METHODS TO IMPROVE MINE VENTILATION SYSTEM EFFICIENCY

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INTRODUCTION

John Marks said in his acceptance of the Hartman Award in 2008 – *"I guess that without the occasional complaint, your mine is probably over-ventilated*" (Marks, 2008). Miners are seldom in this situation and often spend much of the time trying to find enough air to keep the operation running. With examination there are some things that can be done to make the best use of ventilation systems. Should there be surplus air, in which some of these options may result - financial and other benefits can be obtained.

Some of the issues mine operators have needed to address recently are increased airflow requirements to dilute diesel particulates in metal and non-metal mines. Also, operations are faced with demands from reserves that are deeper, hotter and further away from fans and shafts, not to mention increased production demands.

Mine ventilation air is a costly commodity, especially by the time it has been heated or cooled and moved to the bottom of the shaft and through the mine airways.

Most of the options presented in this paper are useful for metal non-metal operations but some may be applicable to coal too.

OPTIONS FOR IMPROVEMENT

Some of the areas to be addressed are shop ventilation methods, auxiliary equipment areas, dedicated intakes and returns, optimizing development, examination of mine airway utilization and alternative ventilation methods.

UNDERGROUND SHOPS

First, examine what is being done with the underground shop air. If it is being coursed directly to the returns there may be some potential to better utilize this, in most cases, relatively contaminant free air. Research the legal options for ventilating mine shops.

MSHA regulations in 30CFR 57.4761 (1) allow the following options:

> *To confine or prevent the spread of toxic gases from a fire originating in an underground shop where maintenance work is routinely done on mobile equipment, one of the following measures shall be taken: use of control doors or bulkheads, routing of the mine shop air directly to an exhaust system, reversal of mechanical ventilation, or use of an automatic fire suppression system in conjunction with an alternate escape route. The alternative used shall at all times provide at least the same degree of safety as control doors or bulkheads*.

Discussion

This regulation gives some operators flexibility in ventilating underground shop facilities. If shop air is to be coursed through the work area, and then directly to the mine return, the question should be asked – is the quality of air good enough to be reused in the mine, and if so, what are the risks? Can the risks be accommodated and managed to accomplish the change? If so, a considerable increase in mine level airflow could be attained by reusing shop air.

Clearly, regulations are a minimum standard, and can be exceeded. Metal non-metal mine regulations are not as specific as coal due to the multitude of different mining methods and conditions utilized. Risks must be thoroughly examined and addressed to assure a safe environment.

Issues

Determine what contaminants are being produced in the work area – welding fumes, diesel exhaust, paint fumes, chemicals and solvents, etc. Survey the area and determine exposures. MSHA requires exposure monitoring in 30 CFR 57.5002 (1) of dust, gasses mists and fumes to assure air quality is being met. Perform surveys and examine existing data to quantify personal and area concentrations of contaminants. Often there is adequate circulation such that exposure levels in shop work areas are low. After sending shop air back into the system any contaminants would be further lowered by dilution with other mine intake air downstream.

Look at the shop work schedule. If only on day shift, the other two shifts and possibly weekends have no activity or source of contamination to affect the ventilation system.

The worst case planning scenario would be a shop fire. Study and simulate how this would affect the mine and shop area. MSHA regulations require an escape route and a fire suppression system be installed and maintained as follows in 30 CFR 57.4671 (1):

(d) Automatic fire suppression system and escape route. If used as an alternative, the automatic fire suppression system and alternate escape route shall meet the following requirements:

(1) The suppression system shall be--

(d)(1)(i) Located in the shop area;

(d)(1)(ii) The appropriate size and type for the particular fire hazards involved; and

(d)(1)(iii) Inspected at weekly intervals and properly maintained.

(2) The escape route shall bypass the shop area so that the route will not be affected by a fire in the shop area.

Case Study

In an underground room and pillar mine, active mine workings were advancing further away from the mine shaft with deteriorated returns and leakage having a negative effect on ventilation airflows to the face. Mine level airflows were 236 m^3/s (500,000 cfm) and shop airflows were 24 m^3/s (50,000 cfm) (see Figure 1A). No additional capacity was available at the main surface fan. A solution was to utilize the shop air then send it to the mine areas instead of directly to the return.

Considerable information on shop air quality and exposures from many years of operation was examined and no negative data was discovered. A risk analysis determined that moving forward with a shop air reuse program was desirable. A plan was developed, analyzed and decision to proceed approved by mine management.

The change was simulated on the computer with the USBM/MTU MFire program before being implemented. This included utilizing fire scenarios to examine potential exposures to inby mining sections and plan escape routes. A monitoring system was designed and installed in cooperation with the US Bureau of Mines to monitor carbon monoxide levels at three locations: in the shop intake, end of the shop bay and at the mixing point of the shop and east mine intake split.

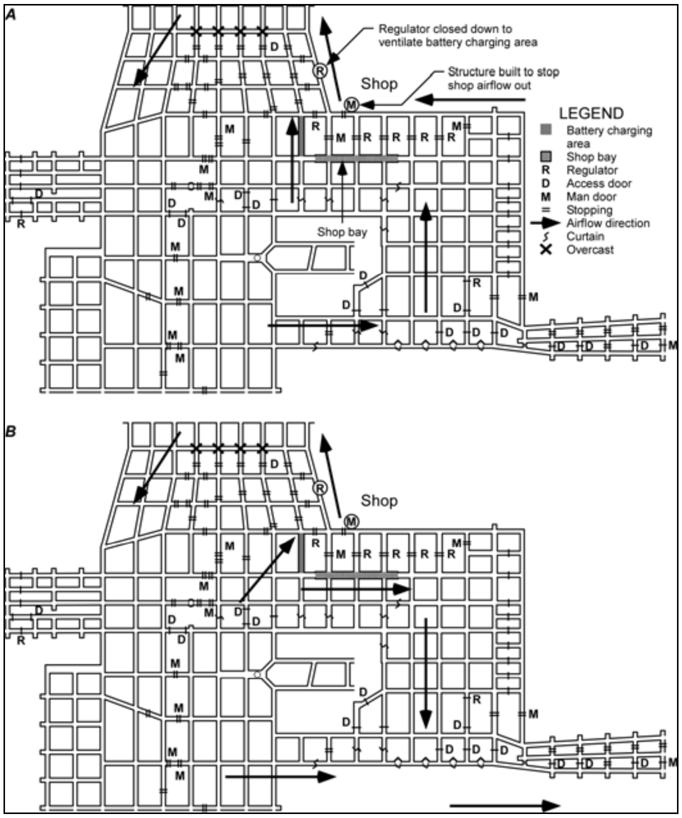

Figure 1. A & B Shop Ventilation.

Additional work done to accomplish the change was to install a sprinkler system to the shop bay from the mine fresh water line with thermal links to actuate sprays. Considerable work was done designing the system per NFPA standards on pressure, flow and sprinkler spacing. System water pressure was monitored and checked on a weekly basis. The north shop return to the regulator was closed off by a stopping with access mandoor. Airflow through the shop battery charging station was isolated and sent directly out of the mine as required by state law, utilizing 4.7 m^3/s (10,000 cfm). The existing shop access door was opened to let intake air flow through the shop, effectively reversing airflow direction, then joining the main intake split further inby the shop (see Figure 1B).

Result

Of the 24 m^3/s (50,000 cfm) previously utilized in the shop, 19 m^3/s (40,000 cfm) was saved and sent to the mine production areas. Actual shop airflow volume increased from 24 to 38 m^3/s (50,000 to 80,000 cfm) when opened up as a parallel intake, providing a more efficient route for intake air to flow.

AUXILIARY EQUIPMENT STATIONS

Another area to examine is where miners install equipment in a crosscut and knock a hole/regulator in the stopping for ventilation. This airflow loss includes worker lunch rooms, compressors, pump stations, etc. All mine facilities need ventilation, it is how that is best accomplished is in question.

Often auxiliary facilities need to be ventilated, and the main travelway right next to the facility has plenty of available air. An option is to utilize a split of travelway air to accomplish the task instead of sending it directly into the return.

This may be done by the use of an auxiliary fan and ducting, either blowing (shown Figure 2) or exhausting can ventilate the back end of the drift and send the warm air out of the crosscut to the travelway. A wing curtain can also do this, but often blocks access for inspection or maintenance. Although a fan will require continuous power, if 9.4 m^3/s (20,000 cfm) is otherwise vented to the return and system efficiency is 50%, this saves 19 m^3/s 40,000 cfm at the main fan!

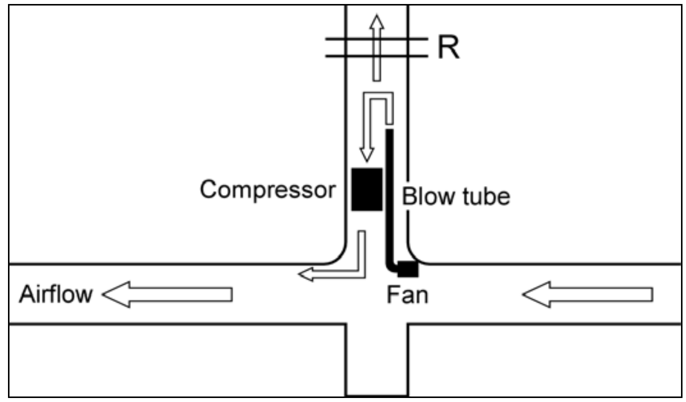

Figure 2. Auxiliary Equipment Ventilation.

Should fire be a concern at the installation, a thermal or carbon monoxide sensor could be installed and provisions made to automatically stop the fan and open a regulator at the back end should it be activated. This would prevent fumes from entering the intake airway or escapeway.

What about the heat being put back into the mine intake system? In some applications this is an important consideration if mine cooling is involved. Many auxiliary facilities can be situated in a place not of concern to face or district cooling. Looking at most mines, heat or cooling source air has damped back to natural rock temperatures in a short distance. The effect of the source is localized. Think of a room and pillar system as a big heat sink at rock temperature.

Case Study

While planning for a longwall block, the subject of ventilating the longwall hydraulic pump bank and compressor station came up. In the past this required 14 m^3/s (30,000 cfm) for each installation depending on the panel layout. In the previous longwall block the situation was brought to management's attention and the compressor was placed next to the secondary travelway and not back against the stopping, utilizing travelway flowby air for cooling instead of sending air to the return, saving 14 m^3/s (30,000) cfm. The new block was a semi-permanent installation for four longwall panels and both pumps and compressors were going to be installed in separate crosscuts up against the stopping, requiring cooling ventilation directly to the returns. Since this was 8 miles from the shaft at the end of the ventilation circuit it was pointed out during the planning meeting the ventilation system could not afford loosing 28 m^3/s (60,000 cfm) here.

The longwall district airflow requirements were: 94 m^3/s (200,000 cfm) longwall, and 57 m^3/s (120,000 cfm) for two development sections plus 14 m^3/s (30,000) cfm for a setup panel, totaling 165 m^3/s (350,000 cfm). Ventilation intake air available would be 189m^3/s (400,000 cfm). Resources would be stretched to handle the additional 28 m^3/s (60,000 cfm) for two auxiliary facilities.

Plans were drawn up to modify the auxiliary installations to allow placement adjacent to the travelway to utilize flow-by intake air for cooling and minimize air wasted to the return. A regulator was installed at the back end of each facility but utilized at a reduced rate of 2.3 m^3/s each (5,000 cfm).This saved around 23 m^3/s (50,000 cfm) of the 28 m^3/s (60,000 cfm) and illustrates the importance of involving ventilation in the mine planning process and remaining vigilant**.**

MINE PLANNING AND SYSTEM ANALYSIS

Discussion

Better utilization of shop and auxiliary equipment air are the two big hitters in finding additional air for the mine. Other options are also available to make mine airflow more efficient short and long term.

Eliminating Stoppings through Long Pillars

Every installed ventilation structure leaks, and will also deteriorate over time depending on ground movement and stability. The best solution is to minimize the number of ventilation structures and resultant leakage by having less. This can be aided by lengthening crosscuts to minimize stoppings per unit of development (Grau et al 2008). Much of this depends on the mining equipment used, number of entries and cable lengths, etc. Work with mine production to maximize crosscut length. This will also save ventilation material cost, and possibly reduce the number of belt and power moves. Make sure the auxiliary ventilation system can handle the increased distahce to provide adequate face airflow.

Case Studies

Crosscuts spacing was increased from 30 to 37m (100 to 120 ft), saving 8 stoppings in a 1500m (5000 ft) panel. Installation costs and leakage were reduced. This was especially helpful as ground deterioration took a toll on stoppings and required extensive resealing and maintenance over time. Changes were also required to the mine roof control plan to implement this change.

In a variation to the above concept, a multi entry mains development intake and returns were mined separately for three breaks, then connected, with only one of three crosscuts mined through between the two, saving two stoppings per three crosscuts. This eliminated 32 stoppings in 1500m (5000 ft) based on 33m (100 ft) crosscut centers! (*See Figure 3)*

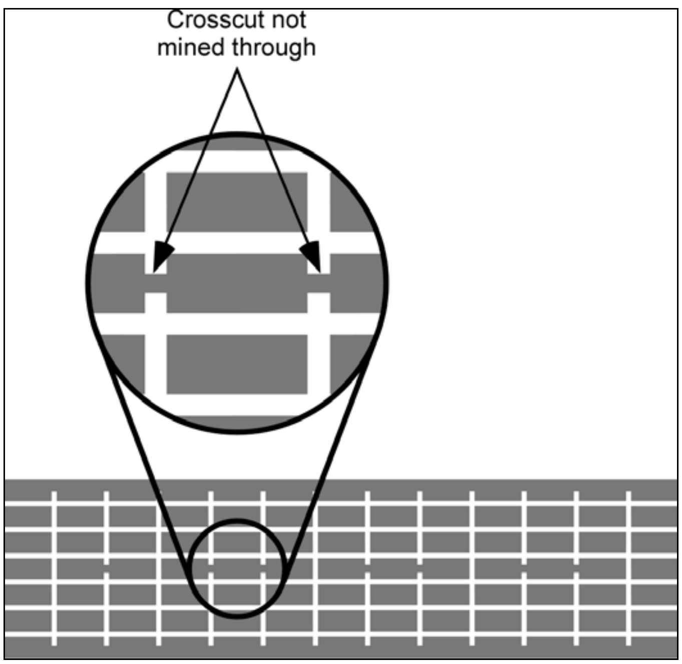

Figure 3. Eliminating Stoppings by Not Mining Crosscuts.

Long term development options

Long term airways need to be planned to maximize efficiency. That goal is challenging if ground conditions are difficult, requiring considerable ventilation structure maintenance or the location of main intake and returns are next to each other, continually leaking.

Case Study

A trona mine's difficult ground conditions utilized yield pillars for ground control. Floor heaved, roof sheared and sagged, and ribs failed, causing stoppings to deteriorate, increasing leakage. Anytime high extraction mining occurred nearby, the higher pillar loading would intensify ground movement, further causing leakage and decreasing the entry opening area for airflow, a terrible combination (see *Figure 4).*

Solution: original main developments (see Figure 5A) were ultimately turned into dedicated intake or return airways, away from high extraction mining,. This eliminated or greatly reduced the amount of stoppings and stabilized airways to minimize floor heave which reduced loss of airway area and maximized district airflow.

Figure 4. Poor Ground Conditions.

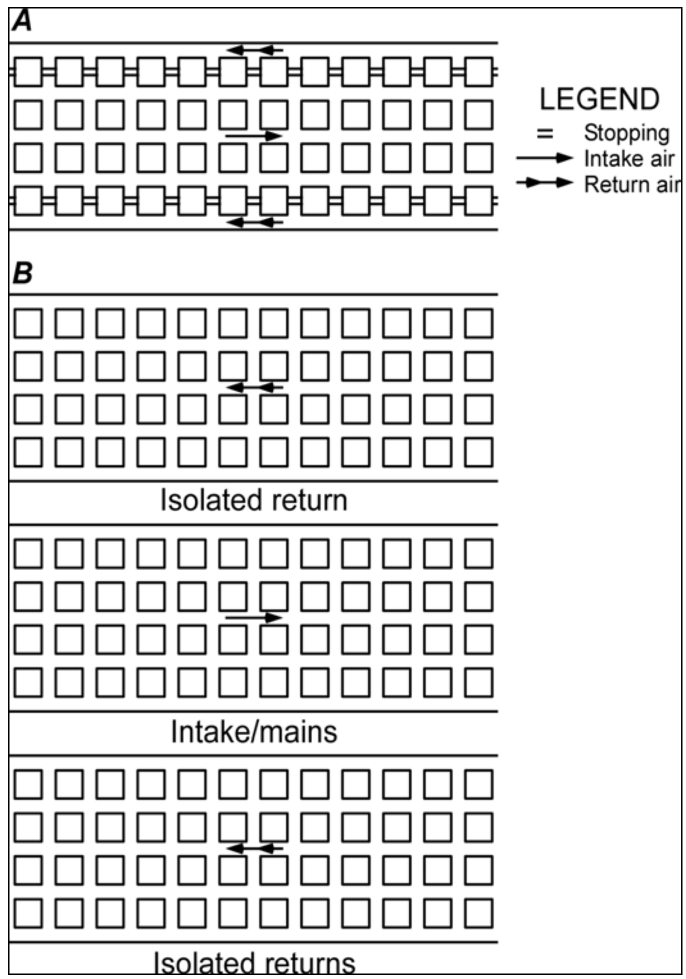

Figure 5. Dedicated Intake/Returns.

The main intake was up the center of the orebody and two dedicated returns/bleeders were mined parallel north and south, remote from extractive mining (see Figure 5B). This eliminated many leaking stoppings and isolated areas from high extraction mining which minimized floor heave and resultant airflow area reduction, maximizing long term airflow to production areas.

DAY TO DAY SYSTEM EXAMINATION/OPTIMIZATION

As the mine expands or changes, there is a need to examine the system utilization and analyze overall efficiency regularly. Often mine plans change from those envisioned years ago and implementation has not been optimal. Personnel changes over time result in losing track of those efficiency goals.

The key to ventilation is having adequate cross sectional area to support the required airflow. Pressure required is proportional to velocity squared, so the goal is to economically minimize velocity. Some airways may be better utilized by changing "gender" – from intake to return or vice versa.

Consider if some of the old returns could be opened to intake and better utilized. When intake velocities are dropped there is less dust generated from conveyor belts and travelways. What procedure should be followed to determine if the change is beneficial? First, verify assumptions by simulations on the computer model. If favorable, then test the hypothesis by temporarily isolating the old return with curtains and check if it makes any difference to inby airflow. If not, open it up to intake. The change will probably reduce leakage too, which may make up for the increased system resistance.

Case Studies

Longwall block mains were developed with three center intakes and three returns, two west and one east (see Figure 6). Three intakes would be adequate for development ventilation and allow dual parallel travelways, one on each side of the belt entry. Returns on both sides were necessary for ventilating developments off each side as the mains advanced. As identified by mine planning, when the longwall moved inby, the east return would be changed to intake, allowing increased intake capacity necessary for future longwall mining. Longwall return air will be routed away from the mains so the return capacity needed here would be less. A long stopping line will be eliminated, saving about 9.4 m^3/s (20,000 cfm) leakage.

Next, underutilized airways should also be examined. Further outby in an older development, a return carries 9.4 m^3/s **(**20,000 cfm) and if taken out of the circuit will have no negative effect on airflows inby. Intake airways next to this return have high velocities and pressure losses coming from the main shaft. Opening up this underutilized return to intake will lower system resistance, increase main fan airflow, and lower total system leakage due to reduced pressure differentials. The mine is a big pipe system: make sure it is utilized efficiently.

Changes made to intake and return airways should be done with consideration of mine escapeways and the existing emergency plan for ventilation and evacuation routes.

Think Out of the Box

It's tough these days to find time to do serious analysis of the ventilation system, but doing so could have big payoffs in air quality for miners and cost savings for the operation.

If certain areas are difficult to ventilate consider a booster fan installation. A little extra horsepower in the right place could make a big difference and a lot less horsepower required than at the main fan!

Another possibility to consider is controlled district recirculation. (Pritchard 1995, Robinson 1989) Examine the air quality in the mine return. Sometimes, it's equivalent or better than the intake. Mine returns can act as a big "bag house" system helping dust settle out. Even diesel soot settles out in time. Contaminants from face areas are also diluted by leakage. Reheating this air isn't necessary as it's already at rock temperature. Blasting fumes, cooling requirements and methane may be issues with this option in some mines**.**

The main fan may be operating at low pressures and off the efficiency curve. Talk to your fan manufacturer about de-blading or removing fan blades (Loring 2007) – this can drastically improve efficiency, especially at high altitudes**.**

With multiple main mine fans, behavior is not always as expected. When one of three main fan's blades were reduced, total mine airflow went down but mine section airflow went up. Airflow increased because the fans didn't have to fight each other and mine pressure differential went down, reducing leakage. Operating cost was reduced and airflow to the working areas went up – the ideal outcome.

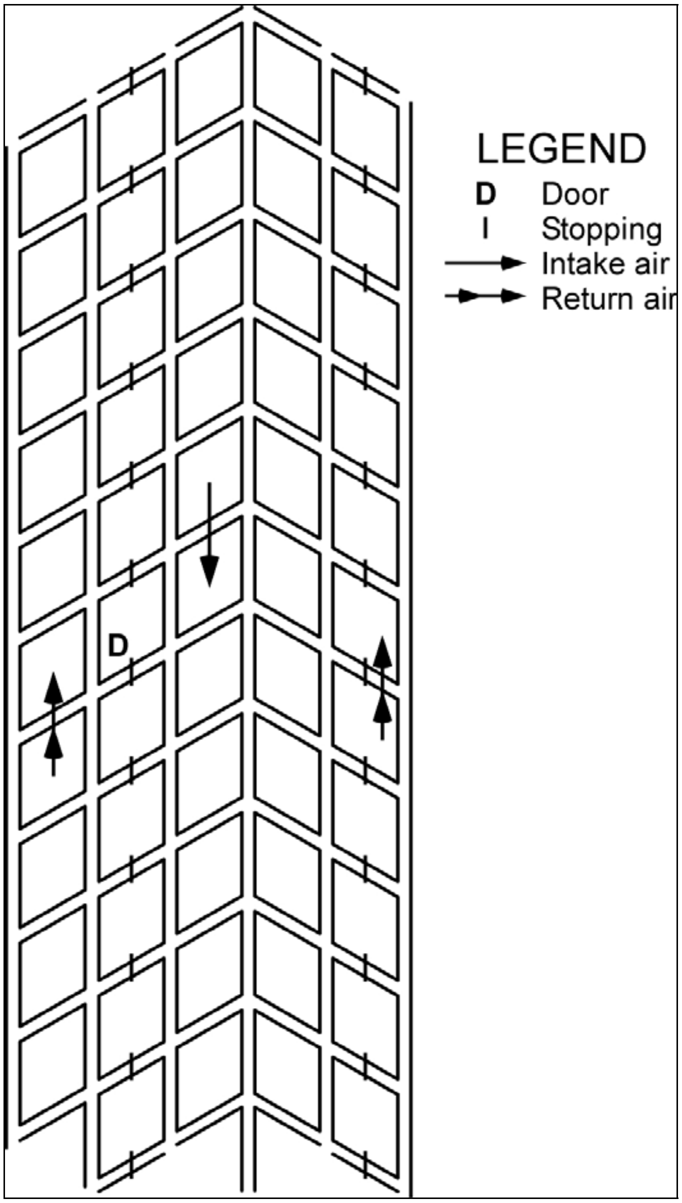

Figure 6. Main Entry Optimization.

Look to flexibility in mine ventilation. Investigate applying Ventilation on Demand (VOD) principles. Apply air where it is needed, when needed instead of fixed airflow quantities at all times. There is considerable monitoring and control capability in the industry, use it to your advantage (Allen, 2008). A flexible ventilation system is a win-win for production and safety.

CONCLUSION

There are many things that can be done to improve airflow in the mine. What is needed is to look around, inquire, measure and understand. Actions to dilute contaminants and improve the working environment will result in a healthier, happier workforce and most likely improved production and lower turnover.

This paper has discussed some ways to find extra usable air when there is no extra ventilation capacity. If there is adequate air, then the option is to implement some of these changes and reduce expenditures through lowering operating costs. Since airflow power is proportional to velocity cubed (Marx 2008) the first fan blade setting reduction is the biggest savings. Don't forget, each cfm saved doesn't have to be heated or cooled either (Hall, 1985).

Remember to take the entire system into account. Develop and utilize a good computer model. All changes have consequences, so be sure to perform a risk analysis and determine the effects on emergency and evacuation planning.

So – after this, I hope you only get "the occasional complaint"!

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