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Application of a Ventilation Management Program for improved air quality

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ABSTRACT
The purpose of Ventilation Management Systems is to ensure the health and safety of underground workers by creating and incorporating structured Plans, Procedures and Processes on the day-to-day operations of the mine ventilation system. Application of Ventilation Management Programs consists of audit, verification and corrective action procedures used to, i) ensure adherence to regulatory standards or to ii) return to compliance and safety standards when an upset condition arises. The present study describes how a Ventilation Management Program can be developed and implemented to ensure regulation compliance, to increase safety, to improve operational efficiency and to reduce the operating costs of an operating mine. A case study is presented in which air quality conditions have been substantially improved with the development and implementation of a Ventilation Management Program for an operating underground hard rock mine.

KEYWORDS: mine ventilation; ventilation management; air quality; ventilation efficiency

1. INTRODUCTION

Mine ventilation systems must not only provide for the health and safety of underground personnel, but also operate in compliance with regulatory bodies. Studious day-to-day management of the mine ventilation system is crucial to meet all the objectives of the ventilation system. A Ventilation Management System is used to provide, measure, and control the quantity and quality of airflow throughout the mine ventilation network.

The Ventilation Management System consists of a series of documents describing means of auditing and controlling the mine ventilation system in order to ensure the system meets all regulatory and safety requirements.

Five main document types form the structure of a Ventilation Management System: Standards and Guidelines, Code of Practice, Procedures, Work Instructions and Directives (Figure 1). These documents provide guidelines for applying audit, verification and correction processes used to ensure the mine ventilation system operates within compliance standards.

The Standards and Guidelines constitute the foundation of the management program. This support documentation is a handbook providing a detailed description of the ventilation system, including all design and operational aspects of the ventilation network. The Code of Practice is documentation that defines the minimum operating standards and action levels based on regulatory bodies, and provides appropriate corrective and emergency action plans when an upset condition exists. Procedures is documentation that explains inter-departmental activities and each department's or individual's role in specific work procedures. Work Instructions is documentation describing the process of a specific procedure and task; including who is involved, how to do the task, and what materials or supporting documentation is needed. Directives is documentation issued for any changes to the ventilation that will ensure the correct installation or change to any design, equipment or condition.

2. EXECUTION OF A VENTILATION MANAGEMENT PROGRAM

Execution of a Ventilation Management Program follows an iterative process, as illustrated in Figure 2.

Management Plans, which are carried out on a daily basis, are an audit of the state of the entire mine ventilation system. They include detailed inspections of all components and appliances, pressure and flow surveys of the network and air quality surveys. Verification Programs are used to assess the information collected from the management plans in order to verify if the ventilation system is in compliance and if it meets all defined objectives of the program. If the verification process indicates the system not to be in compliance, then action plans and ventilation directives are initiated to restore the system to compliance. Action Plans and corresponding directives can also be directly launched in response to upset ventilation conditions or when problems are encountered during an inspection.

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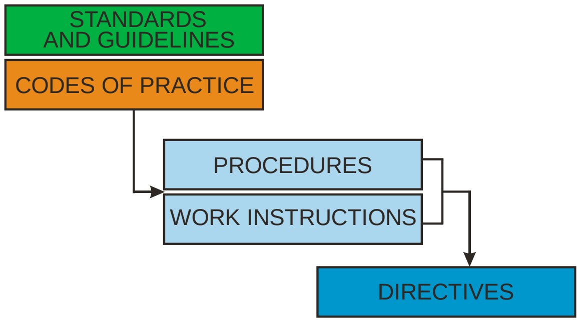

Figure 1: Typical structure of a Ventilation Management System.

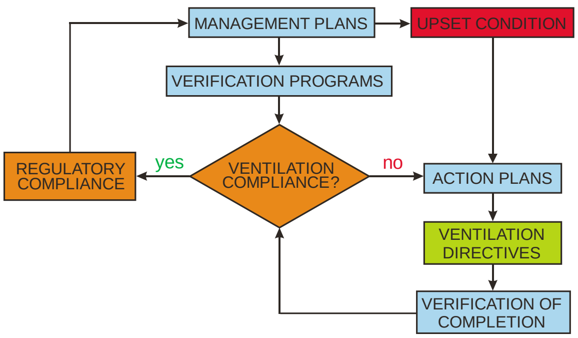

Figure 2: Execution process of a Ventilation Management Program.

3. OPPORTUNITIES AND BENEFITS

The easy to implement iterative framework of a Ventilation Management Program (Figure 2) allows mining operations to efficiently and consistently audit the mine ventilation system.

Significant benefits can be gained from day-to day management of the mine ventilation system. It ensures: that the ventilation system performs according to design; that all ventilation appliances operate efficiently and economically; an adequate air supply to all active workings; that the mine atmosphere meets quality conditions; compliance with all regulatory requirements; safety; improved system economics.

4. CASE STUDY

A case study is presented in which air quality conditions have been substantially improved with the development and implementation of a Ventilation Management Program for an operating underground hard rock mine.

A two-phase integration approach of the Management Program was successfully completed for the mine. The first phase involved regional leakage control, resulting in an increase in airflow volume in the main production blocks by 28% and the second phase involved improvements in local ventilation installations in the main production levels, resulting in substantial improvements in underground environment conditions (air quality, dust and heat). This permitted uninterrupted production with much improved safety, reduced re-entry times and lower costs.

The underground mine applies sublevel stoping with backfill to mine gold at a rate of 900 tonnes per day. Mining activities exist at the lower levels of the mine (below 1030 level) with 7 upper levels being mined out. Overall underground flow requirements at the underground production blocks approximate 118 m^3/s, determined from the production rate and operating diesel fleet. The mine utilizes a push system with a primary surface air fan installed on a dedicated fresh air raise. Figure 3A presents a distribution of mine flows through the dedicated fresh air raise prior to application of the Management Program.

A detailed ventilation audit was conducted to assess the primary fresh air system prior to implementation of the first phase Ventilation Management Program.

Over the years, prior to application of the Ventilation Management Program, the mine had to limit use of its available diesel fleet and also had to curtail development and production activities due to limitations in fresh air supply to the active levels (available 94 m^3/s versus required of 118 m^3/s) and also had to limit stope blasting and mucking cycles due to excess concentrations of NO_2 (well above the limit of 3 ppm).

The fresh air system consisted of a surface fresh air fan of 2.13 m casing diameter and 1.27 m hub diameter. It had a 597 kW motor installed, operating at 1200 rpm. The fan was delivering 142 m^3/s at a static pressure of 1.84 kPa. The brake power was 539 kW and the annual operating cost was $377,650. The fan operating point is shown in Figure 4. With the fan delivering 142 m^3/s, the flow reaching the active mining area was 94 m^3/s; leakage was estimated at 33.6% (Figure 3A). As previously mentioned, leakage occurred at raise connections to 7 mined out levels, above the active mining levels.

As part of the Ventilation Management Program execution, extensive work was conducted to reduce leakage by sealing off and shotcreting all bulkheaded raise connections to the 7 upper inactive levels. Leakage was reduced to 7.2% from 33.6% (Figure 3.B) Where level access was required, appropriate door locks were installed. With the sealing off of the raise connections, the surface fan was now delivering 130 m^3/s at a static pressure of 2.38 kPa (Figure 4).

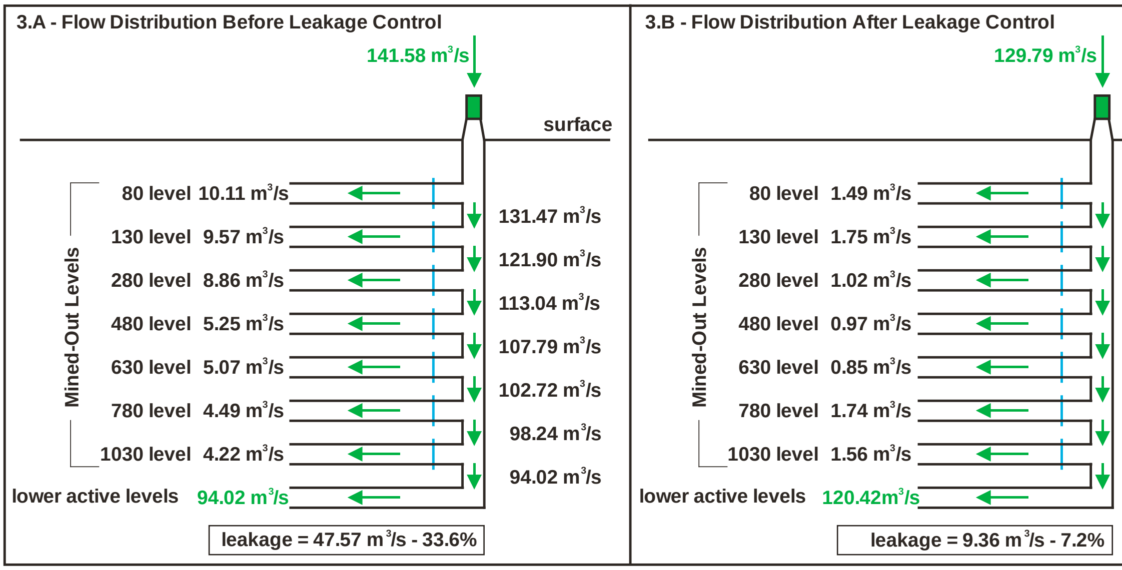

Figure 3: Mine ventilation schematic.

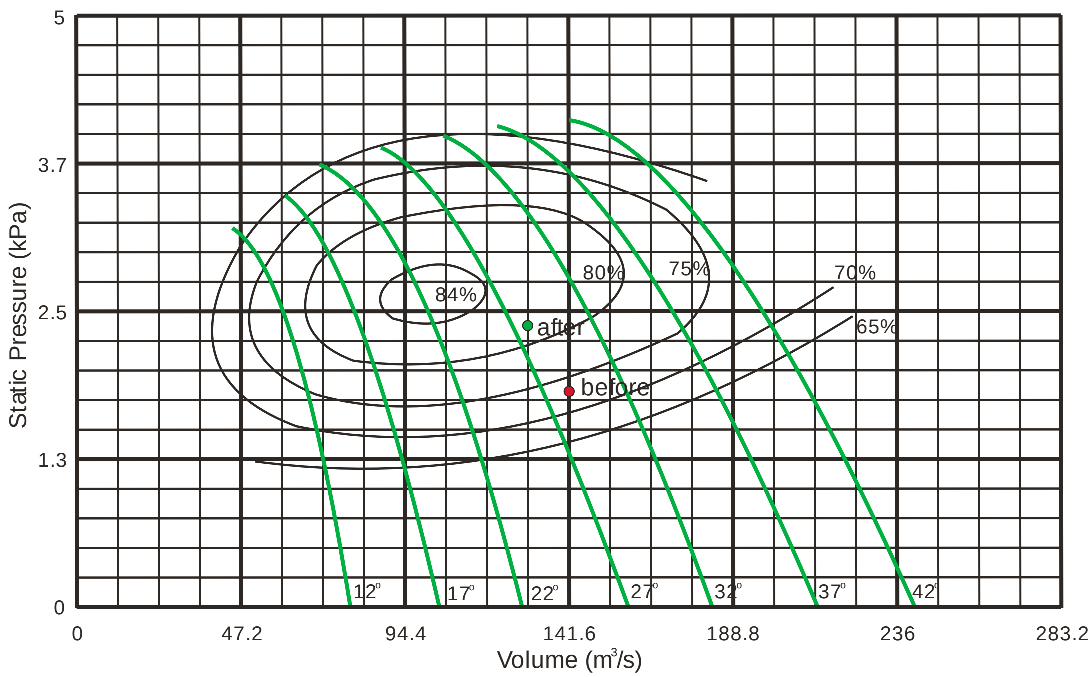

Figure 4: Main fan operation before and after leakage control.

The brake power was 502 kW and the annual operating cost per fan was $352,018. With the fan now delivering 130 m^3/s, the flow reaching the active mining area was maintained at 121 m^3/s, above the production based requirements of 118 m^3/s. Leakage was estimated at 7.2%.

The reduction in air leakage to 7.2% from 33.6% permitted an overall annual savings in fan operating cost of $25,630 or a 7% reduction in operating costs. Even though the reduction in fan operating costs is relatively small, the operation now meets the flow requirements at all active levels, being able to safely achieve and maintain full production activities.

Having successfully improved the mine overall flow conditions, the second phase of system implementation was initiated. This Ventilation Management Program phase aimed at improving safety and air quality conditions in all producing faces.

First, a quality assessment of ventilation installations and airflows in all production stope access drawpoints was performed. To meet production requirements, 10 active faces were ventilated at the mine. All access crosscuts to the sublevel stopes were ventilated with auxiliary ventilation. Face ventilation requires a flow of 9 m^3/s per cross-cut, based on the production equipment utilized. Flow surveys at all active faces indicated flows ranging between 5 m^3/s and 7.4 m^3/s, with 3 faces meeting the minimum flow requirements. The auxiliary fans are 1.22 m in diameter with 0.69 m hubs, operating with 22.4 kW motors and running at 880 rpm. Layflat duct of same diameter are utilized.

Detailed inspections and surveys of the 10 duct installations classified the installation practices as 'poor', with much higher than desired static pressure losses along each duct column. Some fans were not correctly hung and duct-to-fan connections were very leaky. Several of the duct columns were not installed straight and had severely damaged sections.

The fan operating point for one of the surveys is presented in Figure 5. The system produced 7.4 m^3/s at the face with the fan operating at 17 m^3/s. Leakage was estimated at 57%. The fan total pressure was 0.72 kPa and the brake power 15.4 kW. The fan annual operating cost was $11,943. High diesel exhaust gas concentrations were measured at the faces due to insufficient dilution ventilation air volumes.

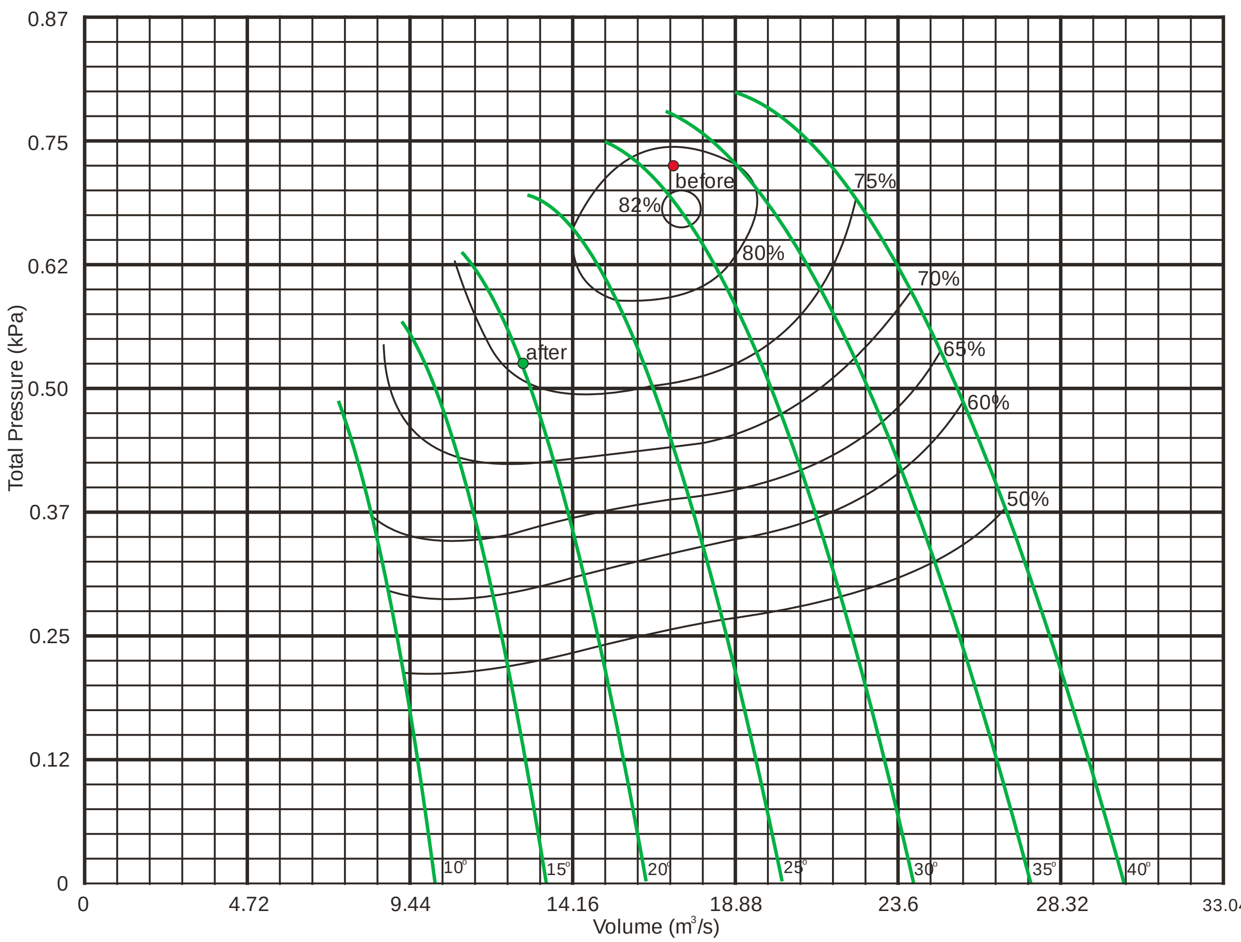

Figure 5: Auxiliary fan operation before and after system installation improvement.

The auxiliary system installation was improved (duct column repaired, column straightened, connections tightened, etc.) to reduce resistance pressures and minimize leakage. The fan blade pitch angle was changed from 30° to 20°. The system produced 9.44 m^3/s at the face with the fan operating at 12.75 m^3/s (Figure 5). Leakage was estimated at 26%, a reduction of more than half the original leakage. The fan total pressure was 0.52 kPa and the brake power decreased to 8.77 kW. The annual operating cost for the single fan was reduced to $6,822, representing a reduction in cost by 43%.

Having now achieved the required flow at the production face the mine could operate safely and in regulatory compliance.

Following this successful application of the Ventilation Management Program, all additional 9 drawpoint auxiliary fan installations were similarly investigated and improved, with annual savings in fan operating costs approximating $93,000, representing a 58% reduction in operating costs.

The successful application of the 2-phase Ventilation Management Program resulted in overall annual cost savings of $118,650 for the mine. More importantly, the mine was now operating safely and in compliance with regulations.

The mine continues to incorporate the Management Program in its day-to-day production operations, resulting in increased safety, improved air quality, reduced post blast re-entry times, regulatory compliance and cost savings.

5. CONCLUSIONS

The structure and process implementation of a Ventilation Management Program have been presented in this paper.

Day-to-day application of the Ventilation Management Program ensures the mine operation meets all regulatory requirements and cares for the health and safety of all personnel working underground.

A case study for an operating underground hard rock mine has been presented to demonstrate the functionality of the management program and the safety, efficiency and economic benefits realized by the mine.

6. REFERENCES

De Souza, E. (2015) Mine Ventilation System Management. Section 19. Mine Ventilation Course Notes. Kingston, ON. 16p.