of the surveys is presented in Figure 4. The system produced 7.28 m^3/s at the face with the fan operating at 17.04 m^3/s. Leakage was estimated at over 57%. The fan total pressure was 1.356 kPa and the brake power 42 kW. The annual operating cost was $29,344.

The auxiliary system installation was improved (column straightened, connections tightened and duct column repaired) to reduce resistance pressures and minimize leakage. The system produced 9.53 m^3/s at the face with the fan operating at 11.64 m^3/s (Figure 4). Leakage was estimated at 18%. The fan total pressure was 0.83 kPa and the brake power decreased to 21 kW. The annual operating cost for the single fan was reduced to $14,362, representing a reduction in cost by 51%.

Following this successful retrofit all additional 9 drawpoint fan installations for this mining block were similarly improved, with annual savings in fan operating cost approximating $180,000, representing a 52% reduction in operating costs. The mine also adopted a proposed management program with appropriated procedures for the installation, inspection and maintenance of all future planned or current operating auxiliary systems.

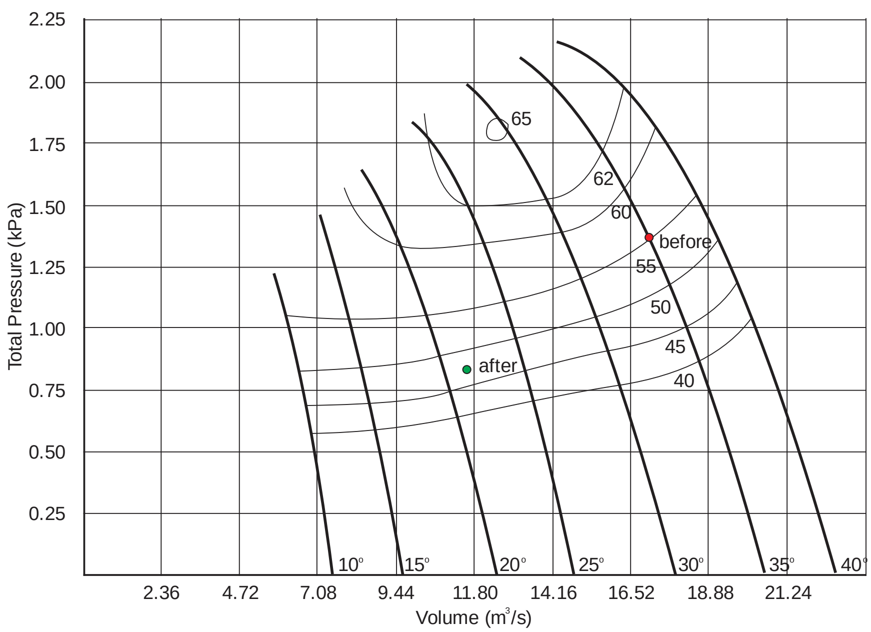

Figure 4 - Fan Operation Before and After System Installation Improvement

Case Application 4 - Ventilation System Leakage Control

A detailed survey was conducted in an underground hard rock mine to assess the economic efficiency of the mine ventilation system.

The mine utilizes a push system with primary surface fresh air fans installed on a dedicated raise. Based on the operating diesel fleet, overall underground flow requirements were estimated at 220 m^3/s.

The fresh air system consisted of two surface fresh air fans operating in parallel configuration. The fans were 2.6 m in diameter, with 1.55 m hub diameter. They had 448 kW motors installed operating at 710 rpm.

Each fan was delivering 193.5 m^3/s at a total pressure of 1.69 kPa. The brake power was 410 kW and the annual operating cost per fan was $287,200. The fan operating point is shown in Figure 5.

With both fans delivering 387 m^3/s, the flow reaching the active mining area was 224 m^3/s. Leakage was estimated at 42%. Leakage occurred at raise connections to 15 mined out levels, above the active mining levels.

Extensive work was conducted to reduce leakage by sealing off and shotcreting all bulkheaded raise connections to the 15 inactive levels. Where level access was required, appropriate doors were installed. With the sealing off of the raise connections, the surface fans were modified to operate at a blade of 22 degrees. Each fan was now delivering 125 m^3/s at a total pressure of 0.83 kPa (Figure 5). The brake power was 145.7 kW and the annual operating cost per fan was $102,120.

With both fans now delivering 250 m^3/s, the flow reaching the active mining area was maintained at 224 m^3/s. Leakage was estimated at 9.9%.

The reduction in air leakage to 9.9% from 42%, permitted an overall annual savings in fan operating cost of $370,160 or a 64.4% reduction in operating costs.

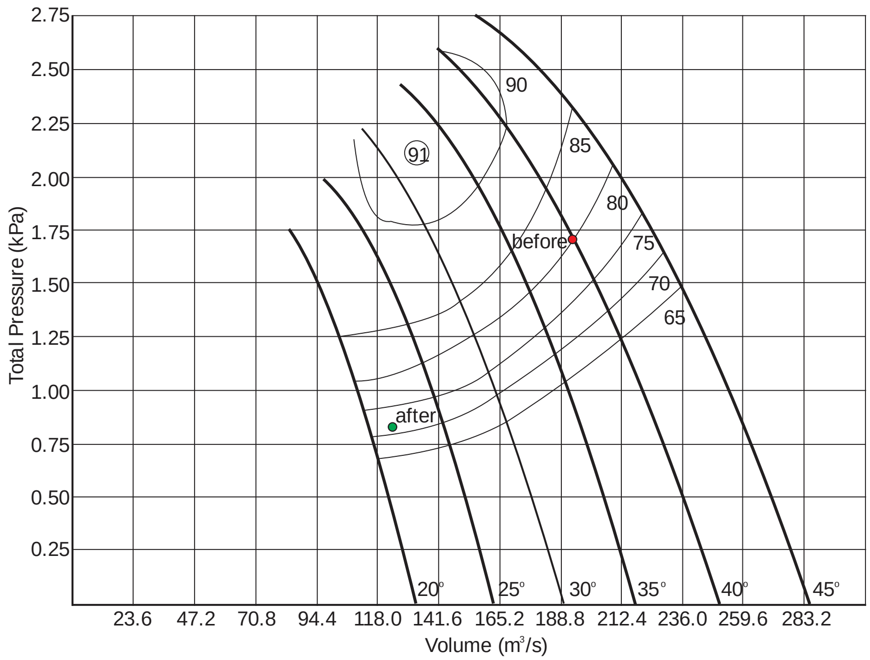

Figure 5 - Fan Operation Before and After Leakage Control

CONCLUSIONS

A number of economic facts associated with mine ventilation are well known to the practising engineer:

- Ventilation accounts for 40 to 50% of a mine’s total energy consumption.

• Fan energy consumption can account for up to 50% of the mine's electricity costs.
• By reducing air leakage by 10% one can reduce the system overall operating cost by 30%.
• Use of Variable Frequency Drive technology can substantially decrease fan energy usage and operational costs.
• Retrofitting of inefficient main fan assemblages will result in substantial fan operating cost savings.
• A properly designed fan cone can save substantial fan operating costs.
• Proper duct installation can reduce auxiliary fan operating costs by 20% or more.
• Application of Ventilation on Demand may result in reduced energy usage by 20 to 40%.
• Vibration is the primary cause of fan / bearing failure. Proper fan alignment and balancing will greatly reduce maintenance costs.

Being one of the main electricity consumers in the mining industry, the optimization of ventilation systems is a point of first priority to the ventilation engineer. Even though ventilation systems can be very complex engineering systems, by using proper engineering concepts of fluid physics and fluid flow, system efficiencies can be drastically increased, resulting in an appreciable reduction in a mine's overall costs and base electrical and energy loads.

Four case applications associated with engineering work conducted by the author have been presented to demonstrate how simple solutions can be devised to increase system efficiency, reduce power consumption and lower operating costs.

References

Belle, B.K. (2008) Energy savings on mine ventilation fans using 'Quick-Win' Hermit Crab Technology-A perspective. Proceedings of the 12th U.S./North American Mine ventilation Symposium. 427-433.

Bonnington, S.T. and Young, G.A.J. (2008) Some model studies of mine shafts, shaft insets and fan drifts. Journal of the Mine Ventilation Society of South Africa. vol 61, no. 1. 8-18.

du Plessis, J.J.L. and Marx, W.M. (2008) Main fan energy management. Proceedings of the 12th U.S./North American Mine ventilation Symposium. 441-446.

De Souza, E. (2009) 'A practical guide to mine ventilation design and control'. Department of Mining Engineering, Queen's University.

De Souza, E. (2013) 'Improving the Energy Efficiency of Mine Fan Assemblages'. 23rd World Mining Congress. Montreal. 11-15 August.

Gundersen, R.E., von Glehn, F.H. and Wilson, R.W. (2005) Improving the Efficiency of Mine Ventilation and Cooling Systems Through Active Control. Proceedings of the 8th International Mine ventilation Congress. Brisbane. 13-18.

Marx , W., von Glehn, F.H. and Wilson, R.W. (2006) Design of energy efficient mine ventilation and cooling systems. Proceedings of the 8th U.S./North American Mine ventilation Symposium. 641-648.

McPherson, M.J. (1993) Subsurface Ventilation and Environmental Engineering. Chapman & Hall. pp. 905.

Schraml, E. (2003) Mine Ventilation Networks - Balancing the Network Performance and Energy Demands. CIM Mine Operators Conference. pp. 4.

von Glehn, F.H., Marx, W.M. and Bluhm, S.J. (2008) Verification and calibration of ventilation network models. Proceedings of the 12th U.S./North American Mine Ventilation Symposium. 275-279.